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CHAPTER 7

Induction and maintenance of anaesthesia



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Headline

This chapter looks at the reports of events that occurred during induction or maintenance of general anaesthesia, specifically excluding problems in head and neck cases which are reported separately in Chapter 18. About one third of the 55 events occurred during elective surgery, with the majority of events occurring during general surgery emergencies and orthopaedic trauma cases. More than half were aged 21–60 years and more than half were ASA 1 or 2 (with no ASA 4/5 patients). These were therefore not elderly or sick patients having complex surgery, but patients who would often be considered low-risk, and therefore perhaps managed by solo trainees with distant supervision. Nine patients in this group died and another five had a lasting impairment as a result of the event. The majority of patients, even fit healthy day cases, were admitted to ICU with its attendant personal and institutional costs. An emergency surgical airway was attempted in a quarter of the events occurring at induction, clearly illustrating that rescue oxygenation should be a core skill of the solo anaesthetist. There was evidence of muddled thinking about control of laryngeal reflexes, problems managing both anticipated and unanticipated difficult intubation, failure to protect the airway and failure to confirm correct placement of the tracheal tube. Airway management was considered by the review panel to be poor in a high number of these cases. It must be the goal of the specialty of anaesthesia to drive down to zero the serious morbidity from airway management in fit, healthy patients and the events reported in this chapter must promote change.

What we already know

Induction of general anaesthesia is a testing time – of anaesthetist, strategy and resources – and, not surprisingly, features prominently in studies of adverse outcomes. In a recent report¹ of litigation related to airway complications in the UK 1995–2007, airway claims most frequently described events at induction of anaesthesia, involved airway management with a tracheal tube and led to patient death or brain damage due to hypoxia. Airway trauma, including deaths from mediastinal injury during intubation, accounted for one third of claims. Pulmonary aspiration and the oesophageal placement of tracheal tubes were causes of other claims.

A North American closed-claim analysis² found 63% claims related to induction of anaesthesia (mortality 35%) and 14% to intraoperative events (83% mortality).

The main causes of adverse outcomes at induction or during maintenance of anaesthesia are:

- pulmonary aspiration
- inability to establish or maintain the airway
- difficult or failed intubation (including unrecognised oesophageal intubation)
- iatrogenic airway trauma.

Regurgitation and aspiration

The risk of aspiration should be assessed by the anaesthetist preoperatively. Where the risk is higher than normal consideration should be given to minimising volume and raising pH of gastric contents and protecting the airway through Rapid Sequence Induction (RSI). Morbidity will arise where the risk of aspiration is not taken into account, the 'no-risk' assessment is incorrect or the elements of RSI fail to protect the airway. Cricoid force applied as part of RSI may itself cause problems with intubation and oxygenation, particularly when applied force is excessive or incorrectly applied. It must always be applied intelligently with a constant review of whether it is causing more harm than good when there are problems with airway management. This topic is considered in detail in Chapter 19.

Inability to establish or maintain the airway

The first complication of note in airway management is failure. Anaesthetists are used to high levels of success at what they do and routine airway management does not usually fail. Tracheal intubation by an experienced anaesthetist fails completely in around 1 in 2,000 routine cases,^{3,4} LMA placement in around 2% of cases and both intubation and ventilation are unexpectedly impossible in about 1 in 5,000 to 10,000 anaesthetics.⁵ However the consequences of these infrequent problems are potentially catastrophic and CICV accounts for over 25% of all anaesthesia-related deaths.

In emergencies all these failures increase several-fold. Complications of airway management undoubtedly increase in cases of difficulty and when care is delivered on an emergency rather than elective basis. Failed tracheal intubation in obstetric emergencies is reported between 1 in



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300–800⁶ and CICV in the emergency department may be 1 in 600.⁷ The CICV situation is examined in Chapter 13.

Such difficulties will be reduced by the following strategies.

- 1 History and airway assessment.** This enables the anaesthetist to identify whether there have been previous problems and whether morphological or physiological features suggest there may be difficulties with one or more of the four main methods of airway management (facemask, SAD, tracheal tube or direct tracheal access). Effective airway assessment enables formulation of an airway strategy (i.e. a series of co-ordinated plans) that optimises the chances of success and minimises the chances of failure and or complications. Airway assessment and the concept of an airway strategy is discussed in depth in Chapter 17.
- 2 Pre-oxygenation (denitrogenation).** This is now routine for many, but not all, anaesthetists. It is certain that formal pre-oxygenation increases the time to hypoxia when airway problems occur. While numerous methods of pre-oxygenation have been described, breathing 100% oxygen for three minutes using tidal volumes and a leak-free mask, is acknowledged to be effective.⁸ It does not require additional equipment (e.g. extra-large reservoir bags, use of oxygen flush) and is more effective in maintaining oxygenation during apnoea than some other methods.⁹ For more problematic patients oxygenation may be improved further by use of a ramped anti-Trendelenburg position (e.g. in obesity)¹⁰ and by use of Continuous Positive Airways Pressure (CPAP) (e.g. in the critically ill and those with airway obstruction as well as obese patients).¹¹ When pre-oxygenation is not possible this immediately represents a potential risk for the patient and this is acknowledged in the ASA difficult airway algorithm.¹²
- 3 Appropriate abolition of laryngeal reflexes.** It is clear that protective laryngeal reflexes can frustrate attempts at ventilation by facemask and SAD, and make intubation more difficult or impossible. Muscle relaxation abolishes the impact of laryngeal reflexes in generation of a critical airway event but at the expense of introducing concerns about removal of spontaneous respiration and ability to wake the patient up. Some suggest that for many patients after induction of general anaesthesia the administration of muscle relaxation is beneficial¹³ and should precede any attempts to confirm ease of facemask ventilation. There seems to be a move away from checking facemask ventilation (squirt-puff-squirt) to non-checking (squirt-puff).¹⁴ There is no recommendation from any authority that muscle relaxation will always improve the situation, or is safe, in all patients and the anaesthetist must make a judgement in each individual case.

Even if the airway is satisfactorily managed at induction, the situation may change during maintenance of

anaesthesia. The principal risk factor for losing a previously established tracheal tube or SAD is patient movement including during transfer from anaesthetic room to operating theatre, from theatre trolley to operating table and during final positioning for surgery. Further changes in position may of course occur intentionally or inadvertently during surgery. Small changes in the position of a SAD may occlude the airway, particularly in children. Light anaesthesia or intense surgical stimulation can promote coughing and laryngospasm. Occasionally an established airway may be lost because of blockage by tissue, blood, secretions or sputum.

Difficult or failed intubation

Some difficulty with tracheal intubation is expected in 1% cases with failure occurring in about 1:2000 cases of routine intubation and perhaps 1 in 250 during RSI. These figures are for a 'general population' and in certain groups (e.g. cervical spine surgery, ENT, intubation outside theatres) rates of problems and failure are known to be much higher. Difficult intubation may lead to failure to maintain or protect the airway or trauma associated with repeated attempts. Guidelines for the management of unanticipated difficult intubation in elective patients stress limitation in the number of attempts before moving onto another technique or abandoning the procedure. The UK Difficult Airway Society (DAS) guidelines¹⁵ promote intubation, in the elective setting, through a SAD as Plan B.

When direct laryngoscopy is difficult, oesophageal placement of the tracheal tube is more likely. Capnography is mandatory during general anaesthesia to confirm continual intra-tracheal placement of the tube, its patency and also to guide effective alveolar ventilation. The required standard of satisfactory tracheal placement is repeated capnograph traces (at least 6 breathing cycles) with appropriate values of end-tidal carbon dioxide. Without this pattern the tube must be assumed to be in the oesophagus and should be re-sited and checked again. A number of conditions, particularly low or absent cardiac output, may produce capnograph traces with very low carbon dioxide values. When capnography is unreliable other methods for confirming tube position and patency are available and include mechanical balloon or syringe oesophageal detection devices and direct inspection with a flexible fibrescope. Acceptance of an abnormal capnograph trace as confirmation of tracheal placement of a tube during cardiac arrest is a known serious error. Capnography may fail to give satisfactory discrimination when the monitor is malfunctioning, is not attached, or has a blocked sampling line. The subject of capnography and confirmation of tube placement is also discussed in Chapters 6, 9, 10 and 12.

Latrogenic Airway Trauma

The consequences of airway trauma range from minor self-limiting morbidity to death. Mort has published data



demonstrating that increasing numbers of attempts at tracheal intubation were associated with increasing severity of morbidity and the associated trauma could be correlated with an increased risk of cardiac arrest and death.¹⁶ Serious trauma from airway adjuncts such as bougies and airway exchange catheters has been described. Some work has been done on axial forces generated by different bougies suggesting that the stiffest devices may be most likely to cause trauma,¹⁷ however it is not possible to confirm this with clinical data.

Both UK¹ and American data² on anaesthesia litigation indicate that mechanical trauma during airway management (particularly use of adjuncts during intubation) can lead to major trauma including tracheal and oesophageal perforation, mediastinitis and death.

Case review

Difficult or failed tracheal intubation

This was the commonest problem at induction. Some were completely unavoidable, for example two cases presented with undiagnosed tracheal stenosis preventing intubation; one was managed with urgent surgical tracheostomy, the other was eventually successfully intubated with a small tube and was admitted to ICU because of concerns over potential airway trauma. Eleven of 41 cases had difficulty with airway management anticipated before induction of anaesthesia, but too often this did not apparently lead to development or implementation of a robust airway management strategy. The commonest interpretation by the reporters of the root cause of the problem was 'poor judgement'.

There were several cases where patients with known difficult intubation in the recent past had anaesthesia induced and muscle relaxants given only for the anaesthetist to be faced with a very difficult laryngoscopy again, sometimes accompanied by difficult or impossible ventilation. An example was a patient who was found to be a grade 3 laryngoscopy at elective abdominal surgery. Several days later the patient required emergency laparotomy and a consultant anaesthetist performed RSI which was followed by failed intubation, and failed ventilation by facemask and laryngeal mask. An emergency surgical airway was performed. Awake intubation would have avoided these problems.

Some anaesthetists chose to avoid muscle relaxants when difficult laryngoscopy was anticipated, techniques varied but included both inhalational (sevoflurane) and intravenous (propofol and remifentanyl) techniques. Conditions for laryngoscopy were sometimes not optimal and the ability to ventilate by facemask and SAD deteriorated. Indeed some reporters commented that an aspect of 'what went well' was that muscle relaxants were avoided when difficulty arose. In contrast the review

panel considered that delay or avoidance of administering a muscle relaxant in this scenario likely contributed to the adverse event in at least three cases.

Case 1

An adult was scheduled for elective surgery, tracheal intubation was indicated but was predicted to be difficult. After pre-oxygenation and intravenous induction of anaesthesia both facemask ventilation and tracheal intubation were difficult. Intubation was eventually successful after about an hour with three consultants involved. Although the oxygen saturations had always been maintained above 85% the patient was admitted to ICU as significant airway trauma was suspected.

During the review process no one anaesthetic technique emerged as ideal to reduce the risks associated with difficult or failed intubation. What did become apparent was that failing to move on from the initial plan when it was not working and implement a plan B or C was a common theme. Occasionally the initial anaesthetic plan chosen was deemed by the review panel to be inappropriate (e.g. choosing intravenous induction of anaesthesia rather than awake intubation for a patient with obstructive sleep apnoea, tracheal deviation and limited cervical spine mobility).

There were three cases of undiagnosed oesophageal intubation. In two cases a flat or absent expired carbon dioxide waveform on the capnograph was interpreted along with other signs to indicate anaphylaxis. One case involved a middle-aged adult having elective minor surgery who became rapidly hypoxic and had a cardiac arrest when facemask ventilation proved impossible following induction of anaesthesia with propofol and fentanyl. Tracheal intubation was difficult and tube misplacement was only recognised when the capnograph trace remained flat after cardiac output was restored. The second case again involved elective minor surgery in a healthy adult patient, but in this case tracheal intubation had been planned from the outset. Following transfer from the anaesthetic room to theatre, increasing hypoxia was ascribed to a possible allergic reaction. Help was summoned and arrived very quickly, it was then that the absent expired carbon dioxide trace was correctly diagnosed and the tracheal tube reinserted into the trachea. The patient was admitted to the ICU and subsequently made a good recovery. There was a further case where a healthy adult having minor surgery was given suxamethonium and intubated to rescue worsening hypoxia from an inadequately functioning SAD. After nearly an hour of cardiopulmonary resuscitation the patient died. The tube was in the oesophagus. In all cases when cardiac arrest occurred the flat capnograph was apparently (incorrectly) attributed to absent cardiac output.



Of note two cases of severe bronchospasm at intubation presented very similarly to the above cases with hypoxia, poor ventilation and flat capnography. In these cases the tube was seen to pass through the vocal cords. However in both cases the tracheal tube was removed to exclude oesophageal intubation, in one case three times. The point that 'absolute bronchospasm' and oesophageal intubation may be difficult to distinguish is worth remembering. Blood clot causing tracheal obstruction may also present in this manner. All need active steps to be taken to make the correct diagnosis.

There were at least five cases where there were five or more attempts at tracheal intubation. In one a patient for minor day case surgery had a failed regional technique followed by failed intubation, cardiac arrest and failed SAD insertion. Despite cardiac arrest repeat attempts at intubation were continued rather than progressing to an emergency surgical airway. In some cases several anaesthetists were involved, giving the impression that each one 'had a go' at several attempts at intubation. In such cases the review panel identified potential teamworking problems and a lack of leadership in determining when to stop trying to intubate.

In another case the anaesthetist had planned to avoid tracheal intubation as it was predicted to be extremely difficult, in the middle of surgery which was performed in a position such that airway access was difficult the airway was lost and could not be regained by repositioning the SAD: no rescue strategy was in place and the patient died.

Aspiration

There were 26 cases where aspiration of gastric contents clearly occurred during induction and maintenance of anaesthesia representing nearly half of the reported complications. Aspiration was however responsible for seven of the nine deaths that occurred in this group of patients. Accordingly the importance of minimising the risks associated with this problem at induction, and during maintenance of anaesthesia cannot be overstated. An in depth analysis and case reviews of aspiration can be found in Chapter 19.

Some of the cases of aspiration were primary events and others complicated other primary airway events

(e.g. difficult intubation). Twenty-two were urgent or emergency cases covering the spectrum of orthopaedic trauma involving bony fractures (eight cases), incarcerated hernias and bowel obstructions (six cases), incision and drainage of abscess (four cases) and six others from a variety of specialities. Four were elective cases with no clear risk factors for aspiration. Aspiration occurring at induction was equally common whether anaesthesia was planned with a tracheal tube or a SAD.

Case 2

An elderly patient was listed for surgery for an irreducible inguinal hernia. Despite the surgical condition the patient was not thought to be at significant risk of aspiration on account of normal bowel sounds and having had their bowels open that day. A laryngeal mask was chosen to maintain the airway for general anaesthesia with spontaneous ventilation. During surgery the patient regurgitated and aspirated, tracheal intubation was performed within two minutes and oxygen saturations did not fall at the time. Post-operatively oxygenation could not be maintained after extubation. The patient died later that day despite reintubation and admission to ICU.

Case 3

A previously fit and well elderly patient required emergency incision and drainage of a buttock abscess. The patient had been starved for more than 24 hours, was dehydrated and had signs of sepsis. Following a pre-operative anaesthetic review RSI was planned. Following a change in anaesthesia personnel a routine intravenous induction of anaesthesia was performed and a laryngeal mask placed. On transfer to the operating table the patient regurgitated and aspirated. Despite ventilation on ICU the patient died.

Difficulties with ventilation

In several cases mask ventilation was difficult or ventilation via a laryngeal mask failed. On review concerns were raised that the cause of such problems appeared to be light anaesthesia on several occasions. A reluctance to administer further anaesthetic agent or muscle relaxant was noted. Calls for assistance were also delayed until there was a substantial risk of patient harm.



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Case 4

A healthy young adult was anaesthetised for minor surgery. After propofol and fentanyl a laryngeal mask was placed but ventilation was not possible. Ventilation remained impossible via the laryngeal mask and via facemask despite further propofol. Oxygen saturations remained below 70% for about 10 minutes while attempts continued to ventilate the patient. Eventually suxamethonium was given, ventilation became possible and the trachea was intubated. Post-operatively the patient spent more than two weeks in ICU having shown signs of cerebral irritation.

Numerical analysis

Of the 55 reports, 41 occurred at induction and 14 during maintenance. Details of the patients and operations are given in Table 1.

Thirty-seven reports were in normal working hours and the risk of aspiration was considered increased in 24.

Table 1

Age: <21 / 21–40 / 41–60 / 61–80 / >81	2 / 14 / 14 / 18 / 7
ASA: 1–2 / 3 / 4–5	37 / 18 / 0
Body habitus: cachectic/normal/obese	1 / 34 / 20
Senior anaesthetist at start of case: trainee/NCCG/consultant	17 / 8 / 30
Urgency: elective or scheduled/urgent or emergency	24 / 31
Surgical specialty (urgent and emergency surgery) Orthopaedic/bowel and hernia/abscess drainage/other	10 / 10 / 5 / 6

There were nine deaths. Five patients died following an event at the induction of anaesthesia, four due to aspiration of gastric contents and one due to oesophageal intubation. Four patients died as a result of an event during maintenance of anaesthesia: three from aspiration of gastric contents and one due to losing the airway mid-surgery and being unable to regain it by facemask, laryngeal mask or tracheal tube.

Five of the remaining 46 patients did not make a full recovery. Two were left with continuing neurological deficit following elective minor surgery which was planned via a laryngeal mask, both patients were difficult to ventilate via facemask and laryngeal mask after induction of anaesthesia. In one case muscle relaxants were not used at all during the difficulty and in the other there was a significant delay before administration of suxamethonium after which ventilation became easy and oxygenation improved.

Forty-seven of the 55 cases were admitted to ICU. Ten of 41 cases at induction and one of 14 cases during maintenance had an attempt at an emergency surgical airway.

Difficulty at the time of tracheal intubation (including failed intubation, unrecognised oesophageal intubation and CICV) was the commonest problem at induction of anaesthesia accounting for 19 of 41 cases. Aspiration of gastric contents occurred at induction in 16 of 41 cases and during maintenance in ten of 14 cases. Problems also arose associated with aspiration of blood following traumatic airway management. Primary problems associated with SADs (excluding aspiration) accounted for two cases at induction and two during maintenance.

The review panel considered that the most common contributory factors to the adverse event were patient (32 reports), poor judgement (28) and education and training (26). Problems in communication, organisation, task and team working were identified less commonly. The factors most commonly considered causal were poor judgement (eight), patient (six) and education or training (six). The person reporting the event considered contributory factors to be poor judgement (25), training (four) and team working (three).

Airway management was considered good by the review panel in 11 reports, mixed in 16, and poor in 25 with three unclassified.

Discussion

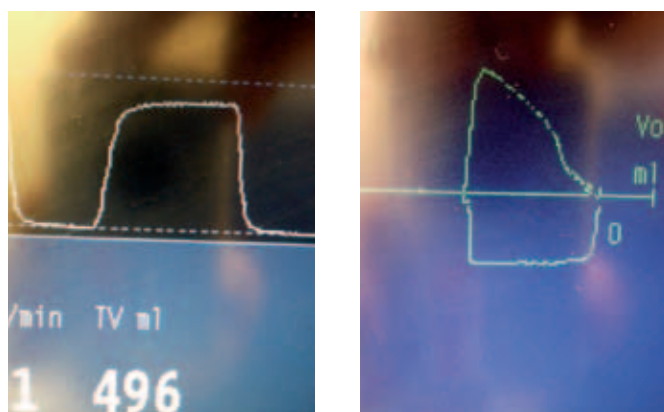
The majority of patients who suffered serious complications of airway management during induction and maintenance of anaesthesia were young healthy adults. Forty percent of cases were undergoing elective or scheduled surgery and some of the worst outcomes (one death and two brain injuries) occurred in patients having minor surgery.

Of concern is that the vast majority of the reports concerned events that are already well known to the anaesthetic community but it seems that we have not yet taken on board the lessons we could have learned from the past. This is supported by the views of the LRs and the review panel that poor judgement was a major contributory factor in many events. Aspiration remains the leading cause of mortality during induction and maintenance of



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anaesthesia as it was some 50 years ago, despite advances in anaesthetic techniques (RSI) and airway devices (advanced/second generation SADs).

Inability to establish or maintain the airway is still a problem and well thought through management strategies for dealing with this are, evidently, not universally applied. Difficult and failed intubation (including unrecognised oesophageal intubation) has been extensively reviewed by many authors but identified risk factors and national guidelines are still being ignored; airway trauma from multiple attempts or blind attempts at tracheal intubation was a frequent indication for admission to ICU in this cohort of patients.

Themes identified by review of the cases during induction and maintenance of anaesthesia include:

- Aspiration was the most common cause of death in patients suffering serious complications of airway management during induction and maintenance of anaesthesia. Choosing tracheal intubation for airway management does not eliminate the possibility of aspiration of regurgitated gastrointestinal contents. Using a classic LMA or equivalent SADs offers limited protection from aspiration.
- Difficulty with tracheal intubation often led to airway trauma and ICU admission.
- Multiple attempts at intubation using a single anaesthetic plan were not uncommon.
- Anticipation or prior knowledge of difficult intubation was often followed by routine intravenous induction of anaesthesia, sometimes with muscle relaxants and sometimes with great emphasis on their avoidance. Clinicians using either route appeared to frequently omit consideration of securing the airway awake, or formulating a strategy to manage the airway if problems arose.
- Oesophageal intubation was missed in several cases. A flat capnograph trace (i.e. no expired carbon dioxide detected) was ascribed to poor cardiac output (cardiac arrest or anaphylaxis). There is good evidence that

there will be expired carbon dioxide (an attenuated capnograph trace), even during cardiac arrest with CPR.

- Airway problems arose that appeared to be a consequence of light anaesthesia. Prompt deepening of anaesthesia, and or use of muscle relaxants was often delayed. In some cases delay was until and beyond the time that patient harm occurred.
- Problems were noted both as a consequence of giving muscle relaxants in patients with predicted or known difficult airways, and also because of persistently avoiding them during airway difficulty: arguably supporting both sides of the 'squirt-puff-squirt' debate. A useful conclusion might be that 'anaesthesia by rote' without back-up plans, especially when difficulty is predicted, is bad practice.

Learning points and recommendations

Problems with tracheal intubation

Numerous cases were identified in which difficult intubation was managed in an unstructured manner and with apparently unlimited attempts at intubation.

Recommendation: All anaesthetic departments should have an explicit policy for management of difficult or failed intubation (e.g. formal adoption of the Difficult Airway Society guidelines as departmental policy). The strategy should limit the number of intubation attempts.

Recommendation: Where difficulty with airway management is anticipated or has occurred previously a comprehensive airway strategy must be planned before induction of anaesthesia. Plans B and C should be discussed and the equipment and skills to carry them out must be available.

Recommendation: Anaesthetic departments should provide a service where the skills and equipment are available to deliver awake fiberoptic intubation whenever necessary.

Oesophageal intubation

Cases of tracheal intubation complicated by oesophageal intubation or total airway obstruction were reported. Failure of interpretation of capnography, particularly during cardiac arrest with CPR, delayed diagnosis of the problem.

Recommendation: If a flat capnograph is seen after attempted tracheal intubation the anaesthetist should actively exclude oesophageal intubation (and absolute airway obstruction).

Aspiration

Aspiration of gastric contents led to several deaths. Aspiration at induction was a notable problem and occurred both in patients who had not been assessed for risk of aspiration and also in some who were assessed but incorrectly





considered low-risk. Aspiration during maintenance occurred predominantly with first generation SADs.

Recommendation: Anaesthetists must assess all patients for risk of aspiration prior to anaesthesia. This applies particularly to urgent and emergency surgery.

Recommendation: Once placed a tracheal tube offers the highest protection against aspiration.

Recommendation: Second generation SADs may offer better protection than first generation devices but further research is needed to confirm and quantify this.

Inadequate anaesthesia, muscle relaxants and ventilation

Light anaesthesia contributed to some events. In others severe airway difficulty was encountered and the anaesthetist made strenuous efforts to avoid administering muscle relaxants, even beyond the point of patient harm.

Recommendation: Where facemask or laryngeal mask anaesthesia is complicated by failed ventilation and increasing hypoxia the anaesthetist should consider early administration of further anaesthetic agent and or a muscle relaxant to exclude and treat laryngospasm.

Recommendation: No anaesthetist should allow airway obstruction and hypoxia to develop to the stage where an emergency surgical airway is necessary without having administered a muscle relaxant.

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Headline

Thirty-eight of the 133 reports (28%) associated with anaesthesia were airway complications at emergence or in the recovery period. In all reported cases airway obstruction was the root cause of the complication and in 50% of cases there was a delay in recognising the problem. Two of these patients died, one sustained brain damage, ten emergency surgical airways (ESA) were attempted and the remaining patients were admitted to ICU. Post-Obstructive Pulmonary Oedema (POPO) was noted in 13 reports, accounting for 10% of all anaesthesia-related complications reported to the project.

What we already know

When airway problems occur during anaesthesia they tend to occur most commonly at induction or during emergence and recovery. Eighteen of the 156 Peri-operative claims for airway management included in the 2005 American Society of Anesthesiologists (ASA) Closed Claims report were associated with extubation alone.¹ The Anaesthetic Incident Monitoring Study (AIMS) identified that airway problems constituted 43% of reports from the recovery room.²

Airway problems at the end of anaesthesia

Airway problems at emergence or in recovery fall into two categories: contamination or obstruction.

Contamination. The use of opioids, neuromuscular blocking drugs, intravenous or inhalational anaesthetic agents, impair airway protective reflexes, leaving the respiratory tract open to contamination with gastric contents or blood.³ Inhalation of gastric contents or blood can cause pneumonitis, or pneumonia, whilst aspiration of gross particulate matter produces airway obstruction. Airway devices offer variable degrees of protection to the lower airway during anaesthesia and their removal as the patient recovers leaves the airway vulnerable to contamination.

Airway obstruction. Until full recovery from general anaesthesia the residual effects of anaesthetic agents commonly lead to reduced tone within the supporting musculature of the airway and unless the airway is supported occlusion follows. Alternatively, under residual or light anaesthesia a semi-conscious patient may bite on a tracheal tube or supraglottic airway device (SAD) or develop laryngospasm in response to the presence of an airway device or secretions in the pharynx.

In the majority of cases the cause of airway obstruction is immediately obvious⁴ but this is not limited to those listed above. When a patient fails to respond to initial treatment it is important to consider other causes of airway obstruction. At the end of anaesthesia less frequent causes of airway obstruction include glottic oedema which can complicate traumatic airway instrumentation, either at induction or during airway surgery such as rigid bronchoscopy. Prolonged surgery in the head down position produces oedema of the face and conjunctiva and may also be associated with laryngeal oedema. By a similar mechanism a neck haematoma raises local tissue pressure leading to impaired venous drainage with progressive, sometimes insidious airway obstruction. Surgical procedures within the airway carry the additional risk of intra-luminal obstruction by blood clot or retained material, such as human tissue or a throat pack. In 2008/9 the NPSA produced guidelines to prevent the retention of throat packs during operations.⁵

Recovery from general anaesthesia in the absence of specific risk factors

A patient recovering from anaesthesia makes a transition from the unconscious to the awake state. Routine precautions at the end of anaesthesia would normally include the removal of secretions, any regurgitated gastric contents and in the case of operations within the airway inspection for swelling or bleeding. After the airway has been cleared the patient can be turned to the lateral position which may offer some additional protection against airway obstruction and aspiration. The timing of airway removal is important, if removed too early the risk of aspiration and airway obstruction is increased but equally if removed too late laryngospasm or occlusion by the patient biting the airway may follow.

If total airway obstruction occurs in a spontaneously breathing patient, forceful inspiratory attempts may lead to pulmonary oedema which becomes apparent after the airway obstruction has been relieved. Post-Obstructive Pulmonary Oedema (POPO) can occur in the absence of cardiac disease and in otherwise fit healthy people. Hypoxia which persists after relief of airway obstruction is a common presentation but the development of frank pulmonary oedema is also well recognised. All patients, even those with an uncomplicated or normal airway are at some risk of these complications.





The recovery unit was the location for 1 in 6 reported events

Extubation of an at-risk airway

A systematic approach to airway management at the end of a procedure is required, as recommended in the extubation strategy of the ASA guidelines.⁶ Factors which make the need for postoperative airway intervention more likely should be identified. The presence of hypoxaemia, hypercarbia, residual neuromuscular blockade, hypothermia or airway oedema, or if difficulty with mask ventilation is expected, increase the likelihood of re-intubation. Supplementary airway evaluation by direct laryngoscopy, fiberoptic examination or confirmation of an audible leak around a tracheal tube may assist decision-making. Alternatives to routine extubation include, extubation over an airway

exchange catheter, tracheal tube exchange to a SAD under anaesthesia, prolonged intubation until the problem resolves, or surgical tracheostomy. Whichever action is taken, thorough pre-oxygenation prior to intervention is important.

When a decision to perform extubation has been made the potential difficulties should be considered, including the options for oxygenation, and re-intubation if required. It is necessary to establish back-up plans appropriate to the patient, to be deployed if the primary plan fails. Extubation should normally take place in the operating room where experienced staff and appropriate airway equipment are immediately available. Afterwards, a period of observation and assessment will usually follow before transfer to the recovery room. It is an obvious precaution to retain the airway equipment until it is evident that it will not be needed again.



An airway exchange catheter is placed prior to extubation and retained for use in the event that reintubation is required.

Transfer at the end of surgery

It is incongruous that patients are fully monitored during an operation but this is often discontinued at the end of surgery to enable the unconscious patient to be transferred to another area. The Association of Anaesthetists of Great Britain and Ireland (AAGBI)^{7,8} has made recommendations about monitoring after surgery including the transfer of patients. Where the recovery area is not immediately adjacent to the operating theatre, or if the patient's general condition is poor, adequate mobile monitoring is recommended during transfer. If the patient is being transferred to critical care whilst still intubated and ventilated continued monitoring is essential and a plan should be formulated to manage accidental extubation during transfer. The appropriate drugs and equipment needed to ensure ventilation and oxygenation must accompany the patient.

Recovery room

The recovery period can be a very busy time, involving simultaneous changes in the patient's airway, breathing,

circulation and the need for administration of pain relief. It is common for the anaesthetist to outline the plan for oxygen therapy, intravenous fluids and pain relief;⁹ airway management requires the same attention. There are relatively few publications specifically addressing airway problems occurring in the recovery period and perhaps evidence of this is the very brief attention devoted to the airway in European Guidelines on Post Anaesthesia Care.¹⁰ In 2005 a postgraduate issue of the *British Journal of Anaesthesia* was dedicated to recovery but did not specifically address the airway, focusing on other areas such as postoperative pain, cardiovascular problems, nausea and vomiting and cognitive recovery.

Staffing. In the UK and elsewhere it is common practice for anaesthetists to leave unconscious patients in the care of recovery room staff. To safely delegate care a reliable infra-structure is needed, this includes; well-trained recovery room staff, effective monitoring and medical input should urgent airway problems develop. Under some circumstances the primary anaesthetist may be unable to attend immediately; the availability of another anaesthetist to help in the event of airway compromise is being increasingly recognised and addressed with the rostering of Peri-operative anaesthetists and the adoption of a 'named consultant' policy.¹¹ This practice is not universal and is often unavailable out of routine working hours.

Most recovery rooms provide staff experienced in airway management, but this cannot be assumed in all units. The AAGBI rightly recommend that anaesthetists remain with their patient until it is safe for their care to be taken over by a competent member of staff.⁴ In some areas, e.g. on delivery suite, patients emerging from general anaesthesia may not be recovered by specifically trained staff. There is a need for the national published standards on recovery to be supported by audit and quality assurance. Policies may vary from region to region and some Trusts, local policies can even vary throughout differing parts of the hospital. Recovery nurse practice is governed by the Nursing and Midwifery Council generic standards and the British Association of Recovery Nurses (BARNAs) standards document 2004.¹² The AAGBI will shortly publish guidelines on UK National Core Competencies on Post-anaesthetic Care.

Equipment. Currently capnography is not routinely used in the recovery area. The AAGBI recently recommended that capnography should be used in all intubated patients and those whose airway is maintained with a SAD, regardless of their location within the hospital.¹³ Capnography is not required for all patients and is more difficult to use if the tracheal tube or SAD has been removed, but recently facemasks with a built-in attachment for capnograph monitoring have been introduced.¹⁴ Wider use of capnography may offer the opportunity for early detection of airway obstruction, respiratory depression or occlusion of an airway device.

Case review

All problems reported to NAP₄ that occurred at the end of anaesthesia and in recovery were related to airway obstruction. Regurgitation and aspiration of gastric contents may have precipitated or complicated some of these events, but aspiration was not recorded as the primary problem in any case. Wheezing, bleeding or lower respiratory tract obstruction complicated some reports.

Blood in the airway

ENT, oral maxillofacial (OMF) procedures and laser airway surgery were noticeably represented in this group and bleeding into the airway had a close association with airway obstruction. There were two examples of sudden massive haemorrhage immediately after extubation. In contrast blood in the airway was sometimes not immediately apparent; a child was extubated after tonsillectomy and transferred to the recovery room. Cyanosis developed and airway obstruction was noted, mask ventilation was difficult, tracheal intubation was easy but ventilation was still not possible via the tracheal tube. Airway obstruction was attributed to bronchospasm. Severe hypoxia with asystole followed and in an attempt to provide higher inflation pressures a cuffed tracheal tube was inserted, at this time a clot was delivered. Resuscitation was successful and the patient was transferred to ICU but died later as a consequence of the prolonged hypoxia. Case 1 is another similar example.

Case 1

A young adult ASA 4 patient with severe underlying cardiac disease underwent dental surgery prior to cardiac surgery. Induction and surgery were uneventful, throat packs were placed and subsequently removed by the surgeon. Following extubation, the patient became severely hypoxic, mask ventilation was not possible and even after re-intubation capnography showed no waveform. Four consultants from several specialties were involved in the patient's care. Attention was initially focused on getting the patient onto cardiopulmonary bypass. There was profound bradycardia and hypotension which required CPR. This continued for ten minutes before tracheal suction yielded a large amount of clotted blood. Ventilation and oxygenation immediately improved. The patient was admitted to ICU for management of suspected brain injury and subsequently made a full neurological recovery.

Foreign body

Throat packs have historically been a common cause of airway obstruction after anaesthesia and a case was reported to this project. A patient underwent spinal surgery in the prone position and a throat pack was inserted by the anaesthetist. During surgery there was a change of anaesthetist and the presence of a throat pack was not communicated. The patient was slow to recover consciousness, and in recovery was noted to be drowsy,



with signs of airway obstruction. The patient deteriorated and only during re-intubation did the second anaesthetist become aware of a throat pack which he then removed.

Airway device occlusion

Tracheal tubes and SADs became obstructed by compression or blockage. In particular there were several examples of both types of airway devices being occluded by the patient biting on them during the recovery period.

Case 2

A very muscular middle-aged patient with a BMI of $>40 \text{ kg m}^{-2}$, asthma and hypertension was scheduled for superficial day case surgery. The reporter stated a disposable laryngeal mask was selected in preference to an i-gel to avoid contact with expensive, delicate dental work. On emergence the patient bit the laryngeal mask and there was complete airway obstruction, which did not resolve with simple measures; after a delay the laryngeal mask was forcefully removed. Hypoxaemia, hypertension and florid frothy pulmonary oedema were observed. No nasopharyngeal airway was available. The trainee anaesthetist was slow to ask for help (the recovery staff did) and two consultants arrived within minutes. Mask CPAP with the patient in the upright position was not effective so the patient was re-anaesthetised and intubated. Pulmonary oedema persisted and the patient required 100% oxygen. The patient was transferred to the ICU and made a full recovery.

Drugs

Case 3

A middle-aged patient with a BMI of close to 40 kg m^{-2} presented for intermediate surgery and had a grade 3 view on direct laryngoscopy after induction of anaesthesia. The surgery became more complex and required muscle relaxation for intra-abdominal surgery. After extubation reversal of neuromuscular blockade was incomplete, the patient was hypoventilating with very low oxygen saturations. Re-intubation in the operating room was difficult and the patient was admitted to ICU for management of possible hypoxic brain injury but made a prompt recovery.

Residual anaesthetic agents, opioids and muscle relaxants reduce muscle tone which may lead to airway obstruction perhaps compounded by carbon dioxide retention. There were several clinical examples where patients became hypoxic and/or hypercarbic which alerted staff to the need for airway intervention. In some cases this was attributed to failure to maintain a patent airway.

Case 4

A young, healthy patient with normal body habitus and normal airway examination underwent plating of facial fractures. Extubation was uneventful but subsequent airway obstruction went unrecognised in recovery until the patient became hypoxic. Although the airway obstruction was then recognised and corrected the oxygen saturation of 80% failed to improve and pulmonary oedema was apparent. The patient was re-intubated and following brief ventilation on ICU made a full recovery.

Laryngeal problems

Laryngospasm was the root cause of several events at the end of surgery and in the recovery room, often being followed by post-obstructive pulmonary oedema and ICU admission. This followed trauma, laser surgery and was precipitated by blood, secretions or the presence of an artificial airway.

Case 5

A young ASA 2 patient with a BMI of $>35 \text{ kg m}^{-2}$ and obstructive sleep apnoea underwent elective nasal surgery. The patient gave a history of smoking, snoring and daytime somnolence. Preoperative airway assessment was recorded as normal and a staff grade anaesthetist performed intubation (grade 2 view) using a size 8.0mm id tracheal tube, with the aid of a bougie: initially a size 9.0mm id tracheal tube had been used but this was found to be too large. The operation was uneventful and the patient was extubated in the sitting position in the operating theatre. Laryngospasm developed, the patient desaturated quickly and was difficult to bag-mask ventilate. Propofol and suxamethonium were given but an appropriate size tracheal tube was not available and it took five minutes obtain it. The patient's oxygen saturation fell to 60% and remained low for ten minutes, bradycardia required treatment with atropine. Reintubation, by a consultant anaesthetist, was difficult (grade 3) and required three attempts. Pulmonary oedema was noted and the patient was admitted to ICU, where a prompt and full recovery was made.

There were a number of examples of stridor and airway oedema complicating surgery to the airway. This was also seen following non head and neck operations performed in the head down position. Fibreoptic endoscopy through a SAD was employed to evaluate the problem in several reports. A middle-aged patient underwent a six-hour laparoscopic operation in extreme Trendelenburg position. At induction laryngoscopic view was grade 3 and a bougie was used for intubation. After extubation the patient developed stridor and upper airway obstruction which improved after insertion of a SAD, but recurred on its removal. Fibreoptic endoscopy through the SAD showed laryngeal oedema and the patient was intubated over an Aintree intubation catheter passed through the SAD over a fibrescope. In total, three cases of airway problems after Trendelenburg positioning were reported.

External compression

Several cases of neck haematoma causing airway obstruction were reported after thyroid, carotid or other neck surgery. Opening a wound to evacuate a haematoma may address local compression, but does little to improve laryngeal oedema which resolves slowly. These cases therefore remain problematic. An elderly patient developed neck swelling following a neck dissection, airway obstruction supervened in recovery and the patient returned to theatre. Under spontaneously breathing general anaesthesia, no airway could be seen on direct laryngoscopy, intubation failed, SAD insertion was not attempted and a tracheostomy was performed to secure the airway. A diabetic patient with cervical spine disease underwent cervical spine stabilisation, sometime after extubation, while still in recovery the patient developed total airway obstruction. A consultant attempted direct laryngoscopy but failed, as did attempts to intubate using a fibrescope via a SAD. Another consultant successfully inserted a Melker cricothyroidotomy.

Post obstructive pulmonary oedema (POPO)

Total airway obstruction at the end of anaesthesia led to 13 cases of acute pulmonary oedema (several are described above). This occurred in some young fit healthy patients without co-morbidities and followed laryngospasm or occlusion of a SAD by the patient biting in several cases. In one middle-aged patient, pulmonary oedema with hypoxia and cardiac arrest, followed a 10–15 second period of total tracheal tube obstruction. In other patients airway occlusion was less acute. POPO followed partial airway obstruction in the absence of airway devices: in these cases poor airway maintenance was the root cause. A patient discharged from recovery after an



Post obstructive pulmonary oedema

incident of airway obstruction, was later admitted to the ICU from the ward with a diagnosis of pulmonary oedema.

End of anaesthesia and extubation planning

Several reports suggested that limited evaluation or preparation of the patient for extubation had taken place. These included seven patients in whom problems had been experienced at induction. Case 3 and others described above are examples.

Careful positioning, full reversal of residual neuromuscular blocking drugs, pre-oxygenation, inspection for oedema or blood, removal of retained throat packs and preparedness for re-intubation would have prevented some events.

Case 6

An elderly ASA 4 patient presented with metastatic carcinoma and a large neck mass that required resection. The patient had previously been an awkward intubation and had since had radiotherapy. Preoperative assessment led to anticipation of difficulty with mask ventilation, SAD insertion and tracheal intubation. The airway was established by AFOL using a small tracheal tube. Following the procedure the patient was transferred still intubated to recovery and then extubated. Airway obstruction developed, a junior trainee attended and immediately requested help as the patient required urgent re-intubation. After a delay of at least five minutes the consultant anaesthetist returned and re-intubated the patient using a fibrescope. The patient was admitted to ICU and made a full recovery.

Case 7

An obese patient with a hiatus hernia, who had significant laryngeal narrowing (and two previous tracheostomies) was anaesthetised by a consultant anaesthetist. The patient was extubated at the end of laser surgery, in a very controlled environment, with resources available for re-intubation, should this be required. A period of observation in the operating room indicated airway obstruction with severe hypercapnia and a SAD was inserted. Assistance was requested but the anaesthetic department was short-staffed that day and no senior help was available to assist. Fibreoptic endoscopy through the SAD demonstrated glottic oedema and tracheal stenosis, the patient was re-intubated with a small tracheal tube and intravenous dexamethasone administered. The patient was transferred to ICU and was successfully extubated the following day over an airway exchange catheter.

Contained in several reports, was an indication that important routine items of equipment, normally required to re-intubate a patient, or manage the airway, were not readily available. In one case an appropriately small tracheal tube, which had been used at induction, could not be found when urgent re-intubation was required. In a second case a bougie, which also had been needed at



induction, could not be located quickly. Missing items were mentioned in other reports, causing delays in rescue airway management in both the operating theatre and the recovery room. Patients experienced prolonged periods of hypoxia, which in some cases lasted for 20 minutes.

In contrast, some complex problems at extubation were well managed with a combination of good communication, preparation and extubation in an appropriate environment. Case 7 is an example of this. Another report described a patient who required re-intubation in recovery. A consultant had been called earlier to assist with tracheal intubation at induction. An Airtraq laryngoscope was obtained before extubation in case it was needed and this accompanied the patient. In the majority of cases the need for airway intervention is often unanticipated, but in this situation it is useful to have assembled appropriate equipment before the event.

There were no reports of complications associated with the use of airway exchange catheters during management of extubation.

Transfer to recovery room

Two patients developed complications in transit. These reports gave no indication of the distance from the operating theatre to the recovery room, of oxygen administration, or patient position during transport. Both patients were cyanosed on entering the recovery room; they subsequently required CPR and later died.

Recovery room

Patients. Many of those who developed airway problems at the end of anaesthesia were patients with inherently difficult airways. Forty-six percent were obese and many had other co-morbidities. Almost half had undergone oral or ENT surgery associated with bleeding into the airway.

Education and training. From the case reviews, it is often difficult to separate deficient training from errors of judgement, but there were examples of both. A young male became hypoxic due to poorly performed basic airway maintenance. There were other patients with unexpected and poorly explained late onset hypoxia, which may have had a similar origin.

Judgement. There were several errors of judgment and planning relating to extubation, some of which have been described already. When airway obstruction developed in the recovery room the review panel looked for a logical approach to airway management and considered the techniques used to manage similar problems at induction should be applied. Such a sequence was not always followed, for example there were delays and problems re-intubating a poorly reversed patient where a SAD might have been deployed to restore oxygenation more quickly.

Medication. Drug related problems were seen infrequently. It was speculated that residual remifentanyl sedation, perhaps from an infusion line, may have been responsible for sudden onset delayed apnoea and difficulty in ventilating an obstetric patient.

Communication. Several examples of excellent communication and preparedness were seen. There were examples where staff had been well informed and were ready and prepared for adverse events. Clear examples of poor communication other than lack of availability of staff when needed were not evident.

Equipment. The absence of, or delay in obtaining, simple and commonly used items was noted. This may indicate a lack of preparedness or a need for improved access to a difficult airway trolley in some areas.

Human Factors. Examples were seen where staff became fixated on one method of managing a problem; this was recorded when an anaesthetist persisted with attempts to correct hypoxia by CPAP when a different approach was required.

Organisation and strategic factors. Consultants were involved in most cases and there were several examples of good support offered to all members of staff in a timely way, though this is to be expected.

Team and social factors. From most reports there seemed to be a high level of support for colleagues. In some cases anaesthetists were reluctant to escalate treatment and in one such circumstance the recovery staff requested help on behalf of a trainee who appeared to have run out of options.

Work and environment. Clinical pressure may have contributed to some events where medical staff were not available when needed to attend patients in the recovery room.

Numerical analysis

Of the 38 reported cases during emergence or recovery, two patients died from the airway event. Hypoxia due to airway obstruction resulted in cardiac arrest in five patients, three of these patients survived including one who remained on ICU 30 days after the airway event, indicating severe harm. Seventeen patients experienced profound hypoxia with oxygen saturation of less than 70% and ten lower than 50%. In 18 patients it took more than ten minutes to resolve an airway problem and in 11 it took longer than 20 minutes. In ten patients an emergency surgical airway was attempted.

Patient characteristics

Six patients were aged ≤ 20 years, ten were aged 21–40, 13 aged 41–60 and eight aged 61–80. In two patients the age was not recorded.

The commonest co-morbidity was obesity, seen in 18 of the 38 patients (46%), followed by chronic obstructive airways disease in 13 patients. Five patients had obstructive sleep apnoea: in two this was unknown at the time of surgery.

Location and type of events

Twenty complications occurred in the operating room, 16 in the recovery room and two between these locations. In 50% of cases airway obstruction was thought to have been detected immediately by those present at the incident and in 50% there was delay. Thirteen cases were complicated by post-obstructive pulmonary oedema.

Risks for airway problems in recovery

Seven of the 38 airway events at the end of anaesthesia or in recovery followed airway problems at induction. There were 13 ENT and five OMF operations and 16 had surgery within the airway. There were three events due to laryngeal oedema after surgery in the Trendelenburg position.

Contributory and causal factors.

The commonest contributory and causal factors in events at the end of anaesthesia or recovery were patient (eight causal, 22 contributory), judgement (five causal, 18 contributory), education and training (18 contributory) and communication (one causal, ten contributory).

Quality of airway management

Airway management was assessed by the review panel as good in eight, poor in ten, mixed in 18 and no comment in two.

Discussion

Anticipation of problems at the end of anaesthesia

There were examples of good and poor management of extubation. Some patients were extubated at the end of anaesthesia in a very controlled environment with all resources available for re-intubation. In contrast patients with known airway problems ran into difficulty due to lack of

anticipation or preparation. Good extubation requires careful preparation: reversal of residual paralysis, pre-oxygenation, appropriate positioning, communication with the team, and planning for management of complications after extubation.

Unanticipated problems

When problems occurred that were not, or could not be anticipated, there were examples of excellent management but in some cases the response was judged to be poor and usually the LRs themselves acknowledged this in their submission. When unanticipated problems developed a number of patients were managed along the lines of published guidelines for management of the unanticipated difficult intubation. The review panel found this approach to be rational.

Transfer

Two patients were cyanosed on arrival in the recovery room, one was subsequently found to have a blood clot in the trachea. There was insufficient detail to comment on the preparation of these patients before transfer but these cases illustrate the need for assessment of the airway, breathing and oxygenation immediately before leaving the operating room. There was no mention in the reports of the distance to the recovery area, oxygen administration, or monitoring in transit. During the review panel meetings, the position of patients after surgery and during transfer was discussed: the use of the recovery position should be considered after extubation, particularly after surgery within the airway or where there are other risks of aspiration.

Availability of anaesthetists

It is widely recognised that the anaesthetist's responsibility for the patient does not finish when they are transferred to recovery. There was a delay in the management of at least one patient as the anaesthetist was busy administering an anaesthetic and therefore unavailable to attend to their patient. Elsewhere help was requested for dealing with a difficult airway at emergence; none was available as the department was 'stretched'. The quality and safety guidelines of post-anaesthesia care issued by the European Board and Section of Anesthesiology recommend that there should be an anaesthetist supernumerary to requirements in the operating theatre immediately available for the recovery room.¹⁰ The presence of such a roving/duty consultant was favourably mentioned in some reports but this service is not universally available.

Staff training

Late detection of airway problems was implicated in some reports. This was specifically mentioned in a report of airway obstruction in a patient after complicated facial surgery. In another case a midwife was left to recover a patient in labour following a general anaesthetic. Although



there was no evidence to suggest that the midwife monitoring this patient failed to perform to a high level, general anaesthesia is now relatively uncommon in obstetric practice and it may be difficult for midwives to maintain their skills in this area. There is no agreed national standard for training of recovery staff therefore anaesthetists may need to stay with a patient if not satisfied the recovery room has appropriately experienced or trained staff.

Equipment

Numerous reports highlighted problems with prompt provision of essential equipment, often of a quite basic nature including tracheal tubes, a bougie, a nasopharyngeal airway and an intubating laryngeal mask. Staff in recovery areas need rapid access to an airway trolley which should include equipment suitable for routine and difficult airway management. Other sections of this report highlight the recommendation for capnography in all areas where tracheal intubation is performed. This also applies to tracheal intubation in the recovery room. Routine capnography might have enabled earlier detection of airway obstruction in some cases, if it had been available and staff trained in its use.

Communication and planning

One anaesthetist commented that he had not warned the recovery staff of the need for jaw thrust to maintain airway patency. Since airway management is a primary role of the recovery staff the need to inform them of this basic requirement would suggest a training deficiency, but the comment highlights the importance of communication. As part of the anaesthetic handover the anaesthetist should outline likely airway problems. If a problem is anticipated the information passed to recovery staff should include the early warning signs, the management plan, whether there is a need to use additional monitoring such as capnography, equipment needed to manage the problem and the location of appropriate medical help if needed. Recovery room staff can then take early action if they recognise the appropriate signs.

Discharge planning

Most recovery rooms follow routine discharge criteria. After an airway problem these may require modification, to allow the anaesthetist to personally reassess the patient before discharge.

Learning points and recommendations

- About one in six anaesthesia-related events occurred during emergence and a further one in six in recovery, emphasising that both are periods of importance for airway complications.
- Upper airway obstruction by laryngospasm, tracheal tube or supraglottic airway obstruction was a leading cause of airway problems during emergence and recovery.

- Upper airway obstruction even of very short duration can lead to post obstructive pulmonary oedema with severe hypoxia.
- Bleeding into the airway was a recurrent cause of reports to NAP4. Blood around the airway requires careful inspection and suctioning before controlled extubation.
- Laryngeal oedema followed several operations in the Trendelenburg or head down position and led to airway obstruction, particularly after airway trauma.
- Neck haematoma produced airway oedema and hampered re-intubation, even where direct laryngoscopy was previously easy.
- Obesity, and asthma or COPD were the most common co-morbidities associated with recovery room events.
- Necessary equipment or staff to manage re-intubation was not always immediately available.

Recommendation: Patients should be assessed and optimised before tracheal extubation to ensure they are extubated with effective neuromuscular function, after pre-oxygenation and appropriate airway toilet.

Recommendation: Patients at high-risk of airway problems at emergence require a specific extubation and re-intubation plan. Extubation should usually take place in theatre with the team assembled and may include the use of specific techniques to facilitate re-intubation.

Recommendation: Supplementary oxygen is needed for transport after general anaesthesia and supplementary monitoring should be considered as recommended by the AAGBI.

Recommendation: In patients at risk of airway problems, an airway management plan should be conveyed to recovery staff which should include: (1) Potential problems, (2) Signs indicating concern, (3) Planned management, (4) Equipment required, (5) Location of appropriate medical help if needed.

Recommendation: Recovery room staff should be trained to an agreed standard in all hospital sites; this must include the prevention, early recognition and management of airway obstruction.

Recommendation: Capnography has the potential to aid early detection of airway obstruction. It should be available in recovery and used in high-risk cases.

Recommendation: Tracheal tube and SAD obstruction by the patient biting should be prevented by the insertion of a bite block, an oropharyngeal airway, or the use of SADs with an integral bite block.

Recommendation: A full range of difficult airway equipment and experienced staff should be readily accessible in recovery.

Recommendation: Patients who have potential airway problems or have had complications should be reassessed by the responsible anaesthetist before discharge.

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Headline

Nearly 20% (36/184) of all airway incidents reported to NAP₄ occurred in the intensive care unit (ICU). The degree of harm that came to these patients was much higher than those presenting during anaesthesia or in the emergency department: 61% of ICU patients suffered either neurological damage or died compared to 14% during anaesthesia and 33% in the emergency department. Seventy percent of reported events and 60% of deaths involved complications of tracheostomies: these cases are considered in more detail in Chapter 15.

There were several themes that ran through the cases. Some acutely ill patients could not be intubated or had unrecognised oesophageal intubations. Displacement of tracheal tubes and tracheostomies occurred, especially in obese patients and on moving patients for care. Recognition of displacement was frequently delayed and capnography, which might have detected this promptly, was rarely used. Unanticipated displacement of artificial airways occurred at all hours of the day or night, not infrequently at times when only relatively junior medical staff were available to deal with potentially difficult airway management. Lack of advanced airway equipment, as well as lack of advanced airway skills, played a part in some of the reports and led to avoidable harm. All 'rescue techniques' (facemask ventilation, supraglottic airway device (SAD) placement, direct tracheal access) failed relatively frequently. In several cases, there was apparent failure to identify ICU patients who had high-risk airways. This led to failure to establish a plan that could be put into action when such patients suffered a critical incident relating to their airway. Even when such cases were identified, planning was ineffectual at times and sometimes a plan was in place but either the equipment or the personnel to carry it out were not immediately available, rendering it ineffectual.

What we already know

Patient factors

Airway control is often difficult in the patient in ICU. Most ICU patients are intubated at some point during their admission. Simpler techniques, such as insertion of SADs or maintaining the airway with a facemask are rarely acceptable options. Airway management of even the 'easy' airway may be compromised by several factors, including:

- Inefficient pre-oxygenation caused by ventilation-perfusion (V/Q) mismatch from the underlying illness, frequently exacerbated by poor patient co-operation.
- Urgency of the need to intubate in many cases.
- Lack of physiological reserve, because of V/Q mismatch (in particular 'shunt') leading to very rapid hypoxaemia during any airway manipulation.
- Full stomach due to gastroparesis of critical illness or to the urgency of interventions.

At the time of (intended) extubation/weaning, V/Q mismatch usually persists making this too, a high-risk period.

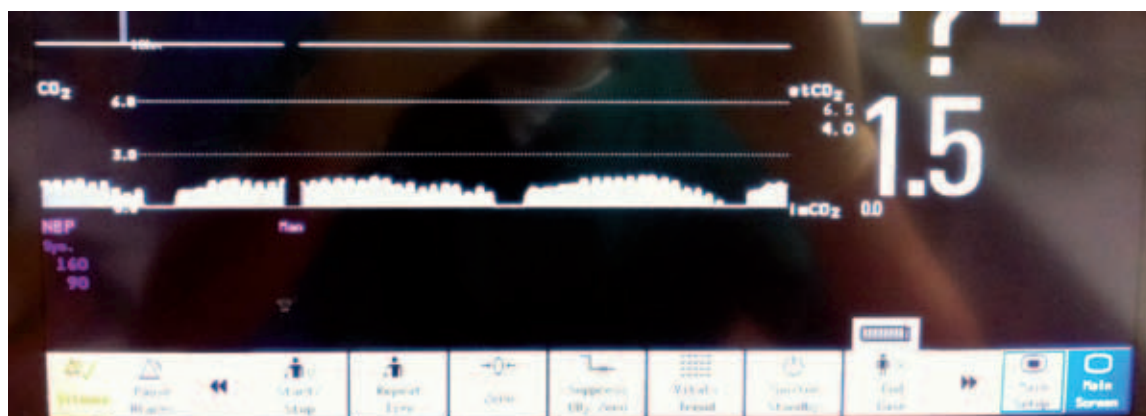
A significant proportion of patients on ICU are there because they have vulnerable airways (e.g. major trauma requiring cervical spine protection, major head and neck surgery or infection, cervical surgery, burns, airway swelling or trauma). Patients who have had surgical treatment of their difficult airway (e.g. ENT procedures), or who have had airway complications leading to ICU admission may have critical placement of their tracheal or tracheostomy tube. Patients who initially may have 'easy' airways become more difficult during a period of critical illness because, for example, of oedema.

Accidental extubation is a recognised complication of critical care airway management, and has been reported to occur at a rate of 0.11 to 2.27 per 100 ventilator days.¹ Factors that may be associated with accidental extubation include imperfect use of sedation and restraints, movement of patients, poor nurse-to-patient ratios and ineffective methods of tube fixation. Morbidly obese patients are at higher risk of tube displacement.² Unplanned extubation is associated with difficult re-intubation in two-thirds of patients.³

When airways are compromised, adverse events and death are more common in the critically ill because of their co-morbidities and decreased physiological reserve. Transfer of the patient, for example, to theatre for definitive management of a compromised airway is fraught with hazard, and many operating departments are remote from their ICU.

Equipment factors

Airway equipment used in ICU is frequently not the same as that used in theatres. UK surveys have shown that



Typical capnograph trace during CPR with the tracheal tube correctly placed

continuous capnography is rarely used in the critical care environment^{4,5} and access to difficult airway trolleys is limited.⁶ Even when a difficult airway trolley is available, it is rarely of the same standard as in theatres.⁷

Specific issues with tracheostomy equipment are dealt with in Chapter 15.

Staffing and training factors

In the operating theatre, anaesthetists, assisted by trained operating department personnel, attend all patients with artificial airways. In contrast in the ICU, critically ill patients with artificial airways are largely cared for by nursing staff, who have a variable background and understanding of airway issues. Immediate availability of a doctor with advanced airway skills is not always guaranteed, and as intensive care medicine trainees and consultants come increasingly from backgrounds other than anaesthesia, the issue of training for airway skills and ensuring access to advanced airway skills is a real and increasing concern. It is likely that changes in practice have not kept pace with the changes in manpower.

Environment factors

The physical environment is not designed for anaesthetising patients and lack of space due to other equipment, poor positioning, poor lighting, poor access to the patient on a bed can all contribute to considerable potential difficulty, in a manner that is not seen in the theatre environment. The ICU might therefore be regarded as 'a hostile environment' for such procedures.

Case review

Most reported cases involved either failed or oesophageal intubation, accidental extubation (tracheal tube or tracheostomy) or haemorrhage. In six cases, aspiration of gastric contents or blood complicated the primary event. In three cases, the airway event was directly related to patient transfer.

Nearly half of reported events (46%) occurred outside 'office' hours when the first medical attendant was a trainee who would not necessarily have advanced airway skills. In contrast, only 31% of anaesthesia events occurred 'out of hours'.

Unrecognised oesophageal intubation

There were four cases, of unrecognised oesophageal intubation, leading to two deaths and perhaps contributing to a third. Two were intubations performed by relatively junior trainees that subsequently proved to be straightforward. Both were performed without capnography. In a third case, following a tracheostomy displacement a patient developed massive surgical emphysema and cardiac arrest: during unsuccessful resuscitation re-intubation was made difficult by the surgical emphysema and there was an unrecognised oesophageal intubation. The report did not state whether capnography was used. In the fourth case, a sick, unintubated, obese patient suffered a cardiac arrest in the CT scanner. Laryngoscopy was difficult, with a grade 3 view, and intubation required two attempts and the use of a bougie. The tracheal tube position was checked by observing chest movement and by auscultation, but capnography was not used. Resuscitation was unsuccessful. The position of the tracheal tube was checked after death by fiberoptic bronchoscopy and found to be in the oesophagus.

Failed intubation

In ten cases, patients could either not be intubated (six patients) or re-intubated when accidentally extubated (two patients). One further patient had a planned extubation complicated by airway obstruction and failed re-intubation and in one patient a tracheal stent placed to alleviate upper airway obstruction became misplaced leading to failed intubation.

In several patients with anticipated difficult airways, intubation was delayed until the patient was in extremis, exacerbating what was already bound to be a difficult



problem. In others there was an apparent failure to recognise potential difficulty. Even when difficulty was recognised, in some, there was a failure to establish a back-up plan for a patient at risk of difficult intubation. Finally, some plans were established but equipment or skilled staff to carry the plan out were not available when difficulty arose.

Case 1

One patient who had a cervical spine fracture and was in a halo traction apparatus, had increasing respiratory difficulty for several hours before being referred to anaesthetists in the middle of the night for emergency airway management; the intensivist was not an anaesthetist. A tracheostomy was secured after considerable delay and the patient's oxygen saturations were less than 85% for at least an hour.

Case 2

A young cachectic patient with a myopathy developed respiratory failure secondary to pneumonia. The patient deteriorated in the middle of the night: by this time on 100% oxygen with non-invasive ventilation intubation was imperative and two trainee doctors attended. The patient could not be intubated and ventilation with a laryngeal mask was inadequate. The reporter commented that a ProSeal LMA was not available. Attempted cricothyroidotomy by the trainees failed, and the patient died.

Case 3

A patient with a known difficult airway had been extubated but needed re-intubation because of respiratory distress in the early hours of the morning. Re-intubation was predicted to need fiberoptic intubation but this was not available on the ICU and the doctor capable of performing the technique was at home. It took an hour for suitable equipment and staff to be assembled. During this time oxygenation was barely maintained by trainees performing airway manoeuvres. When attempted fiberoptic intubation failed, emergency tracheostomy was performed. The patient ultimately recovered fully.

Rescue techniques failed frequently, both mask ventilation and rescue with a SAD, leading to the need for rescue cricothyroidotomy. Although most difficult airway algorithms include cricothyroidotomy as part of the management of the 'Can't Intubate, Can't Ventilate' (CICV) scenario, in this group of patients, the failure rate was high (three of five) and surgical emphysema complicated a further insertion although the airway was established in that patient. In some cases needle cricothyroidotomy was itself rescued by tracheostomy and in others it was a pre-terminal event.

Case 4

A patient with multiple co-morbidities developed oozing after a very prolonged carotid endarterectomy. Initial intubation had been grade 3. During resuscitation from a bradycardic arrest prior to admission to ICU the patient's airway was managed with an i-gel, until the patient awoke. The patient was sent to ICU for monitoring and five hours later, in the middle of the night, had an asystolic arrest. There were prolonged attempts to establish an airway. Attempts to establish the airway with an i-gel, laryngeal mask and ILMA all failed. Intubation failed. Needle cricothyroidotomy failed. A surgical tracheostomy failed and the patient died. The LR commented that a ProSeal LMA was not available.

Accidental Extubation

1 Tracheostomy displacement

Inadvertent tracheostomy dislodgement occurred in 14 patients and led to half of all cases of death and brain damage on ICU. This problem is discussed in more detail in Chapter 15.

2 Tracheal tube displacement

Four patients were accidentally extubated while ventilated through a standard tracheal tube. Three of these patients were obese. Another had a known 'difficult airway' because of cancer. Two patients suffered aspiration during the event.

Capnography was rarely in use at the time of either tracheal tube or tracheostomy displacement. In several cases there was evidence that recognition of extubation was markedly delayed, even until cardiac arrest.

Many of the above patients were obese. Standard tracheal tube displacement occurred in several patients when they either coughed or attempted self-extubation when waking during a sedation hold. Patient movement and minor airway instrumentation also precipitated displacement of standard tracheal tubes. In the tracheostomy group similar patterns were seen (e.g. tracheostomy displacement during passage of a nasogastric tube) and, considering that the majority of these patients were obese, leads to the speculation that the tracheostomy may have been relatively short or of an unsuitable design for the patient's anatomy.

Reporters commented on lack of equipment (e.g. intubating LMA, ProSeal LMA, fibrescope) in three cases; in two cases it was clear there was no 'failed extubation' or back-up plan in place for an obese patient with a challenging airway. These cases emphasise the need for a plan for 'inadvertent extubation' as well as one for failed intubation.

Tracheostomies and tracheal tubes become dislodged at all times of day or night and attending staff did not always have the knowledge or equipment to deal with the problem in a measured way. Attendance by only junior trainees was

common in out of hours cases. Routine rescue techniques (e.g. placement of a supraglottic airway) were not always used during management of the airway event. Staff reporting these incidents did not always know what airway equipment or manoeuvres were (e.g. BURP, Combitube), suggesting a lack of training in advanced airway skills.

Case 5

A patient with cancer of the floor of the mouth had a nasotracheal tube in place and was ventilated on ICU two days later because of facial and airway swelling. The nurse caring for the patient noted that he had stopped ventilating and attempted to assist ventilation by hand. There was decreased chest movement and damped, then no capnograph trace, but oxygenation was maintained. The position of the tube was not checked with a fiberoptic endoscope at this stage. The surgical team promptly took the patient to theatre. Fiberoptic endoscopy demonstrated that the tube had displaced into the oesophagus and a tracheostomy was performed immediately. The patient had apparently been ventilated for 30–40 minutes with the tracheal tube in the oesophagus; the occluded upper airway was thought to result in gas going into the lungs, maintaining oxygenation and chest movement.

Case 6

A neonate with dysmorphic features was intubated in another hospital at sixth attempt and transferred to a neonatal unit. While a non-invasive investigation was being performed the tracheal tube fell out when the head was moved; despite the attempts by a consultant neonatologist, intensivist and anaesthetist, a tracheal tube could not be re-inserted and the airway was rescued with a laryngeal mask. The patient was transferred to theatre for an emergency tracheostomy but the laryngeal mask was displaced during transfer, the airway could not be re-established and the patient died.

Haemorrhage

One obese patient with thrombotic thrombocytopenic purpura suffered life-threatening haemorrhage after the difficult, and presumably traumatic, insertion of a tracheal tube assisted with a bougie; the patient suffered a cardiac arrest secondary to hypoxia but eventually recovered.

A patient had blood loss in excess of one litre after removal of a percutaneous tracheostomy that had been placed to aid weaning from mechanical ventilation 24 hours previously. The tracheostomy was replaced and although the patient had a prolonged ICU stay because of aspiration of blood, recovered.

Another patient with a pathological fracture of his cervical spine developed respiratory difficulties several days after surgery to fix his spine. Intubation was impeded by a soft tissue mass and an urgent surgical tracheostomy attempted. However, the airway was lost because of bleeding in the lower airway and despite prolonged resuscitation efforts the patient died.

Problems during transfer

Three patients suffered adverse events directly related to transfer to or from the ICU: all died or sustained brain damage. In one case the patient was being transferred to theatre to establish a definitive airway when the airway was lost. In the second an oesophageal intubation occurred during cardiac arrest in the radiology department. A third patient, transferred to theatre for a semi-elective tracheostomy for weaning desaturated on moving from bed to operating table. The surgical trainee could not place a tracheostomy but a consultant subsequently did; this patient suffered brain damage.

Miscellaneous cases

One patient had a trachea-bronchial stent inserted to treat a trachea-oesophageal fistula secondary to small cell lung cancer. Respiratory failure developed secondary to hospital-acquired pneumonia and when re-intubation was attempted the stent was displaced. The patient died as a consequence of the massive air leak from the fistula.

A tracheal stent previously placed in a patient with an obstructing oesophageal cancer became displaced during intubation and after failure to rescue the airway the patient died as a result.

A patient recovering from severe acute respiratory distress syndrome developed stridor several weeks after removal of a surgically performed tracheostomy. The ENT registrar who was called to assist in re-intubation underestimated the likely difficulty, assuming the patient had tracheomalacia; in the event, intubation was impossible because of a solidly obstructing stenosis. Cricothyroidotomy was achieved with great difficulty. In this case, back-up equipment and planning were available. The patient was ventilated overnight through a mini-tracheostomy and the tracheostomy was surgically refashioned the following day.

These cases illustrate the complexity of airway difficulty that may be encountered in ICU.

Numerical analysis

There were 36 reported events that occurred on the ICU: 18 resulted in death of the patient and four, significant neurological injury (combined rate 61%). Seventeen (47%) occurred in obese patients and 17 (47%) outside normal working hours: both higher proportions than in anaesthesia or emergency department cases.

There were four cases of unrecognised oesophageal intubation, resulting in three deaths. Capnography was not used.

Ten events involved failed intubation (including re-intubation after inadvertent extubation), resulting in five deaths. Of these ten patients, six patients had a SAD



used to attempt rescue the airway. In all six cases this was initially a laryngeal mask, which was followed in one case by an i-gel then an intubating laryngeal mask. Five events deteriorated to CICV. Five had a cricothyroidotomy attempted, but in three instances insertion failed and in one case despite successful placement there was significant surgical emphysema. Failed intubation was managed with surgical tracheostomy in six cases.

Twenty-two cases involved accidental airway displacement: 14 of a tracheostomy (seven deaths and four patients with brain damage) and four of a tracheal tube (no deaths). Capnography was not in use in nine tracheostomy cases and in five, its use was unclear. Capnography was not recorded in any tracheal tube inadvertent extubations. Obesity was prominent in both groups but particularly with tracheostomy cases. Airway rescue with a SAD was attempted in only three of the patients with displaced tracheostomy and one patient with a displaced tracheal tube.

In all, there were 12 attempts at placement of an emergency surgical airway (33% of all ICU cases) with three completely failing to rescue the airway, a failure rate of 25%. Three were in obese patients. Of these 12 patients three died and one suffered brain damage as a result of the event. Five cannula cricothyroidotomies were attempted, three failed. There were three deaths, two after failed cricothyroidotomy and one despite success. One cannula was successfully placed in the trachea via an old tracheostomy site. Seven tracheostomies were performed (two after cricothyroidotomy) and in at least six the airway was apparently entered; one patient suffered brain damage.

Two cases occurred during planned formation of a tracheostomy: both involved failed placement: one was a surgical tracheostomy performed by a non-ENT specialist and the other a percutaneous tracheostomy performed on ICU.

Three patients suffered life-threatening haemorrhage during airway manoeuvres: two tracheostomy patients and one tracheal intubation. One patient died.

Three events occurred during transfer to or from the unit. Two led to death and one to brain damage.

The most frequent causal and contributory factors, as assessed by the review panel, were patient-related (e.g. obesity, recognised difficult airway (25, 69% of cases), followed by education and training (21 cases, 58%), judgement (18, 50%), equipment and resource (13, 36%) and communication (11, 31%). Positive factors were identified in 19 cases (54%): the most frequent positive factors were good communication (13, 36% of cases) and good organisation or strategic factors (7, 19%).

Discussion

Given the methodology used in NAP₄ (with LRs in all anaesthetic departments and only half of ICUs), it is likely that we have missed more ICU than anaesthesia cases. Despite this, reports from ICU account for a disproportionate number of adverse airway incidents, with one fifth of all events and more than half of all events leading to death or brain damage coming from ICU. It is quite possible that we have only identified a fraction of relevant cases. The project identified that obese patients or patients with oral pathology are at particular risk of these events. NAP₄ confirms that patients are at increased risks of airway hazards such as tube dislodgement when being moved or when having procedures close to the airway. These events are prominent in obese patients (47% of patients were obese) and in those patients who died. Events on ICU were more likely than those in anaesthesia to occur out of hours, to be managed by doctors with less anaesthetic experience and lead to permanent harm, including death.

Themes identified by review of the cases from ICU include:

- Right practitioner: the cases raise concerns that junior staff who are without the experience or skills to deal with airway complications, are resident as the only medical staff on ICUs out of hours. This applies particularly to trainees without anaesthetic backgrounds.
- Right equipment: reporters noted a lack of equipment on several occasions. Reviewers noted that the breadth of equipment used to manage airway compromise was considerably narrower than that available in theatres. Rescue techniques were not always used when indicated and when used, failed more often in ICU than anaesthesia; these factors may be related.
- Right preparation: a major concern was lack of anticipation and planning for difficult cases. Planning has several phases.



- ◆ Recognition of potential difficulty.
 - ◆ Formation of a strategy (plan A, B, C etc).
 - ◆ Confirmation that the equipment to perform these plans is immediately available.
 - ◆ Confirmation that the appropriately skilled and experienced staff are immediately available.
 - ◆ Communication of these plans at staff handovers.
- Right location: three events occurred during transfers to or from the ICU or at locations outside ICU. Equipment and capacity to deal with these events was lacking.

Failure of rescue cricothyroidotomy is noted elsewhere (see Chapter 13), but also occurred in a high proportion of attempts here.

Problems associated with percutaneous dilational tracheostomy, though reported elsewhere to be a significant issue,^{8,9,10} were restricted in NAP₄ to one failed placement and one episode of major bleeding when one was removed within 24 hours of formation. We do not speculate on why this is so.

Finally, and perhaps most importantly, although continuous capnography is a standard of care in the operating theatre,¹¹ it has not been widely adopted in the ICU environment. This may partly, be because of technical difficulties with humidification leading to malfunction, and partly because of the associated costs. Despite this, many units do now use it routinely, so these problems are not insuperable. Failure to use capnography likely contributed to 17 cases of death or brain damage, as a result of failure or delay in recognising displaced or misplaced airway devices. This included three oesophageal intubations and 14 inadvertent tube displacements, which account for 77% of ICU deaths. Use of capnography would likely have prevented or reduced the extent of patient harm in all of these cases. It has previously been noted that recognition of tube displacement in ICU is delayed in the absence of capnography and this report confirms that. While fiberoptic inspection (again unavailable for several events) has a role in such events it is likely capnography is the important missing step. In view of these findings and the identification of avoidable deaths our recommendations on capnography are robust.

Learning points and recommendations

Capnography

Failure to use capnography both at intubation (oesophageal intubation) and during ventilation (misplaced tubes) led to avoidable deaths. This is a starkly different approach to anaesthesia.¹¹

Recommendation: Capnography should be used for intubation of all critically ill patients irrespective of location.

Recommendation: Continuous capnography should be used in all ICU patients with tracheal tubes (including tracheostomy) who are intubated and ventilator-dependent. Cost and technical difficulties may be practical impediments to the rapid introduction of routine capnography. However these problems need not prevent its implementation. Where this is not done the clinical reason for not using it should be documented and reviewed regularly.

Recommendation: Training of all clinical staff who work in ICU should include interpretation of capnography. Teaching should focus on identification of airway obstruction or displacement. In addition, recognition of the abnormal (but not flat) capnography trace during CPR should be emphasised.

Intubation

Intubation of critically ill patients is always hazardous. NAP₄ identified several cases where management of intubation was by staff who were inadequately experienced, and when problems arose they were not managed in a logical or recognised manner.

Recommendation: An intubation checklist should be developed and used for all intubations of critically ill patients. A checklist might usefully identify preparation of patient, equipment, drugs and team. A checklist should include identification of back-up plans (an example is in Appendix 1.)

Recognition of difficulty and back-up planning.

Avoidable harm occurred in this cohort of patients due to failure to plan for difficulty, or creation of plans that did not include confirmation of all the necessary resources and were therefore not feasible. This included several patients who were admitted specifically to manage or monitor airway problems, but in whom no effective management plan was in place when difficulties arose.

Recommendation: Every ICU should have algorithms for management of intubation, extubation and re-intubation. National efforts should be made to develop evidence-based algorithms. There should also be plans for management of inadvertent tracheal tube or tracheostomy displacement or obstruction. (Examples of such plans are in Appendix 2 and 3 and further examples are available at www.tracheostomy.org.)

Recommendation: Patients at risk of airway events (i.e. those patients at increased risk of problems or for whom the standard algorithms are not appropriate) should be identified and clearly identifiable to those caring for them.

Recommendation: A plan for such patients should be made and documented. The planning should identify primary and back-up plans. The plan should also identify any additional



equipment and skills necessary to carry out the plan. The plan should be communicated to on-coming staff at each staff handover, including confirmation that the plans can still be carried out. (An example of a proforma to assist this process is in Appendix 4.)

Tube displacement

Tube displacement may occur at any time but is more frequent in obese patients, in patients with tracheostomy, during or after patient movement and during sedation holds.

Recommendation: Staff education should recognise and emphasise these risks.

Obesity

Obese patients are identified by NAP₄ as a group specifically at risk of airway complications. Displacement of tracheostomy was a particular problem. With demographic changes this problem is likely to increase in the future.

Recommendation: Obese patients on ICU should be recognised as being at increased risk of airway complications and at increased risk of harm from such events. Plans to manage the airway should be particularly meticulous in this group.

Recommendation: Responsible bodies (e.g. Intensive Care Society, Royal College of Anaesthetists) should work with other stakeholders and manufacturers to explore two aspects of tracheostomies for obese patients. (1) Can tracheostomy design be improved to reduce risk of displacement? (2) Can the optimal mode of fixation be determined?

Airway equipment

Avoidable harm occurred due to lack of equipment (as assessed by both reporters and reviewers). There was clear evidence that some ICUs do not have access to adequate difficult airway equipment. Prompt access to a fibroscope for airway inspection or for difficult airway management was a recurrent problem.

Recommendation: Every ICU should have immediate access to a difficult airway trolley. This should have the same content and layout as the one used in that hospital's theatre department. The airway trolley needs regular checking, maintenance and replacement of equipment after use which should be appropriately documented.

Recommendation: A fibroscope should be immediately available for use on ICU.

Cricothyroidotomy

High rates of failure of cricothyroidotomy were identified.

Recommendation: Training of staff who might be engaged in advanced airway management of these potentially difficult patients should include regular, manikin-based practice in the performance of cricothyroidotomy. Trainers should regularly encourage their trainees to identify the correct landmarks, especially on obese patients.

Recommendation: Research is actively needed to identify the equipment and techniques most likely to be successful for direct tracheal access in critically ill patients. This research should specifically address whether the same solutions are effective in obese patients. The role of ultrasound in this area could be explored.

Patient transfers

Patient transfers, whether inter- or intra-hospital, are high-risk episodes.

Recommendation: An airway assessment that includes patient, equipment, back-up and staff skills should be made prior to patient transfers.

Staffing

Airway events in ICU were more likely than anaesthesia events to occur out of hours and to be managed by trainees, often with limited or no anaesthetic experience. Poor outcomes were causally associated with these findings.





Recommendation: Trainee medical staff who are immediately responsible for management of patients on ICU need to be proficient in simple emergency airway management. They need to have access to senior medical staff with advanced airway skills at all hours.

Recommendation: Where senior intensivists do not have an anaesthetic background with advanced airway management skills, it is recommended that specific protocols are in place to ensure experienced anaesthetic cover can be called on to assist in the management of difficult cases. Training and rehearsal of airway management techniques could usefully take place in conjunction with the anaesthetic department. Trust management should support the financial implications.

Education/training

The reviewers found evidence of lack of knowledge of both equipment and advanced airway techniques in staff caring for patients with compromised airways.

Recommendation: Junior medical staff who are to be immediately responsible for management of patients on ICU need airway training. This should include basic airway management, familiarisation with algorithms for management of predictable airway complications and use and interpretation of capnography. Training should identify the point at which trainees reach the limit of their expertise,

and the mechanisms for summoning more experienced clinicians. Such training is likely to include simulation and team training.

Recommendation: Regular audit should take place of airway management problems or critical events in the ICU. Many airway management deaths are avoidable and should warrant special attention at morbidity and mortality meetings. Problems identified with skills, recognition, equipment and support should be rectified.

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Professor Jonathan Bengler

Headline

There were 15 cases reported to NAP₄ where the airway event occurred in the emergency department. Most cases related to difficulty in intubation. Events occurred more frequently out of hours than in anaesthesia cases. Several cases were attended by trainees who lacked the appropriate skills and experience to manage the patients they were presented with. Precipitous care, delayed care, and poor care (failure to use or correctly interpret capnography) all led to avoidable patient harm. Emergency surgical airway was prominent in emergency department reports and was eventually successful in all cases though initial attempts at cannula cricothyroidotomy failed, requiring rescue with a surgical approach. These issues can be summarised in the concept of 'right person, right place, right equipment, right preparation'.

Emergency department airway management is a high-risk area that requires teamwork and a considerable degree of expertise. The majority of the major complications reported to NAP₄ from the emergency department would have been preventable through improved systems, better preparation and good communication. All relevant specialties should therefore plan for likely events, ensuring that those who are called upon to undertake emergency department airway management have the required skills and immediate access to senior support. All emergency department airway practitioners should also be familiar with the environment and the available equipment, which should be standardised to include everything that is likely to be required. Standards of practice, assistance and monitoring (particularly capnography) should conform to nationally accepted guidelines and be identical to operating theatre practice.

What we already know

Approximately 1 in 800 patients attending the emergency department will undergo rapid sequence induction of anaesthesia and tracheal intubation (RSI), and this equates to approximately 20,000 patients every year in the UK.¹ Many more will require simpler airway interventions such as the use of adjuncts, mask ventilation and tracheal intubation without drugs. Airway management, often in an emergency situation, may also be required in the general wards, radiology department and other non-theatre hospital locations: many of the key learning points drawn from the emergency department in NAP₄ will also apply to these environments.

Emergency airway management outside the operating theatre is known to be associated with more frequent problems than routine anaesthesia. Patients with major trauma, though relatively uncommon, merit special consideration in this chapter. They present to UK emergency departments with little or no warning and have acknowledged airway difficulties due to direct airway trauma, haemorrhage into the airway, lung injury limiting pre-oxygenation, physiological compromise (sometimes including critical hypovolaemia) and a requirement to immobilise the neck due to possible cervical spine injury, which is known to increase the incidence of Cormack and Lehane grade 3 and 4 views of the larynx, making intubation even more difficult.²

During elective anaesthesia a failed airway ('cannot intubate, cannot ventilate', CICO) has been reported to occur in 0.01-0.03% of cases.³ Difficult intubation, defined as the need for more than three attempts, has been reported in 1.15-3.8% of elective surgical cases.³ However, the incidence of difficult intubation is significantly higher in emergency departments,⁴ and a failed airway may occur at least ten times more frequently in the emergency department. In the United States, 0.5% of intubations recorded in the National Emergency Airway Registry (NEAR) required a surgical airway.⁵ In a Scottish study, 57/671 (8.5%) of patients undergoing RSI in the emergency department had Cormack and Lehane grade 3 or 4 views at laryngoscopy, and two (0.3%) required a surgical airway.⁶ As a result it is essential that this patient group is managed by experienced individuals who have specific training in emergency airway management outside the operating theatre, and who are able to provide a full range of relevant skills. There must also be a clear system of clinical governance and review to ensure that commonly accepted standards, for example those specified by the Association of Anaesthetists of Great Britain and Ireland, are maintained⁷ and that all the required equipment is immediately available.

Historically, all advanced airway management, regardless of location, has been undertaken by anaesthetists, but this is now changing. In larger hospitals doctors working in critical care (who are usually, but not always, trained in anaesthesia) are often the first to be called for emergency airway management outside the operating theatre. Critical care teams may be more rapidly available if duty

Airway management in the emergency department and remote hospital locations

anaesthetists are occupied in theatre, and a requirement to provide emergency airway management may overlap with the input provided to cardiac arrest and acute intervention or outreach teams. It is also likely that the patients attended by such teams will require critical care interventions beyond airway management, and may be subsequently admitted to the intensive care unit (ICU). However, problems are likely to arise if those attending do not have the expected, or required, airway skills.

Over the past decade emergency physicians in the UK have become increasingly interested and competent in emergency airway management, and 20% of emergency department RSI is now undertaken by this group.¹ This is in keeping with the emergency physician's role at the 'front door' of the hospital, but there are as yet far too few emergency physicians with the relevant skills to be able to provide robust 24-hour emergency airway management in all the UK's emergency departments. Therefore close co-operation with other specialties will continue to be required for the foreseeable future. Increasingly, doctors from critical care and emergency medicine are working together to provide emergency airway management to seriously ill and injured patients, particularly in the larger UK hospitals. The emerging evidence base comparing emergency physicians with anaesthetists in emergency department airway management suggests that there is no significant difference between the two professional groups in terms of intubation success and complications.^{6,8,9} Whilst

this continues to cause controversy in some quarters, the specialty of the person managing the airway is less important than the competencies of that individual and the underlying processes that support effective clinical care and patient safety.

The fact that patients with emergency airway needs often present suddenly and at variable times of the day and night might give rise to the view that it is impossible to plan for this patient group, and that lesser standards of care are acceptable. However, whilst it is impossible to predict exactly where and when such emergencies will arise, the patterns are consistent and predictable when considered over longer periods of time. Any hospital with an emergency department will receive patients with a threatened airway (for example facial injuries in polytrauma or acute stridor), and the frequency of this can be determined from simple audit. Studies have shown that there is often variable, and inadequate, equipment and monitoring available to manage the airway in the emergency department, despite the acknowledged difficulty of this patient group.^{10,11}

It is therefore essential that clinicians from the relevant specialties (usually anaesthesia, critical care and emergency medicine) work together to ensure that robust plans are in place to deal with the emergency airway needs of patients, wherever they arise, and that recognised standards of management and monitoring are maintained. Furthermore, the seniority and experience of available staff must be sufficient to meet the patient's needs. Improved co-operation, planning and oversight of emergency airway care outside the operating theatre will enhance patient safety and outcomes.¹²

Case review

Of the 184 cases reported to NAP4 and meeting inclusion criteria 19 (10%) were as emergency department cases. However, four of these cases were transferred from the emergency department to the operating theatre before any advanced airway management was undertaken. These cases were therefore classified as events related to anaesthesia and are not considered in detail here. The remaining 15 cases (8%) had advanced airway management commenced in the emergency department, and are considered further.

Of the 15 emergency department cases 40% were ASA grade 1–2, 67% male and 80% aged under 60 years. A BMI of $\geq 30 \text{ kg m}^{-2}$ or obese body habitus was recorded in 46% of cases and a BMI of $< 20 \text{ kg m}^{-2}$ or cachexia in 7%. There were 14 adults and one infant. Seven cases occurred during the day, four in the evening and four overnight. The practitioner managing the patient's airway at the time of the reported event is shown in Table 1.



Airway management in the emergency department and remote hospital locations

All cases except three involved attempts at tracheal intubation, the exceptions being facemask anaesthesia for cardioversion and two surgical airways for airway obstruction. In 11 cases (73%) airway management was by an anaesthetist and in eight (53%) a consultant. Anaesthetist involvement fell from 6/7 during the day (0801–1800) to 5/8 out of hours and consultant involvement was 4/7 in-hours and 4/8 out of hours.

Table 1 Specialty and grade of the practitioner managing the airway at the time of the reported emergency department event.

Grade and specialty	Number
Consultant or Associate Specialist in anaesthesia	7
Specialist Trainee Year 7 (ST7) in anaesthesia	1
Specialist Trainee Year 6 (ST6) in critical care (non-anaesthetist)	2
Specialist Registrar (SpR) in emergency medicine	1
Specialist Trainee Year 3 (ST3) in anaesthesia	3
Acute Care Common Stem (ACCS) Trainee in anaesthesia (five months experience)	1

While the most frequent inclusion criterion was a surgical airway (ten cases) the primary problem related to difficult or failed intubation in 14 cases. Of those having an emergency surgical airway two of these patients died, two suffered permanent neurological deficit (one due to the airway event and one severely injured patient whose relationship to the airway event was unclear) and the remaining six were reported as making a full recovery. Of the five patients who did not have a surgical airway established two died as a result of unrecognised oesophageal intubation, two required admission to ICU due to aspiration of gastric contents and one required admission to ICU due to iatrogenic airway trauma. As five patients suffered death or brain damage due to the emergency department airway event the death/brain damage rate is $5/15 = 33\%$. This is higher than in anaesthesia (14%), but lower than for ICU events (61%).

Causal and contributory factors were identified in all 15 emergency department cases. The most frequent causal and contributory factors were patient-related (73% of cases), followed by judgement (57%), education/training (40%) and task (33%). Positive factors were identified in eight cases (53%), the most frequent positive factor being communication (33% of cases). Airway management was assessed as good in 13% (n=2) cases, mixed in 33% (n=5) and poor in 46% (n=7). Airway management was assessed as poor in all emergency department deaths.

Discussion

Right Person

In the four cases managed by junior anaesthetic or ACCS trainees the doctor involved is likely to have lacked the experience to deal with the airway problem they encountered: for example in two reports trainees of this level attempted to undertake RSI in patients with mid-face fractures and blood in the airway. In these situations the trainee anaesthetist may have under-estimated the likely difficulty of the procedure and not sought senior help, even though this was readily available: in both cases a more senior anaesthetist arrived within 1–4 minutes when called during the event, but was not consulted prior to the RSI. These cases suggest poor communication both vertically and horizontally.

Case 1

A previously well young adult presented to the emergency department in the middle of the night with head and maxillofacial trauma. The patient was agitated with a Glasgow Coma Scale of 14 and required intubation to facilitate CT scanning. An unsupervised junior anaesthetist attempted RSI but was unable to intubate or ventilate the patient. Oxygen saturation fell and the patient suffered a cardiac arrest despite attempted needle cricothyroidotomy. A surgical cricothyroidotomy was successful and circulation was restored. A more senior anaesthetist, who arrived within a few minutes of being called, was subsequently able to intubate the patient without difficulty, and a full recovery followed. On review it was clear that the patient could have waited for the more senior anaesthetist to be present, but the junior anaesthetist did not request this and the emergency department staff failed to challenge the decision to proceed.

In view of the acknowledged difficulty of airway management in the emergency department it is important to examine the system of response to emergency department airway emergencies and trauma calls, to ensure that doctors of suitable seniority and experience attend routinely. There was a tendency for junior staff to either undertake advanced airway management precipitously, when additional preparation and the summoning of senior assistance would have been in the patient's interests, or to fail to recognise a deteriorating situation until the patient was critically hypoxic or had entirely lost their airway. These actions suggest inexperience, lack of confidence, poor judgement or a combination of these.

In two other cases the attending airway practitioner was a critical care trainee who appeared to lack the required airway skills. In one case a senior paediatric trainee, working on the Paediatric Intensive Care Unit (PICU), attempted to intubate an infant in respiratory distress but encountered difficulty leading to oesophageal intubation. On review the trainee appeared inadequately experienced

Airway management in the emergency department and remote hospital locations

to anaesthetise the child and did not appreciate the significance of an absent capnography trace. In the other case a senior ICU trainee with novice level anaesthetic experience undertook RSI without using the available capnography leading to oesophageal intubation. In both these cases an apparently avoidable patient death occurred. Again, there was a tendency to underestimate possible difficulty and a failure to seek senior help before commencing advanced airway interventions: in one of these cases a senior anaesthetic trainee was managing another case in the same emergency department resuscitation room, but was not consulted. Where critical care trainees respond to airway emergencies in the emergency department it is essential to ensure that they have the relevant competencies, regardless of their apparent seniority and that there are appropriate support systems.

Case 2

An infant attended the emergency department with respiratory failure, and was anaesthetised by a very experienced trainee from the paediatric intensive care unit (PICU) with very limited anaesthetic experience. Intubation proved difficult, but was believed to have been achieved on the third attempt, despite the absence of a capnography trace. The child desaturated, had two episodes of asystolic cardiac arrest and did not survive. The PICU consultant attended as soon as called, but no anaesthetist or ODP attended because a paediatric cardiac arrest call was not made.

These cases often highlighted a communication gap between the emergency department, anaesthetic and critical care teams. The actual skills of the anaesthetic or critical care trainee may be unknown to the emergency department team, who are likely to presume that the doctor who has arrived to assist them has an appropriate skill set to manage a difficult emergency airway. Similarly, the attending trainee as a visiting 'expert' to the emergency department may find it difficult to admit that they are out of their depth. In one case an emergency department consultant put pressure on an anaesthetic trainee to undertake an immediate intubation in a patient with complex maxillofacial trauma, leading to a failed intubation and surgical airway. It is essential that team leaders in the emergency department establish the skills and role of all team members, and a WHO-style checklist introduction may prove valuable in ensuring staff introduce themselves and their role.²³

There was one report of a major complication during intubation by an emergency physician. In this case the RSI appeared to proceed uneventfully but required a bougie. A pneumothorax was evident on chest X-ray immediately after intubation and the patient subsequently developed a pneumomediastinum. Endoscopic inspection identified a tracheal tear on the posterior tracheal wall above the carina. The local thoracic surgeon judged that 'the tracheal



tear was likely to be secondary to tracheal intubation', which appears a reasonable assumption. The patient required a prolonged ICU stay. Reported details were incomplete, and whether the trauma was due to poor technique, poor equipment or patient factors is unclear.

Right place

There is an understandable desire by anaesthetists to move a patient with airway compromise to a more familiar environment, such as an operating theatre or anaesthetic room. This may be exacerbated when the airway equipment available in the emergency department is below the standard of that in theatre, however it is not without risk. In two cases a consultant anaesthetist elected to move a patient to theatre in order to perform a surgical airway following a failed intubation in the emergency department, and in at least one case this led to a prolonged period of hypoxia and cardiac arrest. Ideally, patients presenting to the emergency department with acute airway compromise should not be moved to another location until their airway has been safely secured. This requires emergency departments to be equipped and staffed to secure the airway by whatever means may prove necessary, including direct tracheal access. Inevitably the decision to move will depend to some extent on the exact condition of the patient and local circumstances, such as the distance between the emergency department and operating theatre, however in all cases it should be made by a senior member of staff after a careful assessment of the relative risks and benefits. Staff who may be called upon to manage an emergency airway in the emergency department should ensure that they are familiar with the team and equipment available so they are able to function effectively in this environment.

Right equipment

In more than 50% of the emergency department events occurring during attempted intubation capnography was



either not available, or not used. Given the established recommendations for monitoring during anaesthesia this clearly represents sub-optimal practice.¹⁴ Failure to use capnography led to two unrecognised oesophageal intubations, both of whom died. In one case the lack of a capnograph trace was erroneously attributed to cardiac arrest, when in fact a somewhat attenuated, but typical, trace can be seen in cardiac arrest whilst cardiopulmonary resuscitation (CPR) is ongoing (Figure One). This problem was also identified in events occurring during anaesthesia, and raises the possibility that there is a deficiency in current anaesthetic training on this topic. Understanding this issue is directly relevant to any practitioner called on to manage the airway in the emergency department.

Figure 1 Capnograph trace during cardiac arrest with CPR in progress



In one case no supraglottic airway device was available in the emergency department, whilst in another the poor quality of the intubating bougie was felt to be contributory to a failed intubation. It is therefore essential that all the required equipment is immediately available, and there is a strong argument for standardisation across a hospital so that the same difficult airway equipment is available in every location where anaesthesia may occur.

Right preparation

Many of the problems outlined above could have been effectively prevented by strong teamwork and communication between all the specialties involved in the delivery of emergency airway management in the emergency department. Whilst it is impossible to predict exactly when particular airway problems will present, the fact that they will is certain. It is therefore sensible to agree in advance who will respond, within what time frame, and what approaches will be used for the most common emergency department airway emergencies so that a clear plan of action is in place. These situations will include:

- patient with acute stridor of unknown cause
- patient with a known cause of airway obstruction (e.g. tumour) presenting with increased symptoms
- acute epiglottitis and supraglottitis
- trauma patient with facial injuries and/or haemorrhage into the upper airway
- foreign body impacted in the upper airway
- child with croup or other upper airway narrowing
- child with acute respiratory failure.

Approximately 25% of emergency department intubations are undertaken for trauma,¹ and 4 of the 15 reports (27%) were in trauma patients. The numbers are too small to determine whether trauma patients are disproportionately over-represented in the reported cases, but we were surprised that more reports did not relate specifically to trauma. This may be due to the recognised difficulty of trauma intubations and the formal deployment of trauma teams including an experienced airway practitioner.

Given that 12 emergency department patients had an event related to intubation, and previously published data indicate that approximately 20,000 patients undergo RSI in UK EDs annually, then a major complication rate of 0.06 (6 cases per 10,000 RSIs) is implied. However, it seems highly likely that emergency department complications have been under-reported for the reasons discussed elsewhere in this report. In addition, an emergency department LR was identified in only half of all eligible hospitals, though most major complications occurring in the emergency department would be expected to come to the attention of LRs in anaesthesia and critical care.



EMERGENCY INDUCTION CHECKLIST			
Prepare Patient	Prepare Equipment	Prepare Team	Prepare for difficulty
<ul style="list-style-type: none"> <input type="checkbox"/> Is preoxygenation optimal? <ul style="list-style-type: none"> <input type="checkbox"/> ETO₂ > 90% <input type="checkbox"/> Consider CPAP <input type="checkbox"/> Is the patient's position optimal? <ul style="list-style-type: none"> <input type="checkbox"/> Consider sitting up <input type="checkbox"/> Can the patient's condition be optimised any further before intubation? <input type="checkbox"/> How will anaesthesia be maintained after induction? 	<ul style="list-style-type: none"> <input type="checkbox"/> What monitoring is applied? <ul style="list-style-type: none"> <input type="checkbox"/> Capnography <input type="checkbox"/> SPO₂ probe <input type="checkbox"/> ECG <input type="checkbox"/> Blood pressure <input type="checkbox"/> What equipment is checked and available? <ul style="list-style-type: none"> <input type="checkbox"/> Self-inflating bag <input type="checkbox"/> Working suction <input type="checkbox"/> Two tracheal tubes <input type="checkbox"/> Two laryngoscopes <input type="checkbox"/> Bougie <input type="checkbox"/> Supraglottic airway device <input type="checkbox"/> Do you have all the drugs required? <ul style="list-style-type: none"> <input type="checkbox"/> Consider ketamine <input type="checkbox"/> Relaxant <input type="checkbox"/> Vasopressor 	<ul style="list-style-type: none"> <input type="checkbox"/> Allocate roles; <ul style="list-style-type: none"> <input type="checkbox"/> Team leader <input type="checkbox"/> First Intubator <input type="checkbox"/> Second Intubator <input type="checkbox"/> Cricoid Pressure <input type="checkbox"/> Intubator's Assistant <input type="checkbox"/> Drugs <ul style="list-style-type: none"> <input type="checkbox"/> MILS (if indicated) <input type="checkbox"/> Rescue airway <input type="checkbox"/> How do we contact further help if required? 	<ul style="list-style-type: none"> <input type="checkbox"/> If the airway is difficult, could we wake the patient up? <input type="checkbox"/> What is the plan for a difficult intubation? <ul style="list-style-type: none"> <input type="checkbox"/> Plan A: RSI <input type="checkbox"/> Plan B: e.g. BMV <input type="checkbox"/> Plan C: e.g. ProSeal LMA <input type="checkbox"/> Plan D: e.g. Front of neck <input type="checkbox"/> Where is the relevant equipment, including alternative airway? <ul style="list-style-type: none"> <input type="checkbox"/> DO NOT START UNTIL AVAILABLE <input type="checkbox"/> Are any specific complications anticipated?

This Checklist is not intended to be a comprehensive guide to preparation for induction

RTIC Severn

Figure 2 Example checklist for use prior to emergency department intubation.

Many of the emergency department events (12/15) occurred during attempted intubation. Case review identified variously: precipitous actions, the wrong personnel, poor communication, incomplete back-up plans, lack of equipment and omission of vital monitoring. A simple checklist based around preparation of the patient, equipment/drugs, staff and for potential difficulty can identify potential problems in a very short time and improve patient safety. An example of such a checklist is shown in Figure 2.

Learning points and recommendations

Recommendation: Emergency department airway management should be based on the concept of the right person, right place, right equipment and right preparation.

Recommendation: Good and ongoing communication between senior clinicians in the emergency department, anaesthesia, critical care, ENT and other relevant specialties is essential in planning for, and managing, the emergency airway problems that present to the emergency

department. Consideration should be given to designating consultant leads from each involved specialty to agree and oversee the management of emergency airway problems presenting to the emergency department.

Recommendation: Agreed plans should be in place for the management of all common and predictable emergency department airway emergencies.

Recommendation: Robust processes should be established to ensure the prompt availability of appropriately skilled and senior staff at any time of the day or night to manage the airway within a reasonable timeframe.

Recommendation: All practitioners who may be called upon to manage airway emergencies in the emergency department must have the required skills and experience, with immediate access to senior supervision. This is particularly important for trainees in emergency medicine and critical care.

Recommendation: In cases of airway compromise it is generally preferable to secure the airway before moving the patient out of the emergency department, but local considerations apply. Any decision to move a patient with a threatened airway should be made by a senior clinician.

Recommendation: All of the equipment and monitoring that may be required, along with a properly trained and skilled assistant, should be immediately available in the emergency department. There is a strong argument for the standardisation of all airway equipment, including difficult airway and rescue devices, across a hospital or group of hospitals.

Recommendation: Staff who may be required to manage airway emergencies in the emergency department should be familiar with the environment and available equipment.

Recommendation: Joint training of Emergency Physician and Anaesthesia/ICU staff is recommended, focusing on the anticipated clinical presentations. Training should include use of the airway equipment available in the emergency department, failed intubation and emergency surgical airway techniques. It should also identify the point at which trainees reach the limit of their expertise and mechanisms for summoning more experienced clinicians. Such training is likely to include simulation and team training.

Recommendation: A checklist should be used for all emergency department intubations. Such a checklist might usefully identify preparation of the patient, equipment/drugs and team, and preparation for difficulty.

Recommendation: Capnography should be used routinely in every emergency department intubation and every emergency department anaesthetic. A somewhat attenuated, but typical, capnograph trace will be present during cardiac arrest if the tracheal tube is correctly placed and cardiopulmonary resuscitation (CPR) is ongoing.

Recommendation: There should be regular audit of emergency department airway management, examining any problems or adverse events that occur.

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CHAPTER 11

Supraglottic airway devices



Dr Tim Cook*

Headline

The majority of SAD-related complications were aspiration, this included most of the worst outcomes. Excluding aspiration, which is discussed elsewhere, the SAD cases were associated with poor assessment and case selection, junior anaesthetists having problems at insertion (perhaps poor placement) that subsequently led to problems during maintenance or recovery. The patients who sustained complications from SAD use included a marked excess of obese and very obese patients. In many of the aspiration and non-aspiration cases the complication was likely caused by poor judgement, selection of an inappropriate airway device and possibly poor technical use of the device. Review panel assessment indicated a high rate of poor quality care.

What we already know

The classic Laryngeal Mask Airway (cLMA) was designed by Archie Brain between 1981 and 1988. It entered practice in the UK in 1989 and transformed practice, having been ordered in every UK hospital within a year. Twenty years on the census phase of this project showed that supraglottic airway devices (SADs) are now the predominant airway for anaesthesia in the UK being used to maintain the airway for 56% of all UK general anaesthetics.¹ Not only has use of SADs become widespread but the applications for which a SAD is considered suitable has widened almost immeasurably.

There have been significant developments in the SAD market in the last ten years. First, since the original cLMA came off patent there has been a considerable increase in the number of similar devices (correctly termed 'laryngeal masks' as opposed to 'laryngeal mask airways') that aim simply to compete with the cLMA. These devices, though ostensibly similar, are often made of different materials, with minor or major design and manufacturing differences. There has been a move, for reasons that are open to debate,² to single use devices. The efficacy and safety of such devices is in most cases assumed, rather than proven by clinical research^{3,4} and most offer no benefits over the cLMA. Second, and perhaps more interestingly, new designs of SAD have been proposed or introduced that are designed specifically to increase efficacy and safety. These second generation SADs include the ProSeal LMA, i-gel, Supreme LMA and the less widely used Laryngeal tube

suction–II and perhaps the SLIPA (streamlined liner of the pharynx airway). Second generation SADs variously have features that include:

- *improved pharyngeal seal* enabling controlled ventilation at higher airway pressures (and hence in a wider range of patients and clinical situations)
- *increased oesophageal seal*, which lessens the likelihood of regurgitant fluids entering the pharynx and leading to aspiration
- a *drain tube* which lies over the top of the oesophagus when the SAD is correctly positioned. This may be used to assist insertion, confirm correct device positioning, enable access to the stomach, alert the user to the presence of regurgitation and enable gastric contents to safely bypass the oropharynx and exit the patient
- *integral bite block*

The combination of improved sealing and the presence of a drain tube improves efficacy and creates functional separation of the gastrointestinal tract from the respiratory tract (like an artificial larynx). This is likely to improve safety (though this is very hard to prove) and several recent publications have suggested use of SADs with effective drain tubes should become a 'standard of care'.^{5,6} The NAP₄ census identified that approximately 90% of UK SAD use is cLMAs or LMs with only 10% of SADs (and approximately 6% of all airway management) being with i-gels or ProSeal LMAs.

SADs now also have a vital role in difficult airway management.⁷ These roles include:

- use as a primary airway rescue device out of hospital
- rescue of the airway after failure of either mask ventilation, tracheal intubation or both
- as a conduit to assist fiberoptic intubation electively or as a rescue technique.

While SADs have become routine airway devices three major concerns exist:

- risk of (and protection from) pulmonary aspiration of gastric contents
- air leak during controlled ventilation with consequent hypoventilation (and increased risk of gastric inflation)
- displacement of the device during use.



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Minimising these risks is likely to be achieved by careful consideration of the following aspects:

- correct patient selection
- limitation of use to appropriate surgery
- understanding the performance limits of the chosen SAD (and choosing the correct SAD)
- correct, expert insertion, fixation and use
- vigilance during use, including recommended monitoring⁸
- appropriate precautions, technique and timing of removal.

These considerations are worth examining in more detail. Correct patient selection and limiting use to appropriate surgery is challenging: in part because the indications for use of SADs are constantly expanding (sometimes appropriately and led by clinical research and sometimes perhaps less so) and in part because predicting which patients are at risk of SAD failure or aspiration are both difficult. In contrast to the extensive work on predictive indices of difficult laryngoscopy and latterly difficult facemask ventilation there is almost no literature examining which patient factors predict difficulty in use of a SAD. Prediction of aspiration risk is similarly complex with few patients having no risk factors (e.g. obesity, reflux, hiatus hernia, drugs affecting gastric emptying, head down position, raised abdominal pressure).⁹ Understanding the performance limits of specific SADs is complicated by the fact that many devices have not undergone formal clinical evaluation before (or after) introduction into clinical practice.²⁻⁴ The profession should reflect on this and those institutions and individual anaesthetists who choose to use such devices likely do so with less ability to understand the devices, performance limits than for well studied devices. Correct use of a device, carefully following the manufacturer's 'instructions for use' should be routine practice, but the reality is that many anaesthetists have probably never read these instructions and simply learn, correct or incorrect techniques, at the bedside. SAD removal is often delegated to recovery staff and occurs shortly after the patient regains consciousness, airway reflexes and the power to bite down on the tube of the SAD. As with tracheal extubation, removal of a SAD, may pose as great a risk as insertion.

Case Review

NAP₄ examines, not the effectiveness of use of these routine airway devices, but events in which serious harm has occurred to patients as a result of airway management. In examining such cases notified to the project this chapter will examine these in detail focusing on the six factors listed above. This chapter considers only cases in which events occurred where a SAD was used to maintain the airway. It

does not examine use of SADs either to rescue the airway or to facilitate tracheal intubation. This chapter should be read in conjunction with Chapter 19.

Several SADs which have specific roles in tracheal intubation rather than primary airway management (e.g. Intubating LMA, C-trach and Cook Intubating airway) are not discussed here.

SADs have a role in many aspects of airway management and several aspects of their use and associated complications are discussed in other chapters. They are not duplicated here.

Aspiration	see Chapter 19
Airway rescue	see Chapter 13
Intubation through a SAD	see Chapter 14

Some case reports including such cases are used to illustrate learning points pertinent to this chapter. Also some cases involving SADs but not included as primary complications of SADs are used for illustration (e.g. Cases 12, 13) and excluded from numerical analysis. This case review section is sparse on commentary and contains a considerable number of case reports. During the review process it became clear that it was by considering the group of reports in its entirety that themes and learning points emerged.

Patient selection

Many of the reports involving non-aspiration complications during SAD use, most of which were standard laryngeal masks, had features that made use of such a device 'high-risk'. These included a significant number of patients with reporter-identified risk of aspiration, patients with predicted difficult airways, those undergoing urgent surgery and most notably a large number of obese and very obese patients. Some case reports suggested assessment was either omitted or poorly performed.

Case 1

An elderly ASA 3 patient with diabetes and controlled gastro-oesophageal disease presented for repair of an irreducible abdominal hernia. The patient had bowel sounds and normal bowel action. The patient was anaesthetised by a consultant anaesthetist with a laryngeal mask for airway management. During maintenance the patient aspirated causing airway obstruction. The patient was intubated. At the end of surgery the patient was extubated but deteriorated and required re-intubation and ICU admission. Further deterioration on ICU was rapid and the patient died the same day.



Case 2

A middle-aged patient weighing >150kg (BMI >40 kg.m⁻²) who had hypertension and ischaemic heart disease was admitted for minor hand surgery. The patient had OSA diagnosed more than ten years previously but did not use a prescribed CPAP mask. The patient was admitted from out of region and was not accompanied by hospital notes. The GP referral did not mention OSA and this was not elicited at pre-assessment. Clinical examination of the airway demonstrated no abnormality. Due to needle phobia regional anaesthesia was declined. Anaesthesia, with a laryngeal mask for airway management was uneventful until the end of surgery when, in the presence of a junior trainee, the patient awoke suddenly, removed the laryngeal mask and developed total airway obstruction. Hypoxic cardiac arrest followed. Suxamethonium was administered and the laryngeal mask re-inserted which partially restored the airway and enabled intubation using the SAD as a conduit for fiberoptic intubation over an Aintree Intubation Catheter. Resuscitation was successful but the patient required prolonged care on ICU and a tracheostomy before making a full recovery.

Case 3

A markedly obese patient was assessed by a trainee anaesthetist who identified and documented dramatically abnormal airway assessment and predicted difficult intubation. The patient had a history of difficult airway management with both facemask and SAD; this was written in the notes and offered by the patient. The patient was due for urgent surgery to be performed out of hours in the lithotomy position. Use of a ProSeal was planned. The patient was anaesthetised by the trainee with no other anaesthetist present or informed. After induction facemask ventilation was difficult and after ProSeal insertion the airway was obstructed. Laryngospasm and aspiration were considered. Intubation failed and the patient became profoundly hypoxic. Assistance, from a similarly experienced trainee, arrived. Ventilation via a laryngeal mask was successful as was blind intubation. A surgical tracheostomy was performed by an ENT trainee. The airway event lasted one hour and the lowest oxygen saturation was below 50%. The patient was admitted to ICU and made a full recovery.

Limitation of use to appropriate surgery

Several complications occurred during surgery that was at the extremes of what might be considered safe for use of a SAD. While the boundaries of safe use of SADs are continuously explored and seemingly expanding, it was notable that many of these reports involved standard laryngeal masks used by juniors.

Cases in these categories included obese patients whose surgery was performed in the lithotomy position and/or head down position. In others surgery was performed for very prolonged operations. Finally, surgery was performed in positions that made airway access difficult such as prone or nearly prone. In some cases predicted difficult

intubation increased the risk of these situations and actually complicated rescue when an airway complication did arise. In one case that combined many of these described features the airway was lost and the patient died.

Case 4

An obese patient was anaesthetised by an experienced anaesthetist. A spontaneous breathing technique was used and a single use laryngeal mask was placed for surgery in the lithotomy position. The patient desaturated towards the end of surgery and the airway then became obstructed requiring intubation. Airway inspection showed airway oedema, bleeding and aspiration of blood into the lung. After a short period on ICU the patient made a full recovery.

Case 5

An elderly patient presented with a severe abscess. Anaesthetic assessment suggested sepsis, dehydration and a rapid sequence induction in theatre was planned. During preparation for anaesthesia there was a change of anaesthetist. The latter anaesthetist judged rapid sequence induction was not indicated. Following induction a laryngeal mask was inserted. During transfer from anaesthetic room to operating theatre the patient regurgitated and aspirated. Because of desaturation the patient was intubated. Chest X-ray confirmed signs of aspiration. The patient was admitted to ICU and subsequently made a full recovery.

Case 6

An obese patient (BMI approximately 35kg.m⁻²) had an uneventful operation in the lithotomy, head down position. During emergence, despite a bite block around a laryngeal mask, the patient developed stridor then complete airway obstruction. This was resolved by brief muscle relaxation but during re-emergence the stridor recurred. Intubation was attempted but failed. Fiberoptic inspection via the laryngeal mask showed laryngeal oedema. Rescue intubation via the laryngeal mask was planned but discouraged by an ENT surgeon and a surgical tracheostomy was performed. The patient was transferred to ICU and recovered.

Inexperience and problems with insertion.

Several reports described very junior anaesthetists, often in their first year or two of anaesthetic practice having problems. These included evidence of inexperience related to assessment and traumatic insertion that caused subsequent problems during or at the end of anaesthesia.



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Case 7

A healthy but obese patient with a BMI $>35\text{kg.m}^{-2}$ required an extensive but superficial operation. The patient had a recent respiratory infection. A trainee ignored senior advice to perform regional anaesthesia. The patient was anaesthetised, breathing spontaneously via a laryngeal mask. During surgery breathing difficulty and hypoxia developed. The laryngeal mask was removed and the patient intubated. Persistent hypoxia required ICU admission. Though reported as a case of aspiration it is possible from the description that this was post-obstructive pulmonary oedema. The patient made a prompt and full recovery.

Case 8

A morbidly obese middle-aged patient who was otherwise well was listed for an urgent operation requiring lithotomy position. Preoperative assessment by a colleague showed reduced neck movement and a limited view of the soft palate. Anaesthesia took place out of hours and was performed by a first year specialist trainee. After pre-oxygenation with three vital capacity breaths anaesthesia was induced and a laryngeal mask inserted. Ventilation was possible, though the airway seal was poor and 'some carbon dioxide' was expired. The patient was transferred to the operating room where soon after the oxygen saturation fell markedly. More induction agent was administered and the laryngeal mask was repositioned, without improvement. The laryngeal mask was removed and bag mask ventilation with an oropharyngeal and with a two-person technique were attempted. Despite administration of muscle relaxant ventilation remained impossible. Intubation was attempted and the larynx was visualised. After intubation ventilation remained difficult, hypoxia persisted, the patient entered cardiac arrest and capnography showed minimal expired carbon dioxide. Despite prolonged resuscitation attempts the patient died. While the tracheal tube was initially judged to be in the trachea no direct actions were taken to confirm this.

Case 9

A young obese patient was anaesthetised by a trainee out of hours for urgent minor surgery in the lithotomy position. A single use laryngeal mask was inserted immediately after loss of consciousness and ventilation was not possible. Despite further induction agent and a change to a facemask, ventilation remained impossible. Profound and prolonged hypoxia developed lasting many minutes. A consultant attended, by chance, and also failed to achieve ventilation until muscle relaxation was administered at which point re-oxygenation was possible. The patient was intubated and surgery completed but during emergence seizures were noted. The patient was admitted to ICU for management of potential brain injury and required a very prolonged ICU stay before making an apparently full recovery.

Problems with insertion included trauma that also led to bleeding, laryngospasm or laryngeal oedema. Problems caused by this often presented after a delay and led to

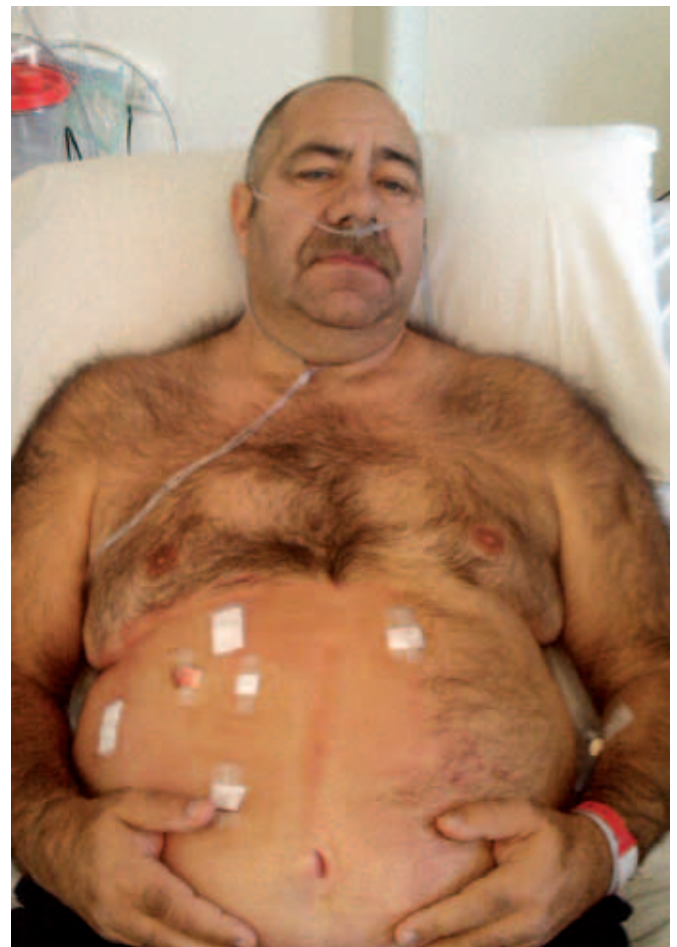
airway obstruction or laryngospasm in recovery. SAD insertion is usually successful and atraumatic. Poor technique increases the likelihood of failure and trauma.

Case 10

A patient was anaesthetised by a junior trainee, accompanied by another trainee, for an urgent minor operation out of hours. After induction laryngeal mask insertion was difficult and abandoned. Anaesthesia was maintained with a facemask. Waking after surgery was delayed. Airway obstruction and likely hypercapnia were identified as a cause. When the airway was cleared the patient remained hypoxic and bleeding in the pharynx was noted. Upper airway bleeding and aspiration of blood, with lung collapse, required intubation and ICU admission.

Use of second generation SADs in difficult cases

Some cases were complex, illustrating the role of SADs in difficult airway management. The role of second generation SADs in such cases was seen in several cases. In some this use was successful and in others it was not.



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Supraglottic airway devices

Case 11

An elderly obese patient with significant co-morbidity including worsening reflux presented for laryngeal laser surgery. The patient had stridor at rest and was hypoxic on air. The patient was known to have laryngeal pathology with a laryngeal narrowing and minimal cord movement; tracheostomy had been previously required. Awake nasendoscopy showed inspiratory airway collapse. Care was consultant-delivered. After joint anaesthetic and surgical discussion the agreed primary anaesthetic plan was transtracheal jet ventilation; a Ravussin cannula was placed awake. The supraglottis was noted to be inflamed on nasendoscopy prior to surgery. After anaesthesia was induced a ProSeal was placed to provide an expiratory route during TTJV. Surgery was performed over 30 minutes via a rigid surgical laryngoscope. The ProSeal was reinserted for emergence but ventilation was difficult, then impossible. Spontaneous ventilation via a facemask was established but barely adequate and the patient did not wake. With the airway deteriorating the patient was re-anaesthetised and the PLMA inserted for a third time. Ventilation was impossible and fiberoptic inspection revealed good positioning, significant supraglottic oedema and significant subglottic stenosis. After a further failed attempt to wake the patient and blood gas evidence of hypercapnia the patient was intubated with a small tracheal tube and admitted to ICU. The surgeon and anaesthetist were present throughout and made joint decisions. A chest X-ray was suggestive of oedema, raising the possibility of post-obstructive pulmonary oedema. Whether the laryngeal oedema was due to anaesthetic (ProSeal) or surgical (bronchoscope) interventions was undetermined. The patient was extubated the following day over a Cook airway exchange catheter without sequelae.

Case 12

An obese patient with a history of previous difficult intubation (unknown to the anaesthetist) was undergoing vascular surgery in the radiology department. After routine induction laryngoscopy was grade 3 and intubation was briefly oesophageal before being abandoned. An i-gel was placed and ventilation recommenced. Gastric contents were then noted in and around the i-gel. A nasogastric tube was passed and almost half a litre of fluid suctioned. The patient was subsequently intubated (via the i-gel). The patient was ventilated on the ICU for several days before recovering.

Case 13

A patient with multiple co-morbidities developed oozing after a very prolonged carotid endarterectomy. Initial intubation had been grade 3. During resuscitation from a bradycardic arrest prior to admission to ICU the patient's airway was managed with an i-gel, until the patient awoke. The patient was admitted to ICU for monitoring and five hours later, in the middle of the night, had an asystolic arrest. There were prolonged attempts to establish an airway with an i-gel, laryngeal mask and ILMA but all failed as did tracheal intubation and needle cricothyroidotomy. A surgical tracheostomy appeared to enter the trachea but the patient died. The LR commented that a ProSeal LMA was not available.

Problems during maintenance

The commonest problem during maintenance was aspiration. Poor patient selection and light anaesthesia were identified as the most frequent problems. Aspiration during maintenance with a laryngeal mask occurred on 11 occasions and is discussed in the aspiration chapter.

There were also cases of loss of airway during maintenance. Whether poor insertion technique, trauma or light anaesthesia contributed to these events was uncertain.

Case 14

Following placement of a single use laryngeal mask by a very junior anaesthetist for minor surgery the patient developed laryngeal spasm intra-operatively with complete obstruction and hypoxia. There was a delay before intubation, following which persistent hypoxia and post-obstructive pulmonary oedema necessitated ICU admission.

Problems at the time of emergence, recovery or removal

Emergence and recovery may be complicated by loss of the airway by mask displacement, laryngospasm or device occlusion by patient biting. Regurgitation may also occur.

Case 15

A young obese, brittle asthmatic was anaesthetised for a minor procedure. A laryngeal mask was used with no intraoperative problems. After the surgery the patient developed prolonged stridor and coughing. There was no response to nebulised adrenaline. Nasendoscopy was normal. No cause was found but the persistence of symptoms required intubation and ICU admission.



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Supraglottic airway devices



Case 16

A senior trainee anaesthetised a morbidly obese patient with asthma for minor surgery and managed the airway with a disposable laryngeal mask. The reporter indicated this was chosen instead of an i-gel to protect the patients 'at-risk dental-work'. In recovery the patient bit and obstructed the laryngeal mask stem leading to hypoxia. The laryngeal mask was forcefully removed. The patient developed profound hypoxia and post-obstructive pulmonary oedema requiring ICU admission.

There were four cases with marked similarities to this case. All required ICU for treatment of post-obstructive pulmonary oedema. One had reflux, two had asthma and three were obese. In some the complication developed on biting the laryngeal mask and in others on removal. It was not possible to determine the exact level of recovery at the time these events occurred.

Case 17

A markedly obese smoker, with undisclosed obstructive sleep apnoea, underwent urgent surgery in the lithotomy position, anaesthetised by a consultant with the airway managed with a single use laryngeal mask. On emergence, airway obstruction occurred. Management was difficult and over the next hour there were repeated failed attempts at ventilation via a laryngeal mask, facemask and intubation. Profound hypoxia lasted up to half an hour. During one attempt to insert a nasogastric tube (to manage gastric inflation) a successfully placed laryngeal mask was displaced; after this an emergency cricothyroidotomy was required and though this failed the cephalad facing cannula enabled successful identification of the larynx and intubation. The patient went to ICU and subsequently returned to theatre for a planned extubation with expert assistance on hand.

Timing SAD removal correctly likely reduces complications. For most SADs this means when the patient has regained consciousness; this is also the time that airway reflexes can be expected to have largely recovered.

Interaction of factors

As the above cases indicate, in many reports multiple events (obesity, co-morbidities, traumatic or inexperienced insertion, disadvantageous surgical position, light anaesthesia) interacted to contribute to events. In several events either a combination of complications occurred or there was diagnostic uncertainty. Airway obstruction was the commonest single problem.

Numerical analysis

There were 34 cases where a SAD was involved as the primary airway in an event reported to NAP₄. In 17 the SAD associated event was aspiration: these cases are discussed in Chapter 19.

ICU events

One event occurred in ICU. This is described above; the patient died. Whether this should be considered a SAD-related event is arguable as airway obstruction occurred before the SAD was used.

Anaesthesia

There were 33 events (25% of all anaesthesia events) including:

- aspiration
- airway trauma
- loss of airway on insertion
- failed insertion
- displacement after insertion
- loss of airway during maintenance
- extubation-related problems.

Aspiration

Thirteen reports described aspiration with a laryngeal mask as the primary (intended or used) airway for anaesthesia, one the i-gel, and three involved the laryngeal mask but the aspiration was secondary to a different primary event. Aspiration during maintenance with a laryngeal mask occurred in 11 patients. Most of these patients had risk factors for aspiration; risk factors were often multiple and some were high-grade risk factors. Several of the uses

CHAPTER 11

Supraglottic airway devices

might reasonably be described as misuse. Six aspiration events occurred out of hours. These are discussed in further detail in Chapter 19.

Non-aspiration events

There were two deaths, five emergency surgical airways and 13 ICU admissions.

The two deaths were due to:

- loss of the airway in the semi-prone position during prolonged surgery in a patient with a predicted difficult airway
- poor laryngeal mask positioning, loss of airway and unrecognised oesophageal intubation during response to this event

Thus it is arguable that only one case of death was directly due to use of a SAD in this group.

One case of temporary brain damage was due to:

- loss of airway during laryngeal mask airway insertion leading to hypoxia. Seizures occurred during emergence. Recovery was eventually complete.

Regarding the 16 anaesthesia events.

Patients were generally young (10/16 aged under 40) and healthy (14/16 ASA 1-2). Seven of 16 operations were designated 'urgent'. All these statistics are similar to aspiration cases.

Obesity was notably over-represented with 11 of 15 (73%) in whom body habitus was identified being obese, compared to 31% in anaesthesia patients outside this group. This included six (40%) patients weighing >100kg and two patients with obstructive sleep apnoea; outside this group 14/116 anaesthesia patients weighed >100kg. Of note, none of the patients who aspirated during use of a SAD weighed >100kg.

Table 1

	Non-aspiration reports	Aspiration reports
disposable Laryngeal mask	7	3
classic LMA	6	8
'laryngeal mask'	1	3
flexible LMA	0	1
ProSeal LMA	2	0
i-gel	0	2

The reporter assessed the root error to be poor judgement in nine non-aspiration cases (and seven aspiration cases) and training in three non-aspiration cases (zero aspiration cases).

The review panel judged outcome and quality of airway management as recorded in Table 2.

Table 2

	Non-aspiration reports	Aspiration reports
Factors (causal)		
Patient	12 (2)	12 (3)
Education/training	13 (2)	8 (0)
Judgement	13 (3)	11 (1)
Other factors judged contributory in >50% of cases	Communication, task and social	-
<i>Quality of airway management</i>		
Good	1	3
Mixed	6	6
Poor	10	5
No comment	0	3

Two patients who had non-aspiration events had asthma and four of the aspiration cases.

All but four events generally occurred in hours. Six cases were designated urgent.

A consultant anaesthetists attended for six events (37%) compared to 66% in anaesthesia cases outside this group.

Events occurred more often during maintenance (six events) or emergence (seven) than during induction (four): though sometimes the root cause occurred at induction but led to a problem later. Such events included difficult insertion (one), poor airway seal after insertion (three) and airway obstruction after insertion (three).

When events occurred they were often prolonged but the period of hypoxia was usually relatively mild (4/16 lowest saturation <70%).

Six patients were predicted to have difficult airways: five problems with intubation and one with SAD placement. Four of the patients sustaining non-aspiration events were judged by the reporter to be at risk of aspiration.

The device used was poorly defined. In some cases the reporters described the device as a 'laryngeal mask airway' at one point in the report and a 'disposable LM' when asked specific details. Table 1 indicates, as best as can be determined, the devices used.





Discussion

The common themes in complications arising during SAD use.

- Poor patient selection
- Poor operation selection
- Inexpert use

Aspiration was the cause of the greatest severity problems associated with SAD use. Major themes were poor assessment, poor patient selection and use for surgical conditions where another airway device was more appropriate. In many cases this added up to what can only be described as misuse.

The non-aspiration cases were frequently urgent cases in considerably obese patients, managed by notably junior anaesthetists, with evidence of difficult or inexpert device insertion.

In several events a number of apparently minor features combined to produce an adverse event: these included obesity, an irritable airway (asthma or recent chest infection) and the presence of a junior anaesthetist. It was often difficult to determine whether one was the causal factor or if their interaction was important.

A disproportionate number of patients with a BMI >35 kg.m⁻² were included in this cohort and there was a notable discrepancy between the aspiration reports which included no patients with this degree of obesity and the non-aspiration cases in which such patients were predominant. As it might be expected that SADs would be avoided in such cases this excess of very obese patients is a notable and important finding.

Where patients with predicted airway difficulty were managed with a SAD to avoid addressing that airway difficulty, many would regard this as bad practice. In several events a more appropriate option might have been awake fiberoptic intubation.

A significant number of patients in both cohorts were having urgent surgery, generally considered to be a relative contraindication for use of a SAD. Urgency of surgery increases the risk of aspiration and it is notable that a large number of patients, both amongst those who aspirated and those who did not, had multiple risk factors for aspiration.

In cases of either moderate obesity (lower compliance for ventilation) or a marginally increased risk of aspiration (low intermediate risk) where a decision is made that intubation is not necessary, there is more logic to using a second generation SAD, than a first generation device. It must be acknowledged that some anaesthetists will take the view that this is never acceptable. When patients are operated on in positions that further reduce lung compliance and/or increase risk of aspiration the argument for increased airway protection is further increased. In 56% of anaesthetics in the UK in 2008-9 airway management was with a SAD but in only 10% of SAD use (6% of all airway management) was this a second generation SAD. The second generation SAD most prominent in the NAP₄ census was the i-gel which was used twice as frequently as the ProSeal; use of the Supreme LMA was not reported at all. The ProSeal currently has the broadest evidence to support its efficacy and safety profile. It is arguable that the cases of SAD complications reported to NAP₄, as a whole, make a strong argument for more widespread use of second generation SADs, most notably in patients with marginally increased risks.

Overall in the NAP₄ project, SAD-related events were in the minority. SADs were important in rescuing lost airways and for use as conduits for intubation (described elsewhere). As NAP₄ is in some respects an audit of failure it is not surprising that these rescue techniques were also reported to fail regularly; successes would be unlikely to be reported. This emphasises the important role of SADs in modern airway management.

Table 1 explores the type of SADs used. The vast majority were laryngeal masks and in the large part the review panel considered the use of a second generation SAD to be a positive feature in several cases (e.g. Case 11). In terms of detailed analysis the reality is that anaesthetists are not particularly reliable at identifying the exact laryngeal mask they are using¹⁰ and there were numerous inconsistencies in submitted forms. Regarding single use laryngeal masks it seems likely that those who specified their use, were indeed using them. It is notable, though the numbers are small, that there were a higher proportion of single use laryngeal masks in the non-aspiration events than in the aspiration events; many of these had elements of difficult or traumatic insertion or poor positioning that contributed to the event. This group is too small to enable robust conclusions to be drawn, but it is notable that many of the single use devices in current use have not undergone formal evaluation of either efficacy or safety.

It is notable (see Table 2) that the review panel's assessment of the quality of care was more critical of management in the non-aspiration cases than in those that aspirated. When it is remembered that the aspiration cases were often moderately obese emergencies with risk factors for aspiration several with bowel obstruction, this is very notable. 'Contributory factors' (excluding 'patient') are surrogate markers of poor care; in the non-aspiration group there were an average 4.0 factors identified per case, compared to 2.2 in the aspiration cases. Elements of poor assessment, poor judgement, inadequate training, poor technique, poor attention to detail and absent supervision run through many of these cases.

While these cases were mostly fit and well patients and most of these 'major' complications were at the lower

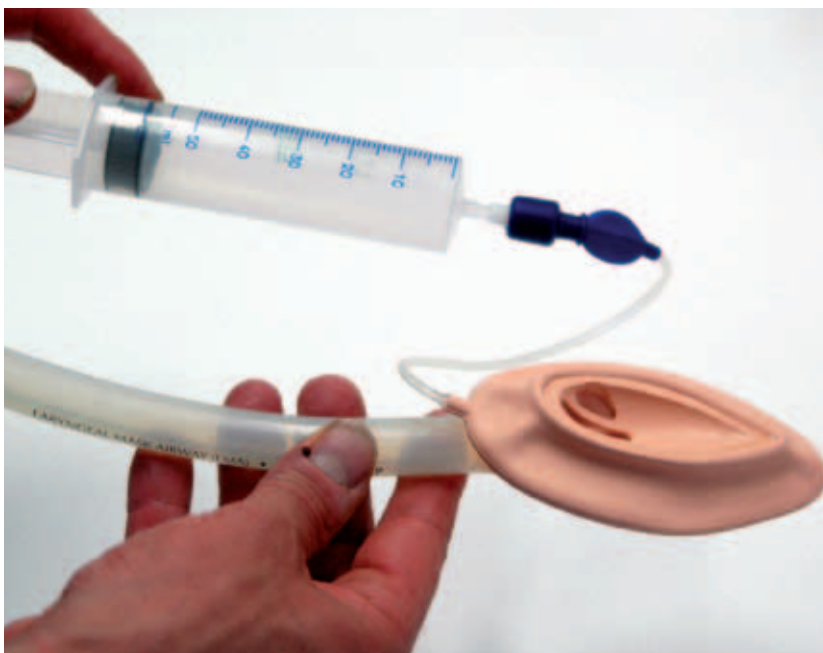
end of severity of complications seen in this project it is worth remembering three things. First as a group of young patients undergoing usually routine surgery there is an expectation of a low incidence of major anaesthetic complications. Second, the incidence of death and brain damage in this overall project was only about half that recorded for tracheal tube use; the tracheal tube being likely to be used for the vast majority of high-risk cases (see Chapter 5). Third, apparently minor problems, such as failing to ensure that the airway is well positioned and ventilation good before progressing to surgery, may appear to be inconsequential. When they set in motion a series of events that includes hypoxia, emergency intubation, unrecognised oesophageal intubation and death, this assumption requires reconsideration.

The overall impression from examination of this cohort of patients is of rather poorly managed patients. Individually each case might be put down to chance and 'bad luck' ('these things happen') but considered as a whole they suggest these cases have their root cause in inadequacies of training and supervision, clinician judgement and attention to detail and in some cases failure to use more appropriate equipment.

Learning points and recommendations

Aspiration: these recommendations address only non-aspiration events. They should be read in conjunction with the aspiration recommendations: see Chapter 19.

Cases of major airway complications associated with SADS included an excess of events in patients who appeared to be poorly assessed and poor selected: both in terms of suitability



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for use of a first generation SAD and in terms of aspiration risk. Many of these cases involved trainee anaesthetists.

Recommendation: Laryngeal mask anaesthesia is a fundamental skill, required by all anaesthetists. The subject should be taught with the same attention to detail as tracheal intubation. This involves patient selection, indications and contraindications for use and practicalities such as insertion, confirmation of correct positioning, management during maintenance and removal.

SADs were used as an alternative to tracheal intubation in some patients in an attempt to avoid managing a recognised difficult intubation. Under these circumstances if the airway is lost (e.g. due to oedema or mechanical displacement) this becomes an anaesthetic emergency.

Recommendation: Awake fiberoptic intubation or fiberoptic intubation through a SAD before surgery may offer a lower risk alternative to SAD use in cases of known difficulty with tracheal intubation.

Complications arose due to traumatic and failed laryngeal mask placement, after a delay.

Recommendation: A difficult or failed SAD placement should raise the possibility of complications during maintenance or emergency/recovery. A heightened level of awareness is required and this information should be passed on to those to whom care is handed over or delegated.

Complications arose when a suboptimal airway was accepted after SAD placement. This then deteriorated leading to major complication.

Recommendation: Continuing anaesthesia with a sub-optimal airway after SAD insertion is not acceptable. As with a tracheal tube the airway should be clear and manual ventilation possible. If this is not the case the device needs repositioning or replacing with an alternative airway, before proceeding to surgery.

Several patients developed post-obstructive pulmonary oedema either due to biting on the airway or airway obstruction after removal.

Recommendation: Recovery staff need to be competent in the correct procedures and timing of SAD removal. They also need to be trained to recognise and manage airway obstruction and post-obstructive pulmonary oedema.

Many cases, in both aspiration and non-aspiration groups, were easily identified as being high-risk cases for SAD use.

Recommendation: If tracheal intubation is not considered to be indicated but there is some (small) increased concern about regurgitation risk a second generation supraglottic airway is a more logical choice than a first generation one.

Recommendation: In patients considered to be at low-risk of aspiration who have other factors that mean that use of a SAD is at the limits of normality (e.g. patient position, access to the airway, patient size) consideration should be given to use of a second generation SAD.

Recommendation: In view of the above recommendations, and the frequency of these circumstances, it is recommended that all hospitals have second generation SADs available for both routine use and rescue airway management.

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*Disclaimer

Dr Cook has been paid in the past for educational lecturing for Intavent Orthofix (now Intavent Direct) who make laryngeal mask airways. He, or his department, has also received free or at cost airway equipment for use in research. Such manufacturers took no part in NAP4. Dr Cook has never been employed by any airway manufacturing company and has no financial interest in any such company.



Dr David Bogod



Dr Mansukh Popat

Headline

Difficult intubation cannot always be predicted, so it must be managed. Examples of good and not so good management have been reported to NAP₄, the former characterised by careful planning and early recourse to alternative methods of achieving an airway, including surgical access. Fifty-four of 96 tracheal intubation-related cases described failed tracheal intubation, of which more than three-quarters occurred in the theatre setting. Fifteen of these cases progressed to the 'can't intubate, can't ventilate' (CICV) scenario. It is heartening that all 12 patients who experienced unexpected failed intubation in theatre survived neurologically intact, suggesting that guidance such as that provided by the Difficult Airway Society is being taken up and proving effective. Outcomes of failed intubation on ICU in particular were less likely to follow a well-planned strategy and were associated with poorer outcomes. Harm due to direct airway trauma and poor technique during airway exchange or use of airway exchange catheters was also reported.

What we already know

While supraglottic airway devices (SADs) continue to proliferate, and the indications for their use expand, there will always be an irreducible requirement for tracheal intubation during anaesthesia. The NAP₄ census (see Chapter 4) showed that, in September 2008, a tracheal tube was the primary airway management device in 38.5% of patients across the UK, and this is probably an accurate reflection of current practice.

A small proportion of these patients will be difficult to intubate safely and, in rare circumstances, this can lead to airway injury, hypoxic brain damage or even death.^{1,2} A multitude of screening tests for predicting difficult direct laryngoscopy exist, and application of one or more of these has become routine practice at pre-operative evaluation. Unfortunately, the predictive value of these tests is poor, meaning that some intubation difficulties will be unanticipated, even with the best assessment.³ Bedside tests do, however, encourage the anaesthetist to focus attention on the airway and, in combination with a full anaesthetic history and review of the records of previous procedures, allow a safe airway management plan to be constructed.

Non-technical human factors such as teamwork, communication and planning play an important part in the genesis and prevention of intubation problems, along with patient safety in general, and these should continually be reviewed and optimised. Technical aspects can be over-emphasised, but some basic principles should not be overlooked. Deterioration of the 'can't intubate, can ventilate' scenario to the hazardous 'can't intubate, can't ventilate' (CICV) position often arises from multiple attempts to intubate using the same device.^{3,4} These attempts, often performed blind, can lead to progressive airway trauma and oedema. It is therefore important to have a plan for every intubation which involves using a device other than that intended for the first attempt. However, the first attempt still represents the best chance of securing the airway without adverse incident, so every effort should be made to ensure optimisation of position, facilities and environment before embarking on the procedure.⁵ Direct laryngoscopy with a Macintosh blade remains the technique of first choice if not actively contraindicated when difficulty is not anticipated: where it is, the gold standard involves keeping the patient 'awake', or at least with the ability to maintain their own airway until the airway is secured. Where intubation is difficult or impossible, priority must be given to maintaining oxygenation.

Rapid Sequence Induction (RSI) is a mainstay of anaesthetic practice in those patients at risk of aspiration of gastric contents but its method means that patients transit very quickly from full consciousness with intact reflexes and a fully protected airway to complete unconsciousness and loss of protection. It is well recognised that the frequency of failed intubation rises when RSI is used.⁶ In these cases, optimisation of intubation conditions is particularly important, as is the formal development of a back-up plan to ensure oxygenation should intubation fail.⁵

Whatever technique is used for intubation, it is of paramount importance to check the correct position of the tube in the trachea by recommended means. Successful placement of a tracheal tube is not the end of the story. Extubation can sometimes be more challenging than intubation, may result in an acute airway event and, as an elective procedure, should be planned as carefully as intubation. Follow-up of the patient whose airway proved difficult is important in order to allow detection of the



late complications of traumatic intubation. Finally, full documentation of any difficulties encountered, along with details of how they were overcome, will inform and guide future anaesthetists caring for the same patient (see Chapter 17).

Minimising harm from tracheal intubation might therefore include the following factors:

- assessment of all patients in whom tracheal intubation is planned to identify those at risk of difficult intubation
- individualised management strategies for those patients who are identified as at high-risk of difficulty
- a strategy (i.e. plans A, B, C etc) for managing unexpected intubation difficulty, both during routine and RSI
- including in such a strategy specific acknowledgement that when difficulty arises:
 - ◆ waking the patient should be actively considered
 - ◆ tracheal intubation may not always be necessary
 - ◆ alternative methods of securing the airway must be immediately available
 - ◆ when intubation fails the priority is oxygenation and avoidance of secondary injury
 - ◆ communication and teamwork play an important role in successful management of these events.

Case review

In the main analysis of NAP₄ a tracheal tube included all variants (e.g. double lumen tubes, tracheostomies, transtracheal catheters etc). Such devices were the primary intended airway for 91 anaesthesia cases and a tracheal tube was involved in all but one of the 36 ICU and 15 emergency department cases. This chapter deals primarily with 'standard tracheal intubation' and other chapters cover the specific topics of tracheostomy (Chapter 15), and direct tracheal access in the CICV situation (Chapter 13).

The review panel identified 96 reports where tracheal intubation was the intended method of airway management or where tracheal intubation, as part of a rescue technique, contributed significantly to the outcome. Of these 96 incidents, 26 occurred in ICU or the emergency department, and these are considered in greater detail in the relevant chapters.

Failed intubation

Fifty-four of the 96 tracheal intubation-related reports described failed tracheal intubation, of which more than three-quarters occurred in the theatre setting. Fifteen of these were classified, after further analysis, as fitting into the classical CICV scenario. It should be stated from the outset that the inclusion criteria for cases in this project (death, brain damage, emergency surgical airway and necessity for

or prolongation of ICU admission) mean that those patients in whom failed intubation was corrected by a relatively simple manoeuvre, such as insertion of a SAD, would not have been reported. The cases of failed intubation reported to and analysed by the review panel will, therefore, be skewed towards the more difficult and complex to manage.

High body mass index was a common feature in many of the failed intubation reports, with 50% of the theatre cases (21 patients) having a body mass index, (BMI) >25 kg.m⁻². Of these, ten had a BMI ≥30 kg.m⁻² and two >40 kg.m⁻².

Anticipated difficult intubation

Of those 43 patients where initial attempts at intubation failed in theatre, difficulty was anticipated in 31 cases. Many of these patients were undergoing surgery for upper airway tumours or stridor, had tracheal strictures or were known to be difficult to intubate from recent anaesthesia. Two of these patients, both with inoperable tracheal cancer, died. Of the others, rescue was largely achieved with surgical tracheostomy or percutaneous cricothyroidotomy (although, as stated above, those patients rescued with SADs would not have been reported unless admitted to ICU as a result of the airway event). In seven cases, needle or catheter cricothyroidotomy was unsuccessful; in general, surgical insertion techniques, whether of small or large bore devices, was more likely to be successful (see Chapter 13).

Several cases were reported where a patient who had been intubated with difficulty some days previously returned to theatre for further surgery and was found to be impossible to intubate. Airway oedema is a common finding after tracheal intubation and may persist for some days, especially when the patient is otherwise compromised. In such cases, an awake technique using a flexible fibroscope might be preferable or, failing this, at least preoperative inspection of the laryngeal inlet with a nasendoscope, prior to attempting intubation.

Case 1

An elderly patient who had undergone abdominal surgery less than one week earlier presented for re-exploration following surgical complications. The trainee anaesthetist in the first operation had described a grade 3 Cormack and Lehane view before achieving successful tracheal intubation. A consultant anaesthetist used a rapid sequence induction but was not able to identify any airway structures on laryngoscopy, probably due to gross oedema. Ventilation with bag and mask was unsuccessful, and insertion of a Guedel airway and a laryngeal mask did not enable ventilation. A trainee anaesthetist performed a surgical cricothyroidotomy and inserted a Minitrach, restoring oxygenation, after which the patient was allowed to wake. Awake fibreoptic intubation was performed. The time from laryngoscopy to securing the airway was ten minutes, with absent ventilation for eight minutes, and a lowest oxygen saturation of 44%.

Case 1 illustrates such an event. The reporter, who was also the clinician responsible for the patient's care, commented that his primary plan to carry out a RSI in a patient with a known difficult airway might have been flawed, although the fact the patient had been intubated recently by a junior trainee was advanced in mitigation. The review panel view was that, as a general point, difficult laryngoscopy, particularly before RSI, should not be ignored even when laryngoscopy was by a trainee. Securing the patient's airway awake might usefully have been considered. A positive finding was the early recognition of failed intubation, close adherence to Difficult Airway Society (DAS) guidelines for restoration of oxygenation and the decision to wake the patient up. The case also illustrates the important point that, when airway difficulty occurs during RSI, considerable airway management may be required simply to keep the patient alive long enough to wake them up.

Case 2 illustrates that appropriate assessment, planning and preparation can contribute to a smooth and successful resolution of a potentially life-threatening problem.

Case 2

A young adult with a known history of vocal cord palsy with stridor at rest presented in extremis to the emergency department. The patient was transferred urgently to theatre after stabilisation with nebulised adrenaline and heliox for an attempt at intubation with an ENT surgeon scrubbed and ready for tracheostomy. Following an inhalational induction, a grade 2 view of the cords was obtained, but oedema and distortion prevented passage of a bougie. A surgical tracheostomy was performed with anaesthesia and oxygenation maintained by facemask. The procedure took 20 minutes from laryngoscopy to completion of the tracheostomy.

The DAS guidelines (though designed for *unexpected* difficult intubation) and other published guidance stresses the need for using different approaches to overcome failed intubation, rather than relying on repeated attempts with the same device, often by different users.⁵ The maxim is appropriate for all intubation difficulty. In general, repeated direct laryngoscopy should only be performed if a different

laryngoscope type is available (e.g. a McCoy blade,) and then only when intubating conditions have been optimised. Apparently unlimited attempts at intubation, as seen in some cases reported to NAP₄, are not indicated and predictably led to deterioration and CICV. Early acceptance of failed intubation and use of a SAD – and possibly a secondary device if the first is unsuccessful – is advisable to rescue the airway. Waking up the patient should be actively considered, but may not always be possible (e.g. case 1). If these strategies fail, and oxygenation is compromised, cricothyroidotomy or tracheostomy should be carried out.

Unanticipated difficult intubation

There were 12 reports of unanticipated failed intubation in an anaesthetic setting. In some cases this was simply because no formal preoperative airway assessment had been carried out (see Chapter 17), but in others assessment had provided reassurance that proved to be false. Three cases were obstetric patients being delivered by caesarean section, and one was a child undergoing herniorrhaphy – these are considered in more detail in their respective chapters (see Chapters 21 and 22). All patients survived without cerebral damage, five requiring emergency cricothyroidotomy or tracheostomy and the other seven being managed with non-surgical airways, usually a tracheal tube passed by another practitioner or using a different laryngoscope. Of the adult patients, only one had a body mass index in the normal range, and this group also includes both patients with a BMI greater than 40 kg.m⁻².

Case 3

An obese patient with diabetes and gastro-oesophageal reflux was listed for minor hand surgery as a day case without ICU facilities. The locum staff grade anaesthetist recorded an unremarkable pre-operative airway assessment. The anaesthetist attempted a brachial plexus block but this did not provide adequate anaesthesia. General anaesthesia was then induced, although the technique was not described, before attempting tracheal intubation. There were three failed attempts, followed by failed ventilation with a laryngeal mask. A hypoxic peri-arrest scenario ensued, necessitating the use of atropine and cardiopulmonary resuscitation. Two consultants attended from nearby theatres and a tracheal tube was successfully passed on the second attempt with a Macintosh laryngoscope and bougie. From initial laryngoscopy to eventual placement of the tube took 20 minutes, and the patient had an oxygen saturation below 70% for six minutes, reaching a nadir of 44%. Surgery was abandoned and the patient transferred to an ICU on a different site. After mechanical ventilation for 36 hours the patient made a full recovery.



In case 3 the reporter commented on what were probably poor processes for induction, assessment and supervision of the locum staff grade anaesthetist, but commended the rapid consultant response and smooth transfer to ICU. The review panel noted that, when a regional technique is felt to be the best approach and then fails, it is less likely that the anaesthetist will have a fallback plan should general anaesthesia prove problematic. It was fortunate that the consultant was able to intubate after the initial failure of the first anaesthetist. A cricothyroidotomy may have been an equally logical approach.

Videolaryngoscopy

In cases reported to NAP₄ videolaryngoscopes or optical-stylets were mentioned infrequently, 12 of 184 (7%) cases (see Table). In 11 of these cases intubation attempts were made while in one report a Glidescope was available but was not used, due to lack of skills. The Airtraq was used most frequently: it rescued a difficult intubation on one occasion and failed on four, including one where it was used with a fibrescope. On several occasions the advanced device somewhat improved the laryngeal view, but the tracheal tube could not be directed to the larynx. NAP₄ is, in many respects, a study of failures and this information tells us little about overall success rates with these devices in their wider use. However two features are of interest. First, these devices were most frequently used when several other devices had already failed to achieve intubation. Second, several patients, after failure with these devices, were then successfully intubated with the McCoy blade and a bougie or by placement of a SAD and fiberoptic intubation, using the SAD as a conduit.

The following were not found in the NAP₄ database: Bullard, Flexiblade, Shikani SOS, Levitan FPS, C-trach, Upsherscope, TruView, ViewMax, Wuscope.

Table 1 Use of advanced blades and fibrescopes: uses (success: failure)

	Anaesthesia	ICU	Emergency department
McCoy	15	9	0
Airtraq	4 (1:3)	1 (0:1)	0
McGrath	2 (0:2)	0	0
Glidescope	1 (0:1)	1*	0
C-Mac	1 (0:1)	0	0
Pentax AWS	1 (0:1)	0	0
Bonfils	1 (0:1)	0	0

*Reported as available but not used due to lack of skills

Unrecognised oesophageal intubation

Nine cases of unrecognised oesophageal intubation were reported. Outcomes were generally very poor, with six deaths and one patient with resultant brain damage. Two patients recovered after a prolonged stay in critical care, oesophageal placement having been belatedly recognised in one when gastric contents appeared in the tube. Of these cases, three occurred in the operating theatre, in two cases misplacement of the tube was mistakenly treated as anaphylaxis (e.g. case 4). Four occurred in ICU, all without the use of capnography. In three of these instances, intubation was carried out by relatively inexperienced trainees. Two other patients, both of whom subsequently died, were intubated in the emergency department. In one case, capnography appears to have been used but the absent trace misinterpreted. These cases are discussed in detail in Chapters 9 and 10.

Case 4

A middle-aged patient with a known history of asthma and latex sensitivity was scheduled for elective peripheral surgery. Airway assessment was not recorded. Pre-oxygenation was not performed. Propofol by infusion and fentanyl were used for induction of anaesthesia, after which ventilation with bag and mask rapidly became impossible. Hypoxia and cardiac arrest ensued and anaphylaxis was suspected. Tracheal intubation was hampered by a grade 3 laryngeal view. After intubation the capnograph trace was flat (ascribed to loss of cardiac output) and ventilation was very difficult (ascribed to severe bronchospasm). No action was taken to actively exclude oesophageal intubation. Cardiac output was restored with adrenaline but the flat capnograph trace persisted, prompting urgent re-intubation. This was successfully achieved, despite a persistent grade 3 view, with a McCoy laryngoscope and bougie. Oxygen saturation was below 70% for 20 minutes. At the time of the report, the patient remained in a persistent vegetative state.

In case 4 the reporter ascribed the delay in recognising what was presumed to be oesophageal intubation to the combination of factors described above. Airway assessment might predict some cases of difficulty, leading to improved planning. Pre-oxygenation can considerably delay life-threatening hypoxia, thus mitigating the effects of airway difficulty, and is strongly recommended even when no difficulty is anticipated.^{7,8}

Aspiration of gastric contents

There were seven recorded cases of aspiration of gastric contents during induction or intubation, of which six occurred in theatre with one in the emergency department. Five of the theatre cases were anaesthetised by trainees. Three of the six were overweight and three obese. There was one elective procedure in a fully-fasted elderly patient undergoing endovascular aortic repair, where regurgitation might have resulted from accidental oesophageal

intubation. All other cases were non-elective, one involving fracture reduction and several others strangulated hernias or small bowel obstruction. One obese patient vomited profusely despite RSI and application of cricoid force, but in the other four cases cricoid force was not used, despite the emergency nature of the procedures and clearly identifiable risk factors for regurgitation. In all cases, the airway was successfully intubated, although in the patient where RSI was used, the laryngeal inlet was so obscured by vomitus that a cricothyroid puncture and Manujet ventilation were required to maintain oxygenation while a secure airway was achieved. In one case aspiration occurred when the airway had been secured by awake fiberoptic intubation but an incompletely inflated tracheal tube cuff failed to prevent aspiration after induction of general anaesthesia. One patient died within hours of the event, one died later of multi-organ failure as a sequela of ARDS, and another was still in ICU one month after the sentinel event.

Case 5

An overweight middle-aged patient was on the trauma list for open reduction of a significant lower limb fracture. The patient was hypertensive and hypothyroid with chronic back pain, but had no relevant gastrointestinal symptoms and had been anaesthetised uneventfully in the past. There was no indication of a pre-operative airway assessment having been carried out. Cricoid force was not used. Following pre-oxygenation and induction with fentanyl, propofol and rocuronium, laryngoscopy revealed a bile-coloured pool of fluid which was suctioned before intubation and aspiration was suspected. Two 20ml doses of saline lavage were administered. After an uneventful procedure and extubation, the patient desaturated in recovery and was admitted to critical care, where respiratory function deteriorated further.

In addition to these cases where the primary airway event was aspiration of gastric contents, there were four reports of aspiration of gastric contents complicating other primary events during use of a tracheal tube (failed or difficult intubation) and three cases of aspiration of blood before, during or after use of a tracheal tube. These cases are discussed further in Chapter 19, Chapter 21 and also in Chapter 8.

In several cases the review panel highlighted the lack of RSI. This one case clearly does not provide any useful evidence to support or refute this practice, but all patients should be assessed for their propensity for regurgitation. It might be argued that the benefits of RSI probably outweigh its risks in such patients. The benefits of bronchial lavage to treat aspiration have not, to the best of our knowledge, been demonstrated.

More generally NAP₄ received reports of several cases where the omission of RSI, in cases where there were strong indications for its use, led to patient harm, or death from

aspiration. There were no cases where cricoid force was reported as leading to major complications. This topic is discussed further in Chapter 19.

Airway trauma

In three cases, airway trauma was a primary event leading to further intervention, although in one of these, laser arytenoidectomy, the trauma was surgical, rather than anaesthetic in origin. Two occurred when tracheal tubes were passed over bougies in critical care units.

In several other cases multiple attempts at intubation were recognised to have caused airway swelling and it was for this reason that extubation was deferred and the patient admitted to ICU.

In one case a tracheal tube exchange, after difficult and possibly traumatic intubation out of hospital, led to a lost airway and CICV requiring emergency surgical airway. The technique used (extubation with no exchange catheter or bougie left in place) was poor and on attempting to re-intubate the view was grade 2 but the larynx was distorted and blood impeded intubation. Intubation, then ventilation, failed with resultant profound hypoxia; lowest recorded oxygen saturation was 10%. It was uncertain to what extent prior intubation trauma led to the failed intubation.

A similar, though less severe, case occurred when a consultant changed a leaking tracheal tube, mid surgery, after awkward intubation by a junior trainee. The tube was removed, without prior inspection and without use of an exchange catheter. Whether pre-oxygenation was used was not recorded. Laryngeal view was grade 3 and the tissues oedematous. Intubation was difficult and prolonged. The patient was admitted to ICU for several days for observation while airway swelling resolved.

Barotrauma, reminiscent of that reported in the Gordon Ewing case,⁹ occurred in one patient when an airway exchange catheter (AEC) was used, in this case to facilitate exchange of a small tracheal tube (placed in a tracheostomy) for a tracheostomy tube. After placement of the AEC a single 'test ventilation' was applied using a high pressure source and a Manujet. This resulted in bilateral tension pneumothoraces, significant surgical emphysema and prolonged hypoxia. There was no loss of cardiac output and prompt airway control and chest drainage followed by care on ICU led to full recovery. While the tube being exchanged was in a tracheostomy the danger and mechanism of harm of applying high pressure source ventilation to a tube where the route of egress of gas is uncertain is worth re-iterating. Two points are worth emphasising. First, the use of an AEC requires extreme care and it should never be necessary to insert it beyond the tip of the tracheal tube that is in place (i.e. the AEC tip remains above the carina); in practice this means the AEC should



never be inserted beyond 26 cm at the lips. Second, the indications for ventilation via an AEC are very rare indeed; given the potential harm this may cause, providing the patient is not profoundly hypoxic, when the AEC is inserted it seems logical to proceed directly to insertion of the replacement tracheal tube and conventional ventilation.

One severe injury occurred during routine use of a bougie for intubation. An RSI was performed in the emergency department for a patient with a low GCS but with no history of trauma. Intubation appeared to proceed uneventfully; laryngeal view was not recorded and a bougie was used but intubation was achieved on first attempt. A pneumothorax was evident on chest X-ray immediately after intubation and the patient subsequently developed pneumomediastinum, bilateral pneumothoraces and pneumopericardium. Endoscopic inspection identified a tracheal tear on the posterior tracheal wall above the carina. This was judged by the local thoracic surgeon to be likely secondary to tracheal intubation. The patient required a prolonged ICU stay. Reported details were incomplete, and whether the trauma was due to poor technique, poor equipment or patient factors is unclear.

On ICU one patient with severe platelet dysfunction suffered life-threatening haemorrhage after difficult, and presumably traumatic, tracheal intubation tube assisted with a bougie. This led to cardiac arrest secondary to hypoxia but the patient made a full recovery.

Numerical analysis

The review panel identified 96 reports where tracheal intubation was the intended method of airway management or where tracheal intubation, as part of a rescue technique, contributed significantly to the outcome. These resulted in 16 deaths, two cases of cerebral damage, 46 cricothyroidotomies or tracheostomies, and 32 admissions or prolongations of stay on ICU. Of these 96 incidents, 26 occurred in ICU or the emergency department.

Of the 70 tracheal tube-related incidents in the operating theatre, a consultant anaesthetist was present at the time of the incident in 43 cases. More than half (43) related to failed intubation, the remaining cases related to gastric aspiration or aspiration of blood and blood clots, airway trauma, unrecognised oesophageal intubation, and miscellaneous complications including blocked tracheal tubes, intractable bronchospasm and extubation-related issues; the latter are covered in a separate chapter (see Chapter 8).

Discussion

Failed intubation

Two-thirds of patients with failed intubation had an anticipated difficult airway. Although major mortality

did not result, multiple attempts at intubation resulted in airway oedema and trauma and difficulty in oxygenation resulting in CICV and recourse to a surgical airway. In many of these patients an airway management strategy that secured the airway awake would have avoided these problems.

All 12 patients who experienced *unexpected* failed intubation in theatre survived neurologically intact. In many cases there was a structured response to the problem. This suggests that guidance such as that provided by DAS is being taken up and proving effective.

Unrecognised oesophageal intubation

Unsurprisingly, the outcome of unrecognised oesophageal intubation is usually very poor indeed. Tracheal intubation in theatre is nowadays carried out in the presence of a trained assistant and a tested and functioning capnograph. The latter, in particular, means that unrecognised oesophageal intubation rarely occurs in the theatre environment. In contrast to the ICU and emergency department cases where capnography was not used, in the cases of oesophageal intubation during anaesthesia capnography was in use during the event. The event progressed due to failure to correctly interpret capnography in the face of situations of peri-arrest or cardiac arrest.

Capnography can become difficult to interpret during low cardiac output states and in cardiac arrest. However a flat line is not usual and even in cardiac arrest, during CPR, carbon dioxide is produced leading to an attenuated but visible capnography trace (see Figure 1). A completely flat capnograph in any circumstances should immediately raise the possibility that the tracheal tube is not in the trachea, or is obstructed. Active measures should be undertaken to confirm or exclude these diagnoses. Clinical signs are unreliable in these circumstances and it is recognised that oesophageal intubation may present both after apparent normal auscultation of the lungs and as cardiovascular collapse.¹⁰



Other tools (syringe and balloon oesophageal detection devices, fibreoscopy¹) are available to help diagnose oesophageal intubation and suspicion should remain high, especially when visualisation of the larynx has been difficult. In particular fibreoptic inspection via the tracheal tube to confirm the position of its tip is advocated. This issue is discussed in detail in Chapter 6.

Absolute bronchospasm or tracheal tube obstruction, which may present with absent ventilation, flat capnography and hypoxia, can be difficult to distinguish from oesophageal intubation and all three diagnoses were reported to NAP₄ and confused with each other. If reintubation does not resolve the problem fibreoscopy may be needed to exclude oesophageal intubation.

Aspiration of gastric contents

Aspiration of gastric contents during tracheal intubation is still a problem. RSI with cricoid force currently remains a standard procedure for patients who are judged to be at risk of regurgitation. In the past this has included trauma victims, in whom gastric stasis may occur at and after the time of trauma. More generally NAP₄ received several reports where the omission of RSI, in cases where there were strong indications for its use, led to patient harm, or death from aspiration. There were no cases where cricoid force was reported to lead to major complications.

Blind intubation: bougies, exchange catheters and videolaryngoscopes

Bougies, are invaluable aids when intubating the patient with a view other than Cormack & Lehane grade 1, and can make the difference between successful intubation and surgical intervention.¹¹ However, bougies, by nature of their function, are relatively stiff devices, and considerable force can be exerted at their tips. If this force is directed against soft tissue, whether tracheal or oesophageal, then trauma can ensue. Some concern has been expressed in recent years that some single-use bougies may not perform as well as the old reusable 'gum-elastic' device and that they

are more likely to cause damage: this view is supported by studies comparing performance, malleability and tip dimensions of the two types of bougie.¹²

Bougies are only generally used when the passage for the tracheal tube cannot be clearly visualised. In this situation, where a relatively rigid device is inserted blindly, great care must be taken not to use excessive force, and to only advance the bougie when there is minimal resistance to advancement. Videolaryngoscopes offer the theoretical opportunity to transform these blind intubations into sighted or visualised intubations. The anticipated benefit of these devices in such circumstances is still unproven and requires further well-designed research.

Similar arguments regarding the risk of trauma apply to AECs. Harm from these devices may occur both due to omitting to use them (e.g. during tube exchange or high-risk extubation) or their misuse: placement too deep in the lungs and application of high pressures through them that risks severe or fatal barotrauma. A recent increased awareness of such problems is welcomed, but NAP₄ indicates that complications of their omission or misuse continue to occur.

Obesity

The excess of patients in this group who were obese is notable. While obesity may increase the risk of difficult laryngoscopy or difficult intubation it is perhaps more important that it results in more rapid desaturation during apnoea⁷; this can be at least partly alleviated by the use of head-up tilt during pre-oxygenation and induction.⁸ In general, effective pre-oxygenation takes longer in the obese patient. Obesity is discussed separately in Chapter 20.

Learning points and recommendations

Primary problems with tracheal intubation (failed intubation, difficult and delayed intubation and CICV) remain prominent causes of airway morbidity and mortality in anaesthesia, and more so in airway events that occurred



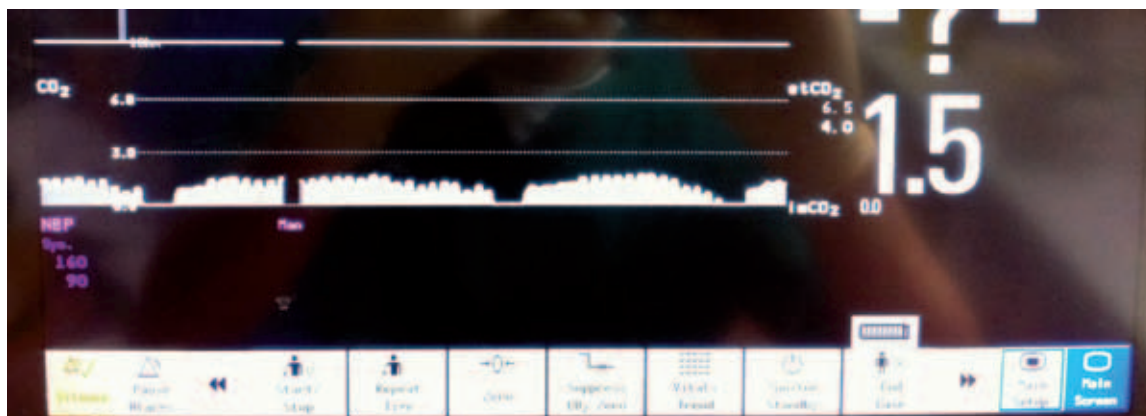


Figure 1 Exhaled carbon dioxide can be seen in low-cardiac output states, although the trace may be abnormal.

on ICU and in the emergency department. The following recommendations focus mostly on tracheal intubation during anaesthesia; many are not new but NAP₄ serves to reinforce established findings.

Assessment

Not all difficult tracheal intubation can be predicted, so a high index of suspicion should be maintained at all times. It is difficult to argue that airway assessment (which will identify at least half of such cases) should not be performed prior to anaesthetising patients for a planned tracheal intubation.

Recommendation: Airway assessment should be performed and documented prior to anaesthetising a patient.

Planning for failed intubation

Any intubation may prove difficult or fail. This applies particularly to rapid sequence induction.

Recommendation: Plans for difficult or failed intubation should be made before induction of anaesthesia and should include the use of different devices both for direct laryngoscopy (e.g. alternative blades) and airway rescue (e.g. supraglottic airway devices).

Recommendation: All anaesthetic departments should have an explicit policy for management of difficult or failed intubation (e.g. formal adoption of the Difficult Airway Society guidelines as departmental policy).

Direct tracheal access

Access through the front of the neck is a vital tool for rescuing the failed airway, although needle cricothyrotomy may have a significant failure rate in these circumstances.

Recommendation: Rescue techniques that involve direct access to the trachea should be included in the policy for management of difficult or failed intubation. These techniques should be taught and practised with equipment that is available at that hospital (see also Chapter 13).

Unrecognised oesophageal intubation

Unrecognised oesophageal intubation can still occur despite the use of capnography.

Recommendation: Capnography should be used during all intubations, irrespective of the location.

Recommendation: Training of all clinical staff who may intubate patients should include interpretation of capnography. Teaching should include recognition of the abnormal (but not flat) capnograph trace during low cardiac output states and during cardiopulmonary resuscitation. (See also Chapters 9 and 10).

Aspiration and rapid sequence induction

Rapid sequence induction with cricoid force does not provide 100% protection against regurgitation and aspiration of gastric contents, but remains the standard for those patients at risk including trauma patients injured shortly after eating.

Recommendation: All cases, but particularly those undergoing emergency surgery, should be assessed for risk of regurgitation and aspiration.

Recommendation: On balance, rapid sequence induction should continue to be taught as a standard technique for protection of the airway. Further focused research might usefully be performed to explore its efficacy, limitations and also explore the consequences of its omission.

Blind intubation and use of bougies and exchange catheters

Blind insertion of a bougie as an aid to tracheal intubation can be a very effective tool, but soft tissue trauma can result; undue pressure should be avoided.

Recommendation: Techniques that reduce the need for intubation involving blind placement of a bougie or introducer probably lessen the risk of trauma. Fiberoptic intubation and indirect laryngoscopy (e.g. videolaryngoscopes) may have a role. Further research is required.

Recommendation: Airway exchange catheters should be used only according to their manufacturers' instructions. This includes limiting the depth of insertion (<26cm). Their use with a high pressure source for ventilation should be reserved for circumstances of necessity and requires the highest standards.

Obesity

Obesity is risk factor for difficult intubation, and for rapid onset hypoxia during apnoea or airway obstruction. Obesity may also be a factor in regurgitation and aspiration as a cause of airway complications, or as a secondary complication. As a result obese patients appear more likely to suffer harm at the time of intubation and extubation than non-obese patients.

Recommendation: Training in airway management should acknowledge the particular problems that overweight and obese patients present. A high index of suspicion is appropriate.

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Headline

Of the 133 serious complications of airway management which occurred during anaesthesia 58 (43%) involved an attempt at a cricothyroidotomy or urgent tracheostomy to maintain or restore oxygenation. There were a further 12 cases reported from intensive care units and ten from emergency departments. This life saving procedure was associated with a significant failure rate. It became apparent through the review process that some techniques for accessing the airway were markedly less successful than others in this cohort. Cannula cricothyroidotomy attempted by anaesthetists had a particularly low success rate.

What we already know

The 'can't intubate, can't ventilate' (CICV) scenario describes the situation where attempts to manage the airway by facemask, (usually also Supraglottic Airway Device – SAD) and by placing a tracheal tube have failed. Inevitably the patient is using oxygen faster than the clinician can deliver it: profound hypoxia will occur if the situation is not rapidly resolved. Experience in the management of non heart beating organ donation suggests that cardiac arrest will typically occur within 5–10 minutes of complete airway obstruction.

Many countries have national guidelines for the management of CICV at induction of general anaesthesia; in the UK guidelines from the Difficult Airway Society (DAS) were published in 2004.¹ The final step in these guidelines is emergency cricothyroidotomy. DAS guidance offers the choice of narrow bore (needle) cricothyroidotomy or surgical cricothyroidotomy. Where needle cricothyroidotomy fails surgical cricothyroidotomy is recommended.

An incidence of CICV during anaesthesia is often quoted as one in 10,000² although Kheterpal's more recent work identified just one case in 50,000 anaesthetics indicating the problem may be less common than previously thought.³ In the emergency department the incidence may be considerably higher with several studies reporting rates of one in 500 and even as high as one in 100.⁴⁻⁷

Discussion in the literature has concentrated on the optimal equipment and training for managing the problem. Simulator based training has been demonstrated to

improve adherence to CICV algorithms.⁸ Skill retention in the technique of cricothyroidotomy has been shown to deteriorate six to nine months following initial training.⁹

Areas of interest include:

- 1 prediction and prevention of CICV
- 2 management of early CICV
- 3 choices and equipment for direct tracheal access in CICV with progressive hypoxia
- 4 behavioural aspects of CICV.

Prediction and prevention of CICV

There are few specific tests for CICV with most airway evaluation traditionally describing tests to predict difficult laryngoscopy and more recently difficult mask ventilation³ (with prediction of difficult SAD insertion still a neglected area). Importantly Langeron showed that patients who are difficult to mask ventilate are four-fold more likely to be difficult to intubate and 12-fold more likely to be impossible to intubate than those in whom mask ventilation is easy.¹⁰ The implication is that when one aspect of airway management is difficult others will also be more difficult than normal. Whenever one aspect of airway management (i.e. mask ventilation, SAD insertion, tracheal intubation or direct tracheal access) is predicted to be difficult an assessment of the ease of the alternatives routes of airway management/rescue should be carried out, and a viable back-up plan created.¹¹

Obesity is an important predictor of increased difficulty in airway management; it increases the risk of difficult or impossible mask ventilation^{3,10} and may increase the risk of failed tracheal intubation. Perhaps more importantly, due to the speed with which hypoxia develops, it dramatically reduces the time available to secure the airway before profound hypoxia occurs.¹²

CICV can arise de novo when unexpected difficult mask ventilation is associated with impossible intubation or can develop over time, most notably when multiple attempts at laryngoscopy and tracheal intubation change a 'can't intubate can ventilate' situation into CICV.¹³

Simple strategies to reduce the risks of CICV include:

- 1 assessing the airway. Assessment enables the formation of a strategy (i.e. a co-ordinated series

Management of the 'can't intubate can't ventilate' situation and the emergency surgical airway

of plans, not just one) for dealing with failure of any part of the airway plan

- 2 performing effective pre-oxygenation. Pre-oxygenation including anaesthetising patients in a head up position increases the time available to move through a failed intubation drill before hypoxia develops²⁴
- 3 limiting the number of attempts at intubation. This considerably decreases the likelihood of poor outcomes.²³ In a hypoxic patient where prompt awakening is not possible, if oxygenation is not improving after four attempts at intubation and two attempts at placing a supraglottic airway, a surgical airway should be performed
- 4 act before it is too late. Making the decision to perform an emergency surgical airway is difficult and it is important to make the most of the extra time available from pre-oxygenation to work through all the alternative options before dangerous hypoxia occurs.

Management of early CICV

The management of CICV should follow a logical sequence, such as that outlined in the DAS guidelines, ensuring the problem is not due to equipment blockage, calling for help early and adopting two-person mask ventilation techniques.¹ CICV should never be declared without at least the attempt to rescue the airway with a SAD. The choice of SAD is debatable but one that is familiar, easy to insert and with a high airway seal pressure is recommended. There is an argument for using a second generation SAD, as they generally have higher airway seals than the standard laryngeal mask and potentially offer increased protection against aspiration. The DAS guidelines, which were published before most second generation SADs were widely available, do not currently reflect this.

If the patient is not already paralysed a muscle relaxant should be given. This will resolve failure to ventilate caused by laryngospasm and may aid mask ventilation. In an emergency setting the muscle relaxant is likely to be suxamethonium.

Making the decision to perform an emergency surgical airway is difficult and it is important to make the most of the extra time available from pre-oxygenation to work

through all the alternative options before dangerous hypoxia occurs.

Direct tracheal access

There are three techniques available for cricothyroidotomy:

- A surgical technique using a scalpel to enable placement of a (small) standard tracheal or tracheostomy tube into the trachea. A 6.0mm id tube is usually chosen. Surgical or percutaneous dilatational tracheostomy can be used for airway rescue but these are not generally included in emergency airway algorithms as cricothyroidotomy is considered to be a quicker technique.
- Wide bore cannula cricothyroidotomy using purpose designed equipment (which may be cannula over needle or based on the Seldinger and dilator principle). The cannula is usually ≥ 4 mm id.
- Narrow bore cannula cricothyroidotomy (using a purpose designed cannula over needle: usually ≤ 2 mm id).

The first two techniques enable conventional ventilation with standard anaesthesia breathing systems and monitoring of exhaled carbon dioxide. Narrow bore cannulae less than 3mm in diameter (most are ≤ 2 mm id) require a high pressure ventilation source such as a Sander's injector or Manujet for ventilation.²⁵

Publications examining the different techniques of accessing the airway in an emergency are numerous. However they are often compromised by the circumstances in which they are necessarily performed (for example having equipment ready and open and the procedures being performed in manikins). Even so the differences between cricothyroidotomy techniques are rather small, usually amounting to less than 30 seconds.

Behavioural aspects.

Perhaps a neglected aspect of CICV research, the behavioural aspects of airway rescue are little studied. Factors such as delays in decision-making and skill-fade associated with increased length of time since training are likely to have a more significant impact on outcome than the choice of device.

The events surrounding the death of Elaine Bromiley²⁷ from CICV reminded the anaesthetic community that this



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complication can and does still occur in overtly normal people, with no obvious abnormality, whilst being managed by experienced clinicians. Although the subsequent investigation did highlight some technical and equipment issues, the key feature that emerged was that in CICV as in other emergencies Human Factors issues may be crucial to the difference between a successful and an unsuccessful outcome. These human factors in the management of CICV are just as important as device factors. Task fixation (failure to accept attempts at tracheal intubation should be abandoned), and reluctance to diagnose CICV and proceed to rescue techniques until too late have been frequently documented in cases of CICV.

The ASA closed claims project analysis of respiratory events is revealing on this subject.¹⁶ Many cases progressed from intubation difficulty to CICV. There was evidence of delay in performing emergency surgical airway. The data suggested that though many airway disasters end in cricothyroidotomy this was often done too late: when the patient was either perimortem or in fact dead. There is a natural reluctance to perform such techniques but the evidence is reasonably clear: it is not the procedure that kills patients, but delaying or not doing it that causes harm. Training programmes could usefully emphasise behavioural aspects of cricothyroidotomy as equally important as technical training.

The DAS guidelines practice notes¹⁸ recommend that when a failed direct laryngoscopy occurs the anaesthetist should audibly announce this stating 'It is a deliberate act to stop attempts at direct laryngoscopy, announcing to your assistant "Failed direct laryngoscopy"'. Whether the announcement informs the assistant, the wider team or indeed alerts the anaesthetist themselves is a matter of debate. It would seem logical that anaesthetists announce clearly and to all present when they have a CICV situation.

Case Review

Anaesthesia Cases

Of the 58 anaesthetic patients who had emergency surgical airways six died. Five of the deaths were in patients with advanced laryngeal or tracheal tumours, three died from failed emergency airway access and two died later from complications of their primary disease. The sixth patient died as a result of surgical complications.

Planning issues

There was a history indicative of airway problems in half of cases: previous difficult or failed intubation in eight and worrying pathology or stridor in 13. In all cases the anaesthetist was aware of the history but this did not always seem to have been taken into account when devising the airway management plan. Risks appeared to be underestimated despite the presence of often multiple risk factors.

Difficulty with airway management had been anticipated in 46 of the 58 anaesthetic cases. This included difficulty with mask ventilation in 15, laryngoscopy in 40 and SAD placement in seven. Access via the front of neck was anticipated to be difficult in 15.

Multiple unsuccessful attempts at direct laryngoscopy were seen both after intravenous induction of anaesthesia and muscle relaxation and after inhalational induction. Evidence of task fixation such as this was seen on a number of occasions (further discussion in Chapter 24).

Case 1

A patient scheduled for tracheostomy and partial laryngectomy had been anaesthetised six weeks previously. On that occasion after induction with propofol and atracurium, mask ventilation had been adequate but direct laryngoscopy had failed and asleep fiberoptic intubation had been performed with some difficulty. On this subsequent occasion anaesthesia was induced with propofol and suxamethonium. Asleep fiberoptic intubation failed, mask ventilation became increasingly difficult and oxygenation could not be maintained with facemask or laryngeal mask. Attempted rescue with a Ravussin cannula and Manujet ventilation caused massive surgical emphysema of the face and neck. An emergency surgical tracheostomy was performed by the surgeon and the patient was transferred to ICU.

In 35 cases it was acknowledged in the reports that an alternative technique had been available for airway management and in 14 this alternative was not discussed before embarking on the case. There were a number of cases where general anaesthesia was used that would have lent themselves well to awake fiberoptic intubation or awake tracheostomy but these options were not considered or not discussed.

It must of course be recognised that awake tracheostomy is not always straightforward and that awake intubation is not without risk; over-sedation during attempted fiberoptic intubation was a contributory factor to the requirement for an emergency surgical airway in more than one case (see Chapter 14). Nonetheless these options should be considered and discussed where airway management is expected to be challenging.

Failure of management of early CICV

Back-up plans were occasionally missing altogether but even when present they sometimes had not been well thought through; on occasion the equipment required for the back-up plan was not available or when the equipment was available the skills to use it were not. This was a particular feature in cases of CICV on ICU and is discussed in Chapter 9.

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Just over half of cases did not have an attempt at rescue with a SAD before attempting the emergency surgical airway. Importantly there were cases where a SAD was placed and provided a good airway after the cricothyroidotomy had been performed, demonstrating that emergency surgical airway could have been avoided in at least a proportion of these patients.

Case 2

A patient with a known airway mass that was reviewed on CT scan preoperatively was anaesthetised using an inhalational induction technique. An attempt at laryngoscopy caused the tumour to bleed and the situation quickly deteriorated to CICV. The team had been briefed and all rescue equipment had been assembled ready to use: a Ravussin cannula was inserted and ventilation commenced with a Manujet in less than two minutes. The oxygen saturations briefly fell as low as 60%. Even acknowledging the excellent preparation and a good outcome the anaesthetist involved considered that, in view of the history, securing tracheal access before anaesthetising the patient might usefully have been considered and discussed.

Case 3

A young adult was bleeding from the mouth in recovery following minor oral surgery. The earlier anaesthetic had been uneventful. Laryngoscopy after rapid sequence induction revealed a grade 3 view and two attempts at intubation failed. Oral bleeding increased (more than 500ml was suctioned) and oxygen saturations began to fall. A Ravussin cannula was inserted at the first attempt and oxygenation improved with high-pressure source ventilation from a Manujet. A size 4 laryngeal mask was then inserted and ventilation was easy. Using an Aintree intubation catheter and fibroscope via the laryngeal mask, intubation was completed. The patient was hypoxic for less than two minutes, the lowest oxygen saturations were 76%. The patient made a full recovery after a night in ICU.

Case 4

A young adult ASA 1 patient was scheduled for incision and drainage of a perianal abscess. The patient was known to have potential airway problems; facemask ventilation and laryngeal mask placement had been difficult during a previous anaesthetic. After induction with propofol and fentanyl, ventilation with facemask and with a ProSeal LMA failed and the patient rapidly became hypoxic. Help arrived in two to three minutes and between efforts to improve oxygenation, attempts were made to intubate the trachea which was achieved blindly on the third attempt with a bougie. An urgent tracheostomy was then performed and the patient was admitted to ICU. The patient had been hypoxic for 20-30 minutes with saturations below 70% for ten minutes. The reporter considered that laryngospasm may have been responsible for the initial difficulty with ventilation. No muscle relaxant was used in the management of this case.



Muscle relaxants may assist when mask ventilation is difficult and should be given before emergency surgical airway

In several cases CICV was diagnosed and treated, including emergency surgical airway, without a muscle relaxant being administered. In some of these laryngospasm may have caused or contributed to CICV. In others muscle relaxants were given but in such small doses as to likely be ineffective. There was a strong consensus amongst the review panel that in CICV (where the clinical circumstance means waking up is not an immediate option) a muscle relaxant should be given and in an adequate dose to fully paralyse the patient.

Difficulties with tracheal access

Of the 58 cases, the anaesthetist defaulted to a surgical colleague to perform the emergency airway in 33 and attempted rescue themselves in 25. Only nine of these 25 anaesthetic attempts were successful. Eleven were subsequently rescued by a surgeon performing a tracheostomy, three were rescued by tracheal intubation, one by a percutaneous tracheostomy placed by an anaesthetic colleague and one patient died.

As the final step in airway rescue in a situation where oxygen saturations are likely to be low it is evident that emergency surgical access should be quick and reliable. The majority of emergency surgical airways in the 58 anaesthetic cases were achieved on first attempt and 15 took just two attempts. Nine patients had their surgical airway completed in under five minutes but at the other end of the spectrum, 11 cases took over an hour to secure the airway from the start of the problem and nine patients



needed multiple attempts at surgical airway before oxygenation was restored.

Case 5

A patient with obstructive sleep apnoea, tracheal deviation and limited cervical spine mobility lost their airway after induction of anaesthesia and an attempt at laryngoscopy. Five or more attempts at cricothyroidotomy using various techniques over a period of 20 minutes (with saturations as low as 35%) were unsuccessful. The surgeon then secured the airway with a tracheostomy. The patient made a good recovery.

Case 6

A patient with a history of surgery and radiotherapy for oral carcinoma presented to the emergency department with stridor and saturations of 80%. Nebulised adrenaline, heliox and dexamethasone were administered with no improvement and a plan was made to transfer the patient to theatre for a fiberoptic intubation under spontaneous breathing anaesthesia. During the anaesthetic the airway became obstructed resulting in rapid desaturation, and cardiac arrest. CPR was started and needle cricothyroidotomy and high-pressure source ventilation performed. Cardiac output returned and a further attempt at fiberoptic intubation was made, and failed while a tracheostomy was performed. The patient had been hypoxic with oxygen saturations below 85% for 30 minutes but survived to discharge from hospital. The LR acknowledged that perhaps a surgical airway might have been done sooner when the inhalational induction failed rather than persisting with attempts at fiberoptic intubation.

Degree of hypoxia

In a minority of cases there was no extreme hypoxia. There were six cases in which oxygen saturations did not fall below 85% and in a further 12 cases saturations fell below 85% for less than three minutes.

In contrast in 20% of cases severe hypoxia (oxygen saturations less than 70%) lasted for more than five minutes and there were four cases where oxygen saturations were this low for more than half an hour. Several of these cases of profound prolonged hypoxia made a full recovery, without neurological deficit.

Behaviour

Some reports showed evidence of task fixation and delays in decision-making but by the nature of the reporting forms used the review panel was dependent on the reporters themselves identifying and describing these human factors issues.

Failures

Anaesthetists almost exclusively chose cannula techniques to try to rescue the airway but the use of these devices was associated with a significant failure rate.

■ Narrow bore cannulae and jet ventilation

Narrow bore cannulae and jet ventilation was attempted in 19 patients but this technique failed in 12 cases (63%). Problems included misplacement, misuse and device failure (such as detachment of the cannula from the hub and kinking).

- Seven of the failures needed rescue by urgent surgical tracheostomy (three of these had surgical emphysema from the attempts at high-pressure source ventilation). One failure was reported when after rescuing CICV with an intravenous cannula placed through the cricothyroid membrane the anaesthetist tried to use low-pressure ventilation from an anaesthetic circuit. This patient suffered a cardiac arrest and during CPR the airway was rescued by blind tracheal intubation. In one case CICV occurred during induction for elective thyroid surgery; non-standard tubing in the emergency airway trolley made connecting the Manujet to the cannula impossible. After an attempt at rescue with a wide bore cannula device the airway was finally secured with a surgical cricothyroidotomy. Three other failures occurred with Ravussin cannulae. One patient died as a result of CICV secondary to airway tumour, the team in this case were not prepared for the possibility of emergency tracheostomy. Two were rescued by tracheal intubation, in one case intubation was achieved via an Intubating Laryngeal Mask which had been used for rescue ventilation after the cricothyroidotomy failed; in the other intubation was guided by the Ravussin cannula which was seen at laryngoscopy pointing cephalad and helped identify the glottis.

■ Wide bore cannulae

Wide bore cannula cricothyroidotomy was the first choice in seven patients and three of these failed (43%). In one case a tracheal tube was dislodged during surgery and could not be replaced as the view was obscured with regurgitated gastric contents. Cannula cricothyroidotomy failed but a subsequent attempt at tracheal intubation was successful. In another, failed intubation was complicated by regurgitation and aspiration: wire-guided cricothyroidotomy failed on three attempts despite the wire being believed to be in the trachea. The airway was rescued with a percutaneous tracheostomy. In the final case CICV occurred at induction of anaesthesia for re-exploration of a neck wound. Cannula cricothyroidotomy failed to establish an airway and the patient was woken up after which the same device was placed in the trachea by the surgeon under local anaesthetic and was used for spontaneous breathing anaesthesia during formation of a surgical tracheostomy.

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■ Surgical

A surgical tracheostomy failed to restore oxygenation in one case even though the trachea was located and a tracheostomy tube was inserted. The patient developed surgical emphysema and pneumothoraces.

Avoidable surgical airways

There were two patients who received tracheostomies that were considered by the review panel to be probably unnecessary, although the amount of information available to the reviewers was obviously less than that used by the attending clinicians in making the decision to proceed. These two patients had good oxygenation after tracheal intubation had failed and had no risk of reflux, neither patient spent a prolonged period on ICU.

Intensive Care Unit cases

Data from ICU cases have similarities with the pattern observed in anaesthesia cases in that surgical colleagues were frequently called to assist with rescue, even on occasion when the patient was in extremis (see Chapter 9).

Case 7

An awake patient was being observed in ICU following carotid surgery. The patient had a prolonged operation and had been successfully resuscitated from an earlier cardiac arrest (using an i-gel for airway management) five hours previously. The patient had a further cardiac arrested but this time the airway could not be secured with a SAD despite attempts with an i-gel, laryngeal mask and ILMA. There were several failed attempts at tracheal intubation. Large bore cannula cricothyroidotomy by an intensivist and surgical cricothyroidotomy were unsuccessful. An attempt at tracheostomy by the surgical team also failed before prolonged resuscitation attempts were abandoned.

Five of the 12 emergency surgical airways in the ICU cohort were tracheostomies performed with the assistance of head and neck surgeons. There were four successful rescues using a cannula technique (two minitrachs, one narrow bore and one wide bore cricothyroidotomy). In three of the 12 cases attempts at emergency surgical airway access failed; one case was rescued by orotracheal intubation after a failed minitrach, the other two patients died. Both these fatal cases involved failed intubation, failed SAD rescue and hypoxic cardiac arrest. In each case juniors initially attended the patient and were then joined by senior intensivists and surgeons. Wide bore cannula cricothyroidotomy and surgical tracheostomy were attempted and failed in both cases before death.

Emergency department cases

Reports from the emergency department (covered in more depth in Chapter 10) support the evidence from the anaesthetic and ICU reports that surgical access to the airway (surgical cricothyroidotomy and

tracheostomy) appears to be more reliable than cannula cricothyroidotomy.

Ten cases were reported. In six the first choice was via a surgical approach (three cricothyroidotomies and three tracheostomies) all of which were successful. In four cases the first choice was cannula cricothyroidotomy, all of which failed.

Case 8

A patient presented with airway obstruction and was peri-arrest. The decision was made to proceed straight to cricothyroidotomy. An attempt to place a minitrach failed and the airway was rescued by emergency tracheostomy performed by an ENT surgeon.

Needle cricothyroidotomy was attempted in three cases without success. Two cases occurred when CICV complicated failed intubation at rapid sequence induction. In one, airway rescue with a SAD was not attempted (equipment not available), needle cricothyroidotomy failed during cardiac arrest and the airway was rescued with a surgical cricothyroidotomy. In the other, needle cricothyroidotomy was attempted and failed before SAD rescue was attempted: this succeeded and a percutaneous tracheostomy was then performed during oxygenation via the SAD. The final case was an adult in extremis with epiglottitis. Tracheal intubation and SAD ventilation failed: a wire-guided cannula cricothyroidotomy was believed to be correctly placed but cardiac arrest occurred. A surgical tracheostomy was performed during CPR. All these patients survived.

Numerical analysis

Anaesthesia

There were 58 cases where an emergency surgical airway was attempted. Forty-three were head and neck cases and the 15 others came from a range of surgical specialties and included two caesarean sections, three laparotomies, three thoracic surgery cases, two incision and drainage of abscess and five other cases (cervical vertebral fracture, fractured arm, minor gynaecology, hernia, PEG).

Four patients died as a result of airway complications. Two patients made a partial recovery: one was left with a permanent tracheostomy, the other also had continuing respiratory compromise. Fifty patients were reported to have made a full recovery.

In eight of the 58 cases emergency surgical access to the airway failed completely and the patient either died (two cases), was woken up (one case) or the airway was rescued by tracheal intubation (five cases).

In 13 cases more than one technique was used before oxygenation was restored or attempts to secure a surgical airway were abandoned.



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ICU

There were 12 cases where an emergency surgical airway was attempted.

These were needed in cases when planned intubation failed, when patients with known airway problems deteriorated, and after both accidental and planned extubation.

Five of the patients died, three made a partial recovery and four were reported to make a full recovery

In three of the 12 cases emergency surgical access to the airway failed completely and the patient either died (two cases) or the airway was rescued by tracheal intubation (one case).

There were two cases where more than one technique was attempted: in neither of these cases was an airway established and both of these patients died.

Emergency department

There were ten cases where an emergency surgical airway was attempted. In four the indication was facial trauma and in one, neck trauma with a retropharyngeal haematoma. Two patients had presented with known laryngeal pathology and increasing respiratory difficulty. There was one case of anaphylaxis, one epiglottitis and one respiratory arrest in a patient with a known difficult airway.

Two of the patients died although the extent to which the airway event contributed to death compared to other injuries was uncertain. Two patients made a partial recovery and the remaining six are reported to have made a full recovery.

In all these cases an emergency airway was achieved. In four cases more than one technique was required before oxygenation was restored.

Reviewing all 80 cases of emergency surgical airway, the panel considered that airway management could be considered good in 16 cases, mixed in 39 and poor in 24. One case was not classified.

The clinicians who reported the cases were asked to reflect on contributory causes and they identified poor judgement as the most common factor, followed by problems with team behaviour, poor training, lack of equipment and finally lack of knowledge.

The review panel considered that the patient's pathology was contributory to the event in 54 of the 80 cases and causal in 18. In accordance with the reporting clinicians' views the review panel found poor judgement was the commonest factor contributing to the event: contributory in 33 cases and causal in nine. The next most frequent (non-patient) contributory factors were judged to be education and training 33, equipment and resource 20, organisation and strategic 18, communication 17, task 16, medication 16, and team and social 15. It is important to recognise that positive aspects surrounding good communication were identified by the panel in 30 of the 80 cases.

Discussion

An emergency surgical airway was required during anaesthesia in 58 cases reported to NAP₄. This equates to one in 50,000 anaesthetics and may be considered a minimum estimate. This means that a UK hospital performing 10,000 general anaesthetic cases per year can expect to see a case approximately every five years. Uncertainty in the number of reports 'captured' by NAP₄ means this figure may represent an up to four-fold underestimate of frequency.

In emergency departments patients will continue to present with head and neck trauma, and with compromised airways secondary to malignancy, infective processes and allergic reactions. It is inevitable that some of these patients will require emergency surgical airways and consideration must be given at an organisational level as to how these patients will be managed when they present.

Intensive Care Units are considered a place of safety within hospitals but it is clear that emergency surgical airways may be required here, as they are in theatres and the emergency department. Plans for intubation, extubation and during

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observation of patients with unprotected airways should aim to minimise the likelihood of requiring an emergency surgical airway while maximising the chance of successful outcome if one is required. This includes ensuring all necessary equipment is available and staff training is up to date.

It is easy to see poor judgement with the benefit of hindsight and the review panel were careful to try to avoid such bias, nevertheless poor judgement did feature highly in the list of contributory factors as assessed both by the anaesthetists who reported the incidents and by the review panel. There were many cases where the review panel judged awake fibreoptic intubation would have been the most appropriate choice of technique but this had not been discussed at the time of the anaesthetic. Poor communication within the team (anaesthetists, surgeons and anaesthetic assistants) for example not considering or discussing alternate anaesthetic plans was a relatively frequent problem.

There was a high rate of failure of cannula cricothyroidotomy performed by anaesthetists. The reasons for failure were numerous and disparate. The project inclusion criteria meant that 'all cases of surgical airway' required as an emergency to manage an airway problem during anaesthesia should have been reported. Whether the cases reported represent a biased sample of failures or whether there is a genuinely high failure rate cannot be stated with certainty. If (as seems likely) there is a high failure rate, we cannot be sure whether this is because of poorly designed equipment, malfunctioning equipment, use of equipment not designed for this purpose, poorly used equipment, poor insertion technique or use of the wrong method of ventilation after insertion: there were examples of each. Optimum training in cricothyroidotomy insertion and ventilation, use of equipment specifically designed for this use and regular practice with such equipment seem logical goals to pursue in trying to minimise this failure rate.

Surgical techniques performed by surgeons, emergency physicians and occasionally by anaesthetists was consistently successful in accessing the airway, although not always with a good patient outcome. The contrast between the apparently high failure rate of needle cricothyroidotomy and the success of formal surgical techniques is a topic worthy of considerably more study.

When a surgical airway is predicted as a possibility, some authors advocate use of a 'prophylactic cricothyroidotomy' before inducing anaesthesia.²⁹ In appropriate circumstances this has numerous advantages, not least the potential to secure and check the 'rescue airway' in a calm and unhurried manner, without hypoxia, before an emergency arises. The ultimate 'prophylactic cannula' is of course the awake tracheostomy and there was evidence in the cases reported that this option was not used on several occasions when it was the logical solution (also see Chapter 18).

Learning points and recommendations

An emergency surgical airway required during general anaesthesia is very rare and most frequently occurs in patients with a history of or identifiable risk factors for a difficult airway.

Elements of poor planning, poor judgement, deviation from recognised algorithms and failures of technical skills were seen throughout the reports submitted to the project although it should be noted that the review panel also remarked upon many instances of good communication and teamwork that mitigated against worse outcomes. It is important to recognise that there were also some patients who had a poor outcome despite exemplary management from anaesthetic and surgical teams who were called upon to deal with extremely challenging clinical situations.

It behoves us as a profession to improve our performance in all these areas in order to reduce the number of occasions when an emergency surgical airway will be needed but also to ensure the optimum chance of a good outcome if all other options for securing the airway have failed.

Planning and prevention

Recommendation: Patients with airway tumours are at high-risk of CICV. In patients with symptoms of airway obstruction, airway imaging and nasendoscopy should be considered a minimum level of investigation in helping assess the options for anaesthetic airway management. Only in exceptional cases should anaesthesia proceed without this level of airway assessment.

Recommendation: Securing the airway before induction of anaesthesia (by awake intubation or awake tracheostomy) should be considered in all cases where the airway is at risk from the presenting condition or where difficulty has been experienced previously.

Recommendation: Where difficulty with airway management is anticipated or has occurred previously a comprehensive airway strategy must be in place before induction of anaesthesia. Plans B, C and D should be discussed with the team and the equipment and skills to carry them out must be available.

Recommendation: All anaesthetic departments should provide a service where the skills and equipment are available to deliver awake fibreoptic intubation when it is indicated.

Recommendation: Where there is a high suspicion that a cricothyroidotomy might be needed to rescue the airway, consideration should be given to placing this (as a needle or surgical procedure) prior to anaesthesia.

Early management of CICV

Recommendation: All anaesthetists should be made aware of published guidelines and trained in their use. Unlimited attempts at intubation are not indicated.





Capnography being used to confirm the position of a Ravussin cannula in a spontaneously breathing patient

Recommendation: Even if it was not part of the initial airway management strategy, if CICV occurs and waking the patient up is not an option, a muscle relaxant should be given before determining the need to proceed to a surgical airway.

Recommendation: An attempt should be made to rescue the airway with a supraglottic airway device early in the management of CICV, before proceeding to an emergency surgical airway. The supraglottic airway device used should be that most likely to be readily inserted and most likely to enable ventilation of the patient.

Direct tracheal access

Recommendation: All anaesthetists must be trained in emergency cricothyroidotomy and keep their skills up to date.

Recommendation: Surgical cricothyroidotomy should be taught alongside cannula cricothyroidotomy, including to anaesthetists.

Recommendation: Further research focused at identifying the success rates and optimal techniques of cannula cricothyroidotomy is required.

Behaviour

Recommendation: Anaesthetists should understand that the decision to perform an emergency surgical airway is commonly inappropriately delayed. The importance of early, clear decision-making should be highlighted during training in cricothyroidotomy.

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Headline

In cases reported to NAP₄, failure of fibreoptic intubation occurred under local anaesthesia, under general anaesthesia, and when being used as an attempted rescue technique through a supraglottic airway. Reasons for failure included inability to view landmarks, airway obstruction, loss of patient co-operation, bleeding and tracheal tube impingement during railroading. The review panel and the LRs identified over-sedation as a significant problem area leading to failed fibreoptic intubation.

More important in terms of harm to patients however, was failure to consider or to employ awake fibreoptic intubation when clinically indicated and this group formed the largest cohort of cases included in this chapter.

The cases reviewed in NAP₄ suggest that as a profession we need to decrease our threshold for considering awake fibreoptic intubation as a first choice for difficult airway management. If it is not possible for all anaesthetists to maintain sufficient skill levels in this area then attention should be given to departmental solutions to ensure the technique is available to deal with challenging airway cases whenever they may present.

What we already know

The first flexible fibreoptic guided tracheal intubation was described by Dr Peter Murphy in 1967 using a flexible choledochoscope.¹ Its significance to airway management was rapidly appreciated by the anaesthetic community and the first reports of awake fibreoptic intubation (AFOI) soon followed.² Difficulty with tracheal intubation or mask ventilation can be anticipated in the presence of a number of anatomical or pathological factors including large tongue, small mandibular space and restricted atlanto-occipital extension.³ Patients with such conditions retain the ability to breathe when awake but when anaesthesia is induced airway obstruction and loss of protective reflexes can become a life-threatening problem; where possible this should be avoided until the airway has been secured. When tracheal intubation is performed under local anaesthesia spontaneous ventilation and oxygenation is preserved and if awake tracheal intubation fails the patient remains in control of their airway. Intubation attempts can be abandoned but all other airway management options remain open. For these reasons the use of the flexible

fibreoptic endoscope (fibrescope) for awake intubation has revolutionised the management of the patient with an anticipated difficult airway.⁴ Fibrescopes offer unique advantages for awake intubation; their flexibility allows continuous visualisation of the airway, the working channel allows administration of local anaesthetic and the position of a tracheal tube can be checked instantaneously. Fibrescopes have other roles and in particular may be used to examine the patency and placement of airway devices or tracheal tubes placed by other means.

Although AFOI can be safely performed in a fully 'awake' patient after meticulous local anaesthesia alone, sedation is widely used since this improves the acceptability of the procedure. The experience of the operator is of paramount importance, as inadequate local anaesthesia, or inappropriate sedation, can lead to failures. Other factors that reduce success include the presence of blood or secretions in the airway, or obstruction to the passage of a tracheal tube by anatomical structures. Effective local anaesthesia requires attention to detail and several local anaesthetic techniques are available.^{5,6} Sedation should be closely monitored and unless very light levels of sedation are used this is ideally done by an anaesthetist other than the operator. The patient must be co-operative and breathing adequately throughout the procedure, otherwise the advantages of the technique are lost. Practitioners favour various techniques but if the patient has reduced respiratory reserve endoscopy should generally be performed with the patient in the sitting position. Contaminants within the airway such as sloughed mucosa or sputum should be cleared by physical means (e.g. coughing, irrigation and suction) before starting the procedure. Pre-treatment with an anti-cholinergic agent reduces the volume of secretions and increases the effectiveness of topically applied local anaesthetic agents. Bleeding is likely reduced by topical vasoconstrictors if the nasal route is used and by a gentle endoscopy and intubation technique. Failures still occur due to difficulties in performing endoscopy or in railroading the tracheal tube, this applies particularly to nasotracheal intubation. In a recent study the nasal route was associated with 10% failure, half of these failures were due to inability to insert the tracheal tube after successful passage of a fibrescope.⁷ The factors influencing obstruction to tracheal tube insertion and methods to avoid or overcome them



have been extensively reviewed⁸ but the selection of small tracheal tubes and rotation during insertion will overcome most problems.

Patients with tracheal or laryngeal pathology such as tumours or oedema, including those presenting with stridor, are at risk of total airway obstruction and the role of AFOI in these patients is debatable.⁹ If the patient is in extremis with hypoxia and respiratory failure, the application of local anaesthetic, or the insertion of a fibrescope into an inadequately anaesthetised airway can precipitate coughing or total airway obstruction.^{9,10} If airway obstruction develops during AFOI the intended safety of this approach is lost and the patient may require urgent airway rescue. For this reason, in patients with severe airway obstruction it has been recommended to induce general anaesthesia after thorough pre-oxygenation in an operating theatre with a surgeon and theatre team scrubbed and standing by.¹¹ An emergency surgical airway can then be performed immediately on an already unconscious patient should direct laryngoscopy fail. Proponents of fibreoptic endoscopy argue that with careful topical anaesthesia and either no, or minimal sedation it is possible to perform a nasendoscopy first, allowing an atraumatic assessment of the upper airway and visualisation of the larynx to gauge whether it is safe to proceed with awake tracheal intubation, or better to stop and allow the surgeon to perform a tracheostomy under local anaesthesia.¹²

Fibreoptic intubation (FOI) can also be performed under general anaesthesia, but loss of muscle tone leads to airway obstruction which makes airway endoscopy much more difficult. Flexible airway endoscopy is only possible in a cavity: if the cavity is obliterated tissues make contact with the tip of the instrument, with the result that light from the light source is reflected directly back into the distal lens of the fibrescope producing a 'white out' with no discernable view. Under these circumstances attempts at endoscopy often produce trauma and bleeding and since structures are unidentifiable it becomes a blind procedure. If airway patency can be restored (e.g. by tongue traction or jaw thrust or use of adjuncts such as airway guides) then endoscopy is usually possible.

Supraglottic airway devices (SADs) have a proven record of providing rescue ventilation when mask ventilation and tracheal intubation have failed. If a SAD is providing an effective means of airway maintenance FOI may be possible through the SAD which acts as a conduit for the fibrescope and tracheal tube. This technique requires minimal knowledge of airway endoscopic anatomy and can often be performed by those with relatively limited experience (so called 'low-skill fibreoptic intubation'). This technique is recommended in the Difficult Airway Society (DAS) guidelines on the management of unexpected difficulty with tracheal intubation.¹³ The use of an Aintree



intubation catheter (AIC) passed over a fibrescope is a useful refinement to this technique.¹⁴ Once placed above the carina the AIC is left in the trachea to act as a guide for intubation after the fibrescope and SAD have been removed. This method requires some familiarity with the equipment but is well suited to practice in workshops before clinical use. As with any technique success is not guaranteed and caution should be exercised. Persistent attempts at intubation may lead to clinical deterioration and a situation where ventilation, which was previously possible, fails.

Review of cases

The largest group of cases identified were those in which fibreoptic intubation had not been used where there were strong clinical indications for its use. Other identified themes are described below.

Failure to use awake fibreoptic intubation.

There were 18 patients in whom AFOI might have offered advantages over airway management under general anaesthesia. These patients showed clinical features suggesting potential difficulty with mask ventilation and tracheal intubation. In none was co-operation considered to be a problem. A middle-aged man required a lower limb procedure, the documented airway assessment was poor but reduced cervical spine mobility was recorded and the patient was known to be difficult to intubate by direct laryngoscopy. General anaesthesia was induced and the airway maintained by a SAD. Fibreoptic intubation

through the SAD was not attempted and later during the operation this was displaced or became obstructed. SAD adjustment and facemask ventilation failed to restore effective oxygenation and direct laryngoscopy provided no view of the larynx. The patient suffered a hypoxic cardiac arrest. FOI at this time failed. After multiple attempts at tracheal intubation this was achieved using a blind technique. The patient could not be resuscitated. In another report a patient with ankylosing spondylitis was recognised to have a potentially difficult airway prior to an emergency laparotomy for intestinal obstruction. A rapid sequence induction intubation failed, an i-gel was inserted but fibreoptic endoscopy through the i-gel failed. No decision to awaken the patient was taken and after a period of an hour further attempts at tracheal intubation were abandoned. The operation was performed with the i-gel in place. The patient was admitted to ICU postoperatively for monitoring of airway swelling and made a full recovery. A third patient, with a high Mallampati class airway and impaired neck mobility required cervical spine surgery for a traumatic injury. An MRI of the neck had been performed but was not viewed by the anaesthetist. The patient was fully pre-oxygenated and anaesthesia was induced with propofol and remifentanyl by infusion without muscle relaxation, mask ventilation was not possible and a disposable laryngeal mask was inserted. Ventilation was inadequate both via the laryngeal mask and with two-person bag facemask ventilation and jaw thrust. Direct laryngoscopy was difficult, airway oedema was noted and the patient was intubated at the third attempt with a McCoy blade and a bougie. Postoperatively the patient was admitted to the ICU for management of airway swelling.

Case 1

A middle-aged ASA 2 patient with obstructive sleep apnoea and a BMI of 35 kg.m⁻² required a total thyroidectomy. The patient had limited cervical spine mobility, tracheal deviation and it was noted that a surgical airway would be difficult. A spontaneously breathing general anaesthetic was performed using propofol and remifentanyl. Direct laryngoscopy showed a grade 3 view and during repositioning complete airway obstruction followed with inability to mask ventilate despite six-handed ventilation. Several unsuccessful attempts at needle cricothyroidotomy, both fine and large bore, were made and the airway was finally secured after a difficult tracheostomy. The patient spent 20 minutes with oxygen saturations of less than 50% and received elective ventilation to manage cerebral hypoxia. A full recovery was reported.

Failed awake fibreoptic intubation

There were 15 reports in which AFOI was unsuccessful. Airway obstruction or apnoea was widely reported in association with failure of AFOI, as were lack of patient co-operation, inability to recognise appropriate airway anatomy, anatomical distortion and airway contamination

by blood, debris or secretions. In most of these cases it was not possible to locate the larynx with the fibrescope, however in two patients, both during nasotracheal intubation, the trachea was visualised but the tracheal tube could not be passed. In one of these cases profuse bleeding developed and the procedure was abandoned in favour of general anaesthesia, airway obstruction then followed and the patient underwent an emergency cricothyroidotomy. In the second case tracheal tube insertion was not possible with the patient awake and it was assumed that it would pass after induction of general anaesthesia. However, once anaesthetised the tracheal tube would not advance, the patient then regurgitated and an immediate surgical tracheostomy was performed.

Case 2

An elderly patient anticipated to be difficult to mask ventilate and intubate was scheduled for an urgent tracheostomy for a rapidly enlarging base of tongue tumour. Topical anaesthesia of the upper airway was achieved and sedation provided with propofol and remifentanyl target-controlled infusions. An 'awake' direct laryngoscopy by a trainee and further attempt with an Airtraq laryngoscope failed. Three further attempts with a flexible fibrescope failed with no recognisable anatomy seen and lumps of necrotic tissue contaminating the field of view. After several episodes of oxygen desaturation, intubation was abandoned and a rescue cricothyroid cannula was inserted followed by a tracheostomy performed under local anaesthesia.

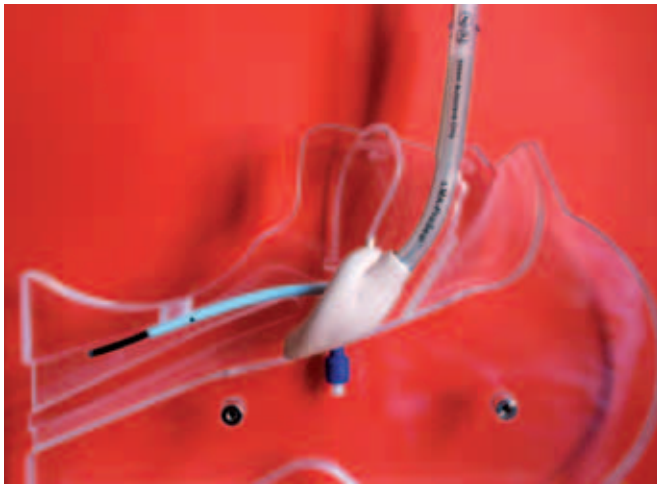
It is notable that in several challenging cases the initial decision was taken to perform AFOI but after nasendoscopy demonstrated contamination of the airway, difficulty achieving a view, or a severely narrowed airway fibreoptic intubation was abandoned in favour of a planned cricothyroidotomy or surgical tracheostomy.

Case 3

An obese patient with a supraglottic cyst, producing stridor, was scheduled for excision. Plan A was to perform AFOI in the sitting position. After topical anaesthesia of the upper airway and sedation with propofol and alfentanil, airway endoscopy revealed that there was no space to advance the fibrescope and plan B, cricothyroidotomy with a Quicktrach in the sitting position was activated. A thick and short neck made it impossible to use the Quicktrach percutaneously and surgical intervention by transverse incision and direct visualisation of the trachea was required to enable prompt insertion of the Quicktrach.

In one case, aspiration of gastric contents complicated an otherwise successful AFOI in a patient with intestinal obstruction. The patient regurgitated before the tracheal tube cuff was adequately inflated. This acts as a reminder that the intubation of an at-risk airway is not complete until it has been completely secured.





The Aintree intubation catheter aids fibreoptic intubation through SADs

Failed fibreoptic intubation under general anaesthesia

Fibreoptic intubation was attempted in seven patients after induction of general anaesthesia (with no SAD in place), either as the primary technique or when direct laryngoscopy had failed. All patients had evidence of anticipated airway difficulties, including some patients with head and neck malignancy. Problems similar to those reported previously during AFOI were noted and all seven patients required an emergency surgical airway.

Fibreoptic intubation via a supraglottic airway device

SADs were commonly used to provide a means of ventilation after failed intubation and in 13 cases the SAD was then used as a conduit for attempted FOI. This was successful in seven cases, in five of which an Aintree catheter was used as part of the technique. A good example of this was seen in the report of an obese middle-aged patient with a history of smoke inhalation who had been unexpectedly difficult to intubate; the anaesthetist inserted a laryngeal mask and then passed a fibroscope and AIC through it. A subglottic stenosis was identified and a small tracheal tube was passed over the AIC.

Although, as described above, fibroscope-guided intubation through a SAD is not always successful there were several potentially suitable cases where the technique was not even attempted. In one case a patient whose airway had been rescued with a SAD following failed tracheal intubation needed transfer to the ICU for postoperative ventilation. Tracheostomy was performed. The review panel judged that the surgical airway might have been avoided by fibreoptic intubation through the SAD. There were other examples where tracheostomy was performed to protect the airway of a patient with an SAD in place without apparent consideration of

fibreoptic intubation through the device. In some reports, in patients with known airway problems, a decision was made to use a SAD as the primary airway instead of tracheal intubation. In at least one of these, early endoscopy and intubation through the SAD might have prevented problems at a later stage.

Successful awake fibreoptic intubation.

In three cases AFOI was not 'the problem' leading to inclusion in NAP₄ but was the solution to the management of other complications that were the inclusion criteria.

Two patients who had undergone AFOI prior to surgery required re-intubation by AFOI with a degree of urgency at the end of anaesthesia or in recovery: one is described as Case 4. These difficult problems were managed with high levels of skill indicating the presence of local expertise with appropriate equipment and support.

One patient who was known to be difficult to intubate was scheduled for urgent laparotomy. After a rapid sequence induction laryngoscopy demonstrated no visible landmarks and ventilation by mask was difficult. An emergency cricothyroidotomy was performed to oxygenate the patient who was then awakened and intubated under fibreoptic guidance.

Case 4

An obese diabetic patient presenting with an anterior neck swelling and voice change was scheduled for incision and drainage of a neck abscess. AFOI was achieved without difficulty. At the end of surgery direct laryngoscopy was performed showing a grade 2 view. A leak around the deflated tracheal tube cuff was confirmed. The patient was extubated awake in the operating theatre with skilled staff in attendance and a fibroscope available in case of problems. Extubation was followed by immediate swelling of the tongue and airway obstruction. Although the patient was agitated an AFOI was quickly achieved, followed by evacuation of a haematoma, tracheostomy and ICU admission. The patient made a full recovery.

Confirmation of airway device placement

It became clear during the review process that the value of fibreoptic endoscopy to confirm airway device placement may not be as widely recognised as it should be. An ICU patient needed intubation and CPR in a remote location, where a capnograph was not available. Laryngoscopy and tracheal intubation were difficult and resuscitation was unsuccessful. A fibroscope was subsequently used to check the placement of the tracheal tube and identified oesophageal intubation.

In several other cases reported to NAP₄ the position of a tracheal tube, or its patency was questioned due to the observation of a flat trace on the capnograph. Unrecognised oesophageal intubations and cases of airway

obstruction by blood clots which led to patient harm could have been diagnosed if fibreoptic inspection had been used.

Fibreoptic airway inspection on ICU would also likely have accelerated the diagnosis of partially displaced or displaced tracheostomy tubes. In several cases there was diagnostic confusion but no endoscopic inspection was made and an emergency subsequently occurred when a tracheostomy tube became completely displaced (see Chapter 9.)

Numerical analysis

Fibreoptic endoscopy techniques were applied in all three areas of practice, during anaesthesia, in the ICU and in the emergency department.

Failure to attempt awake fibreoptic intubation

There were 18 cases where general anaesthesia followed by attempted tracheal intubation was used in which the LR or the review panel judged that awake fibreoptic intubation or awake nasendoscopy would have been a better technique. The vast majority of these patients were anaesthetised by consultants (15) during normal working hours. Half of the procedures were elective or scheduled.

Of these 18 patients, 16 could not be intubated and two suffered hypoxic cardiac arrest. Two patients died, 15 made a full recovery and the outcome of one was not reported. The review panel considered the airway management of these patients to have been good in one case, mixed in nine and poor in eight cases.

Awake fibreoptic intubation

AFOI was attempted in 15 patients, 13 for anaesthesia for surgery (seven failed) and two for airway management on ICU (both of which failed). One patient died.

AFOI performed for anaesthesia was performed by 12 consultants and one associate specialist. A variety of agents were used for sedation. Lidocaine was universally used as the topical local anaesthetic agent and an anticholinergic agent was given to all except two patients before the procedure. Of the patients in whom AFOI was attempted the airway management was assessed by the review panel as good in two, mixed in nine and poor in four.

Asleep fibreoptic intubation

Fibreoptic intubation under general anaesthesia was attempted in 20 cases, with seven successes and 13 failures. In 14 reports a SAD was used as a conduit for the fibrescope: with a 50% success rate. Of seven successes, five were performed via a laryngeal mask, one via a ProSeal LMA and one via an ILMA. Failure was most common with a classic or disposable laryngeal mask since these were the most frequently used rescue devices. All successful intubations performed through a laryngeal mask, (as

opposed to a ProSeal or an ILMA) used an AIC. Success rate when intubating via a SAD with the Aintree Intubation catheter was five of seven, and without it was two of seven. Four attempts were made during spontaneous ventilation and all failed.

Discussion

Awake fibreoptic intubation

AFOI is under utilised. Some patients will reject AFOI and others, particularly children, may be unable to co-operate: for this reason AFOI is not suitable for all cases where difficulty with facemask ventilation and tracheal intubation are anticipated. Fibreoptic intubation is a procedure which requires familiarity with the equipment and an understanding of airway endoscopic anatomy. AFOI also requires proficiency in providing effective local anaesthesia and sedation. The threshold for adopting AFOI depends to some extent on the competence and confidence of the person who will perform the intubation. It is likely some anaesthetists do not acquire the skills to perform the technique and it may be difficult for others to maintain them. Some reports contained evidence that the advice of colleagues was sought when problems arose. If it is not possible for all anaesthetists to maintain sufficient skill levels in this area then attention should be given to departmental solutions to ensure the technique is available to deal with challenging airway cases whenever they may present.

Intubation route

The nasal route is traditionally considered easier than the oral route for fibreoptic intubation but several problems were seen with fibreoptic nasotracheal intubation. In two cases AFOI failed despite visualising the larynx: one due to profuse nasal bleeding and one due to failed advancement after anaesthesia was induced. Both required emergency surgical airway. These two cases serve to act as a reminder that the airway is not secure until the tracheal tube is has been confirmed to be placed within the trachea and the cuff inflated. Safety may be compromised if general anaesthesia is induced in the expectation that it will be possible to pass the tracheal tube over the endoscope.

Sedation

Sedation may be used effectively to calm anxious patients sufficiently to make AFOI acceptable. Ideally sedation should be administered by another anaesthetist and its effects closely monitored. An awake, calm, alert patient will follow commands and can aid the intubator by taking deep breaths or protruding their tongue. Over-sedation increases the likelihood of airway obstruction which makes endoscopy more difficult and contributes to failure. Similarly apnoea occurs increasingly with deeper sedation bringing with it some of the same risks as intentional general anaesthesia.



Lack of patient co-operation, apnoea, and airway obstruction were widely reported complications of AFOI contributing to failure: the review panel and LR considered poorly managed sedation to be a factor in these cases. There were several reports of problems when remifentanyl was used in combination with other drugs for sedation. Problems noted during these events that may have been due to remifentanyl included respiratory depression, apnoea and delayed respiratory arrest. It was the impression of the review panel that remifentanyl was more likely than other sedatives to cause these types of events but this remains unclear.

Fibreoptic intubation under general anaesthesia

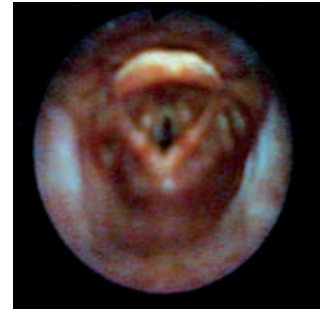
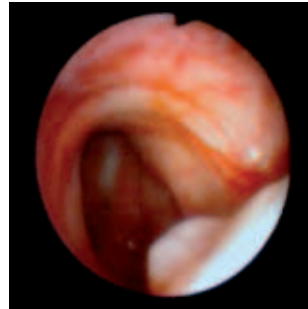
In skilled hands FOI under general anaesthesia can be very effective but it is technically more difficult than FOI in an awake co-operative patient and is therefore more likely to fail. It cannot be assumed that fibreoptic intubation after induction of general anaesthesia will be successful particularly in patients at risk of airway obstruction. Furthermore the back-up option of safely abandoning the procedure may not be feasible under general anaesthesia once the airway has been compromised.

Fibreoptic intubation through a SAD

Though there were several cases where SADs were effective as a conduit for FOI there were an equal number of failures. It was not clear from reports why this technique failed. It was stated that in some cases that the larynx could not be located, in others the tracheal tube would not pass through the airway device. It is possible that the anatomical features which necessitated SAD rescue in the first place may also have compromised intubation through it. The Aintree intubation catheter appears to be a useful aid to intubation through SADs with a notably higher success rate when it was used. A range of SADs were used, including single-use laryngeal masks, the classic laryngeal mask airway, the i-gel and the ILMA: it is likely that not all SADs are 'equal' in this respect, but clearly all may fail. It must be accepted that the nature of the reports notified to this project means a disproportionate number of failures are likely and these rates do not likely reflect routine use.

Nasendoscopy

The review panel considered that anaesthetists did not use nasendoscopy as a means of evaluating the airway as often as it was indicated. Though nasendoscopy is often performed by ENT staff, it can be performed or repeated quite quickly under topical local anaesthesia if the equipment is available. It was used to assess the airway before general anaesthesia in a few reports and these included cases where AFOI was (sensibly) abandoned in favour of a surgical airway under local anaesthetic, after nasendoscopy suggested a difficult endoscopy or the risk of complete occlusion of the airway by the fibrescope.



Nasendoscopy – passage of a fibrescope into the posterior nasopharynx is used to assess the airway.

Confirmation of tracheal tube placement

The usefulness of an endoscope for confirmation of tracheal tube position should be emphasised. In several reports to NAP₄, in high stress situations the absence of exhaled carbon dioxide on the capnograph trace was attributed to an absent cardiac output, bronchospasm or anaphylaxis. In some cases the tracheal tube was in the oesophagus and in others ventilation was prevented by blood clot or bronchospasm (see Chapters 12 and 21).

There is natural reluctance to remove a tracheal tube if placement has been difficult but if the decision is taken to ignore capnographic evidence of absent ventilation, endoscopy of the tracheal tube should be used to confirm tracheal placement. A facemask placed over the nose, mouth and tracheal tube should be considered for ventilation until endoscopy has resolved the diagnostic problem.

Overview

The cases reviewed in this project included a significant number in which fibreoptic intubation failed either by direct routes or when performed via a SAD. There were also cases of successful rescue of the airway with fibreoptic intubation. However the most important finding is the number of cases in which fibreoptic intubation (either AFOI or rescue FOI via a SAD or fibreoptic inspection to aid diagnosis) was omitted when indicated and harm occurred as a result. Thus harm appeared considerably more frequent in this cohort of patients from failure to use fibreoptic techniques than from problems during such procedures.

Learning points and recommendations

There were many cases when the review panel (and reporters) considered AFOI was an obvious solution to a difficult airway. This was not used and predictable complications arose.

AFOI was used successfully in some particularly difficult circumstances for both primary intubation and re-intubation. Of note these cases showed evidence of considerable operator experience and ready availability of necessary equipment and skilled assistance.

AFOI failed due to a number of factors including poor co-operation, inappropriate sedation, bleeding, inability to identify anatomy and airway obstruction. To put this in context NAP₄ focuses on patient with complications and successful uses of AFOI would not be reported to this project.

Respiratory depression, apnoea and delayed respiratory arrest complicated sedation. It was the impression of the review panel that remifentanyl was more likely than other sedatives to cause these types of events but this remains unclear.

Difficulty in railroading a tube after successful endoscopy is a recognised cause of failed AFOI and complications arising from such cases were reported to this project. This was a particular problem with use of the nasal route and consideration should more frequently be given to an oral approach.

Supraglottic devices when used for rescue ventilation can be used as a conduit for fibreoptic intubation but despite adequate ventilation intubation attempts may not always be successful. Use of an Aintree Intubation Catheter increases success rates in this cohort.

General anaesthesia worsens airway obstruction and fibreoptic intubation after induction of general anaesthesia will not always be successful in patients in whom an AFOI is indicated.

Recommendation: All anaesthetic departments should provide a service where the skills and equipment are available to deliver awake fibreoptic intubation whenever it is indicated.

Recommendation: Where FOI is considered the optimal method of securing the airway, an awake technique should be considered unless contraindicated.

Recommendation: Fibreoptic intubation is most effective in co-operative patients. Airway patency and co-operation may be lost by over-sedation. Where complex sedation techniques are to be used strong consideration should be given to delegating the provision of sedation to an anaesthetist not performing the tracheal intubation.

Recommendation: Following awake fibreoptic intubation, general anaesthesia should only be induced after the tracheal tube has been railroaded, its position checked and the cuff inflated to seal the airway.

Recommendation: AFOI may fail. A back-up plan should always be worked out in advance

Recommendation: Oral fibreoptic intubation should be taught and practised alongside nasal fibreoptic intubation so that it can be considered in patients in whom nasotracheal intubation is not specifically indicated.

Recommendation: All anaesthetists should be trained in low-skill rescue intubation through a supraglottic airway. A technique using the Aintree Intubation Catheter is recommended.

Recommendation: Fibreoptic endoscopy should be immediately available to confirm airway device placement in situations where capnography may be misinterpreted.

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Headline

Critical incidents can occur during the initial placement of a tracheostomy, during the care of patients with a pre-existing tracheostomy, or as a consequence of having a tracheostomy. Many patients have tracheostomies performed and managed on intensive care units (ICUs) so this chapter should be read in conjunction with the ICU chapter (Chapter 9).

There were two reports of difficulty in insertion of tracheostomy, with one death. Capnography did not appear to be used during the performance of this tracheostomy.

Displacement of tracheostomies led to several deaths. Tracheostomies were often displaced on movement or during routine care. Continuous capnography was rarely used. The method of fixation of tracheostomies was not consistent. Often, patients whose tracheostomies became displaced were obese, leading to the inference that tracheostomy tubes are not always long enough or of appropriate design for these patients' anatomy. When patients were accidentally decannulated there was an evident lack of a systematic approach, highlighting the importance of having an extubation plan and of training and education of all staff in attending these patients.

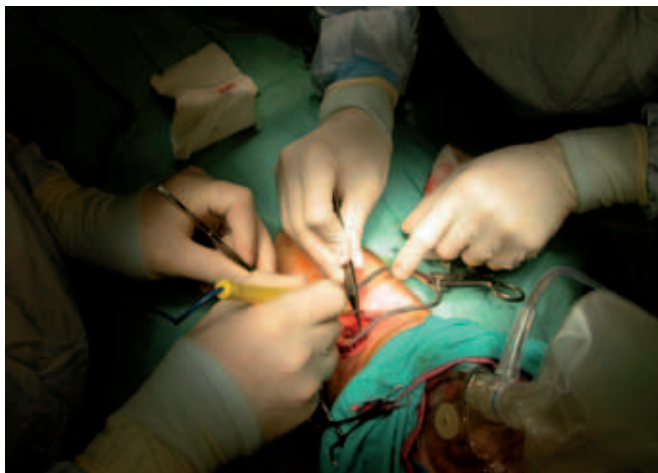
Tracheal stenosis after tracheostomy decannulation provided challenges when patients need re-intubation, requiring team working between anaesthetists and/or intensivists and ENT surgeons.

What we already know

Tracheostomies are inserted electively during, for example, laryngectomy, in patients in whom major airway swelling is anticipated, or to facilitate weaning from mechanical ventilation. They are also inserted in emergency situations, either to rescue a critically compromised airway, e.g. secondary to tumour, or as part of an airway rescue procedure in the 'can't intubate, can't ventilate' (CICV) situation. There were 75 cases reported to NAP₄ of emergency surgical access for airway rescue; most of these are dealt with in the 'can't intubate, can't ventilate' chapter (Chapter 13).

A substantial minority of patients in ICUs have tracheostomies placed and on the day of the EPIC survey 16% of UK ICU patients had a tracheostomy.¹ In ICU intensivists perform the majority of these tracheostomies when placed to aid weaning from mechanical ventilation. In one survey, 97% of responding units performed some type of percutaneous technique for tracheostomy placement.² Rates of complications for both surgical and percutaneous tracheostomies are reported to be as high as 5% during insertion, and include displacement, bleeding, pneumothorax and, later, infection. However, systematic reports of the rates and consequences of these complications are lacking, and what meta-analyses there are in the literature, have conflicting conclusions.^{3,4} Similarly, there are reports in the literature comparing the incidence of tracheal stenosis after surgical and percutaneous tracheostomies but these are sometimes contradictory and patient numbers are generally small. The true incidence of clinically significant stenosis after tracheostomy, however performed, is unclear.

The incidence of complications from tracheostomy in obese patients is greater than those with normal body habitus. El Sohl and Jaafar⁵ found that life-threatening complications were attributed to tube obstruction and extra-tracheal positioning of the tracheostomy after becoming dislodged; morbid obesity was associated with an increased risk of tracheostomy-related complications with an odds ratio of 4.4 (95% CI 2.1–11.7). Mallick and colleagues⁶ studied 50 non-obese patients undergoing percutaneous tracheostomy: they found that standard-length tracheostomy tubes commonly used in the UK were often too short even for patients with normal anatomy, and that the angle between the part of the tracheostomy which





would sit in the stoma and the length which would sit in the trachea varied between manufacturers (see Table on page 124). The authors recommended that tubes be redesigned to increase both stomal and intra-tracheal lengths and that tracheostomies should be formed with an angle between intra-stomal and intra-tracheal sections of 110–120°.

In a survey of UK intensive care units conducted in 2004, 85% of respondents were aware of clinically significant incidents of blocked tracheostomies, more than half of which occurred in normal ward areas, i.e. after discharge from ICU. Few of these events were formally reported as critical incidents.⁷ McGrath and Thomas⁸ examined critical incidents related to airway events from ICUs as reported to the National Patient Safety Agency over a two-year period (2005–07): there were 453 incidents where patients were directly affected, 338 that led to harm and 15 that may have contributed to death. Of these 453 incidents, 276 (60%) involved tracheostomies becoming blocked or displaced.

The NAP₄ census identified that approximately one in 300 anaesthetics in the UK is delivered via a tracheostomy.⁹ A recent analysis of litigation in the UK related to airway events during anaesthesia identified that a disproportionate number of cases involved tracheostomy, at least one in ten of all cases and one fifth of cases of airway trauma.¹⁰

In theatre and during anaesthesia, continuous capnography is a minimal monitoring requirement for patients with artificial airways. However, in the ICU and on the wards, capnography is rarely used for such patients, for reasons of cost, of monitor malfunction due to blockage with water or airway secretions and of culture. In one survey of 169 intensive care units in the UK, only 35% of units used capnography for monitoring at any stage, and only 22% used continuous capnography for patients with intracranial pressure monitoring devices in place. Capnography was not used during 27% of tracheal intubations and 53% of tracheostomy insertion procedures. Only 55% of units responding had facilities to monitor end-tidal carbon dioxide at all bedspaces.¹¹

In view of the available evidence of the 'high-risk' nature of the tracheostomy as an airway, one might anticipate that well-established protocols are available for monitoring and management of complications of their use. A survey of ICUs in the northwest of England showed that only two of 16 units had tracheostomy guidelines for trainees and nurses to refer to.¹² In 2006, Mace et al found that of 103 NHS trusts providing a tracheostomy service in the UK, 14.6% had no tracheostomy care policy, only 31% had a dedicated tracheostomy care team and only 12.5% had ENT input to tracheostomy care.¹³ The northwest group has set up a website to help address this, www.tracheostomy.org.uk, which provides educational advice and algorithms for emergency airway management.

Case review

Cases reported to the project can be divided into three areas – problems during the insertion of a tracheostomy, problems during the care of a patient with a tracheostomy and problems encountered as a sequela of having had a tracheostomy.

Problems during tracheostomy insertion

There were two cases of significant brain damage after failure to insert a tracheostomy that was planned and performed to assist weaning from mechanical ventilation. One occurred during a percutaneous tracheostomy when the tracheostomy tube went into a false passage; it was not clear whether capnography was in use during the procedure or not, or whether a bronchoscope was used to confirm position. In the other, a surgical tracheostomy was being carried out by a non-ENT surgical registrar who was used to performing tracheostomies but who was unable to insert a tube despite multiple attempts. Reintubation was not attempted, nor was transtracheal jet ventilation.

There were cases when a tracheostomy was inserted because the patient had a difficult airway that could not be managed by intubation. These patients were reported



to the NAP₄ project because they had unplanned surgical airways or had an unplanned admission to ICU. In some cases there was careful planning and tracheostomy was performed as part of an accelerating plan of airway intervention. However in other cases, insertion of the tracheostomy was not part of the initial plan and equipment was not immediately available or a plan 'B' was not evident. Many of these cases are discussed in the 'can't intubate, can't ventilate' (Chapter 13).

Lesser degrees of harm occurring during formation of tracheostomy were also reported.

Case 1

A young patient with previous airway trauma pulled out his tracheostomy at home. It was not possible to insert a small tracheal tube through the stoma, so a Cook airway exchange catheter was inserted and the patient transferred to theatre. The patient developed bilateral tension pneumothoraces and surgical emphysema after a test Manujet ventilation, despite using pressures in the lowest range; the patient was hypoxic for some minutes but recovered after placement of bilateral chest drains and performance of a surgical tracheostomy.

Case 2

A patient developed extensive surgical emphysema after two high-pressure inflations through a cricothyroidotomy; the patient required an emergency surgical tracheostomy due to complete airway obstruction from surgical emphysema combined with thyroid cancer, which had already led to critical airway narrowing.

Tracheostomy on the intensive care unit is a routine procedure and may on occasion be required urgently and out of hours. The necessary equipment should be available and the personnel with appropriate skills should be able to attend in a short period of time. Suitable monitoring including capnography and bronchoscopic observation of the procedure from within the airway should be regarded as standards of care as they will reduce the risk of tube misplacement. Good communication and team working is vital to the successful performance of a tracheostomy and this is particularly so when it forms part of management of a difficult airway. Case 3 is an example of this good teamwork.

Case 3

A child had inhaled a foreign body and was transferred to another hospital for further management. The foreign body could not be retrieved until, after two hours, a decision to form a tracheostomy was made. There was an acute fall in oxygen saturation as the surgeons were scrubbing to perform the procedure so an emergency tracheostomy was performed, which was then converted to a formal tracheostomy. The foreign body was removed through a rigid bronchoscope. The child was decannulated two days later.

Less frequently patients will be admitted to the emergency department and require an emergency surgical airway. An emergency tracheostomy may be one of the options but again, outside the operating theatre requires good teamwork, communication and surgical skill: case 4 is an example.

Case 4

A patient with a history of carcinoma of the larynx presented to the emergency department in a peri-arrest state with post-radiation stridor. A senior ENT specialist registrar attended promptly and performed fiberoptic nasendoscopy, which showed no glottic gap so intubation was not attempted. Insertion of a minitracheostomy was not successful and the patient went on to have an emergency percutaneous tracheostomy by the ENT SpR. The patient was admitted to the ICU and the tracheostomy was found subsequently to be in the cricothyroid space. He was referred to a tertiary centre for ongoing care.

The high rate of failure of cannula cricothyroidotomy identified elsewhere in this report (see Chapters 6, 9, 10 and 13) should remind clinicians of the greater importance of both surgical cricothyroidotomy and emergency tracheostomy as airway rescue techniques.

Problems during care of the patient with a tracheostomy

The most common, and most commonly lethal, problem was displacement of the tracheostomy, especially on movement or in the obese patient, or both. None of these patients appeared to have capnography and this frequently led to delays in recognition of the displacement, sometimes to the point of cardiac arrest.

Several cases indicated problems with the length of standard tracheostomies in obese patients. Case 5 describes how in one obese patient, changing an adjustable-flange tracheostomy tube to a more conventional tracheostomy with an inner lumen led to its displacement and near death. In another patient, a size 6.0mm ID tracheostomy tube was placed during an emergency tracheostomy procedure; the tube subsequently dislodged on attempted placement of a nasogastric tube. These cases illustrate how a tracheostomy may not be long enough for a patient's anatomy, either because the patient is large or the tube small. The Table shows the length of commonly used tracheostomy tubes, showing that tubes with an inner lumen and smaller diameter tubes are significantly shorter than adjustable-flange tubes.

Case 5

An obese patient on ICU after major surgery had a surgical tracheostomy with an adjustable flange tracheostomy tube inserted. Ten days later, the tracheostomy was changed for a conventional tracheostomy with an inner tube. In the early hours of the morning, after suctioning the patient and reconnecting to the ventilator, the ventilator alarm indicated high airway pressures. Nurses caring for the patient attempted to manually ventilate, but it was very difficult and oxygen saturations fell. The doctor attended and observed that the patient was breathing around the tracheostomy and that the reservoir bag was moving but determined that the patient needed a definitive airway. The doctor administered propofol and suxamethonium but could not visualise or intubate the larynx. Attempted bag-mask ventilation was unsuccessful. The patient desaturated further, became bradycardic and suffered a cardiac arrest. Fortunately, ventilation then became possible through the tracheostomy tube and the consultant arrived. The tracheostomy tube was changed over a bougie, and holding the tube in place, enabled a return to theatre where the tracheostomy was refashioned.

Table 1 Lengths and angles of commonly used tracheostomy tubes. Angle refers to the angle between the stomal and tracheal parts of the tube.

Make	Size (internal diameter, ID) (mm)	External diameter (OD) (mm)	Length (mm)	Angle (degrees)
Portex Blue Line	6	8.3	55	90
	8	11	82	90
	9	12.4	87	90
Portex adjustable-flange	9	12.4	135	
Shiley dual lumen	6 (6.4)	10.8	74	135
	8 (7.6)	12.2	79	135
	10 (8.9)	13.8	79	135
Shiley Extended Length	6	8.3	95	135
	8	13.3	105	135
Tracoe twist	8	11.4	74	140
Rusch tracoe flex	8	11.4	88	90
Rusch extra length	8	11.4	128-138	90

Tracheostomy displacement occurred most commonly either on moving the patient or performing airway manoeuvres such as suctioning: cases 6–11 are illustrative.

Case 6

An ICU patient whose tracheostomy was secured with Velcro ties was being turned when the ventilator alarmed and the patient developed surgical emphysema. A difficult oral intubation resulted in high airway pressures, but capnography was not available to confirm correct placement of the tracheal tube and it was removed. A laryngeal mask airway did not enable ventilation, attempted tracheostomy replacement was unsuccessful and the patient, although ultimately intubated, died. In this case, airway equipment considered desirable by the reporter including ProSeal LMA and intubating LMA were not available.

Case 7

An obese patient had a difficult emergency tracheostomy placed by an ENT surgeon to manage supraglottic airway obstruction. While on ICU, during turning in the middle of the night the tracheostomy became displaced. Capnography was not in use. Surgical emphysema developed, and the patient could not be intubated or ventilated by the attending registrar. The ENT and ICU consultants arrived promptly and managed to replace the tracheostomy over a bougie at second attempt. The patient suffered hypoxic brain injury.

Case 8

An awake morbidly obese patient (BMI 45 kg.m⁻²) with a tracheostomy, secured with sutures and ties, developed respiratory distress after moving off a bedpan in the middle of the night while on ICU. Capnography was not in use. Recognition of tracheostomy displacement was delayed and the patient became agitated and hypoxaemic. Surgical emphysema developed when attempting to ventilate through the tracheostomy. The patient had complex facial fractures, which made bag-mask ventilation and intubation difficult. The tracheostomy could not be replaced using either a bougie or fibreoptic bronchoscope. It was removed, with difficulty because of the sutures, a bougie passed into the stoma and a tracheal tube placed. During the event, the patient aspirated and ICU stay was prolonged.

Percutaneous Tracheostomy in ICU



A = Fibrescope control
B = Continuous vital signs monitoring
C = Continuous capnography

Complex airway management in the middle of the night can be fraught. The airway knowledge and experience of medical staff attending in these circumstances is now very variable due to changes in medical staffing of ICUs. To some degree problems may have been avoided by identification of patients likely to be problematic and the pre-formulation of a strategy to manage such an event. In some cases, in addition to poor knowledge or use of protocols, poor team behaviour was judged to have contributed to a poor outcome.

Case 9

In the early hours on ICU, an obese patient with a tracheostomy was turned and became 'impossible to ventilate'. The patient rapidly developed surgical emphysema, and bag-mask ventilation was unsuccessful. The tracheostomy had been performed less than four days previously; a fiberoptic bronchoscope was not available to attempt reinsertion. Attempted oral intubation resulted in oesophageal intubation; there was no capnography in place. Airway rescue with a supraglottic airway device or cricothyroidotomy was not attempted.

Case 10

An obese patient with airway obstruction due to an oropharyngeal abscess had an emergency tracheostomy. The tracheostomy was sutured in place. Forty-eight hours later, early in the working day, two junior trainees were on ICU when the tracheostomy became obstructed. Bag-mask ventilation through the tracheostomy was initially partially successful, but then became impossible. The doctors attempted to re-insert the tracheostomy by passing a suction catheter down the tracheostomy and when that failed, attempted to bypass the tracheostomy with a wide bore cannula. They did not attempt oral intubation. The consultant intubated the patient with difficulty after 30 minutes, however the patient had two cardiac arrests and a pneumothorax, did not recover neurologically and died five days later.

**Case 11**

A patient on ICU with a cervical spine injury who was ventilator-dependent requested that sutures securing a tracheostomy in place be removed. The tracheostomy subsequently became dislodged but this was initially unrecognised. Capnography was not in place and the patient suffered a cardiac arrest and died.

Tracheostomy displacement occurred with all types of devices used to secure the tube in place. It is likely that displacement on ICU is unavoidable. It was not possible to identify whether the absence of stay sutures (sutures inserted into the lower part of the tracheal stoma that when pulled aid in re-identifying the stoma) played any role in causing the reported events but few had them. On ICU failure to use rescue techniques that would be used in anaesthesia (oro-tracheal intubation, supraglottic airway device insertion) was regularly identified. While effort should be made to minimise the risk of displacement the greatest benefit will likely come from early detection (nursing awareness, use of capnography) and prompt management of displacement (SOPs and protocols that trainees are familiar with and for which the necessary equipment and skills are available).

The need for protocols to manage predictable events, for identification of patients with particular difficulty and for immediate access to appropriate equipment and skilled staff are discussed in more detail in Chapter 9.

Late complications

Patients who have had a tracheostomy in the past may develop late complications. These include infection, haemorrhage, and tracheal stenosis or tracheomalacia.

There were no reports to the project of airway complications related to infection. There were two reports of haemorrhage. One occurred when a percutaneous tracheostomy inserted for the purposes of weaning from mechanical ventilation was removed 24 hours after insertion. The patient immediately lost more than a litre of blood and sustained hypoxia secondary to aspiration. The tracheostomy was reformed and the patient recovered without the source of bleeding being discovered.

Patients with previous tracheostomy may be difficult to intubate due to either stenosis, tethering of the airway to the tracheostomy scar or, very rarely, tracheomalacia. Such problems should be anticipated and planned for in patients with previous tracheostomy.

Case 12

A patient who had a previous surgical tracheostomy while recovering from severe ARDS developed progressive stridor, several weeks after it had been removed. A CT scan of the neck led to a diagnosis of tracheomalacia and airway collapse. The patient's symptoms were relieved with heliox. The patient was transferred to the ICU and then deteriorated because of copious secretions and coughing so that re-intubation was required urgently. This was expected to be straightforward but staff and equipment were assembled in case of difficulty. A rapid sequence induction was performed but despite a grade 1 laryngeal view a fixed, 'solid' stenosis prevented intubation. Bag and mask ventilation was impossible. The tracheostomy scar was opened to pass a wire but a cricothyroidotomy device did not pass through the stricture. Eventually a mini-tracheostomy wire was manipulated past the stricture and a mini-tracheostomy railroaded successfully. The patient was ventilated for some hours through the device before being taken to theatre for surgical tracheostomy.

Numerical analysis

There were 75 cases of unplanned emergency surgical airway access reported to NAP4. Most are dealt with in the 'can't intubate, can't ventilate' chapter (Chapter 13).

Two ICU patients had adverse outcomes because of failure to place a tracheostomy successfully. Capnography was not used in one of these cases. A further patient had an emergency tracheostomy that was placed in the cricothyroid space.

There were two cases of significant haemorrhage, one on tracheostomy insertion, one on removal of a tracheostomy placed 24 hours previously.

There were 14 cases of accidental dislodgement of tracheostomies reported, all in the intensive care unit, with seven patient deaths (50%) and four patients left with hypoxic brain injury. In two-thirds of these cases, dislodgement occurred on turning or moving the patient. Half of the patients were obese (BMI >30 kg m⁻²). The use of capnography was not recorded in any of these cases. A plan for the management of tracheostomy displacement was clearly lacking in at least six of these cases. Most of these cases occurred outside normal working hours.

In at least two obese patients, tracheostomy dislodgement occurred because tracheostomy tubes may have been too short or ill-designed for the patient's anatomy. The method of fixation of tracheostomy tubes was not specified in a sufficient number of cases to comment specifically, but tracheostomy tubes become displaced even when both sutures and ties are used to secure them.

Of the 25 cases directly examining tracheostomy-specific problems, there were ultimately 12 deaths. Education and training contributed to the airway event in 13 of the

25 cases, and was a positive feature in one. Judgement was questioned in 19 cases and in four was felt to be good. Lack of equipment was assessed to be contributory in 18 cases, and made a positive contribution in two. Organisation and strategic factors figured negatively in nine cases and were positive in a further five. Difficult patients make difficult cases, and it was felt that 19 of these patients presented identifiable management difficulties, most frequently obesity.

Comment

Many of the cases discussed here are cross-referenced in the Chapter 9.

The themes emerging in this chapter have considerable overlap with those in the ICU chapter and highlight many common themes in the management of adverse airway incidents:

- 1 Staff:** Problems with tracheostomy tubes present whatever the hour or the doctor available to deal with them. However, because of the potential complexity of the airway problem, the patient needs an individual with advanced airways skills to deal with the issue. This is not always immediately available and may contribute to patient harm.
- 2 Patient:** Obese patients appear to suffer disproportionately more airway misadventures related to tracheostomy than the non-obese patients, and the outcomes of these events in obese patients are more adverse. In addition, patients with airway pathology (e.g. oropharyngeal tumours or obstruction) are also over-represented in this group of patients. Again, it is important that personnel with appropriate skills are available to deal with their airway problems.
- 3 Procedures and protocols:** Tracheostomy displacement occurs, especially in obese patients, and especially on patient movement or with interventions in the patient's airway, e.g. nasogastric tube insertion. Standardised operating procedures must be available and understood when airway difficulty arises.

Capnography

Of the cases of inadvertent tracheostomy tube displacement, capnography was not reported in any case. It is almost inevitable that this led to delays in recognition of tracheostomy blockage and of tracheostomy displacement. Use of capnography is the standard of care for ventilated patients in the operating theatre and it is difficult to justify a lesser standard for patients who are intubated and ventilated in ICU.

Transfers/movement

Patients who suffered displacement of tracheostomies in the ICU most frequently suffered these events on movement or on manipulation of the airway.



Obesity

Patient factors, most frequently obesity, were felt to be a significant factor in the adverse tracheostomy-related incident in the majority of patients. This suggests that the design of tracheostomies has not kept pace with the change in the body habitus of the UK population, in that tracheostomies were too short for some of the patients who suffered adverse outcomes reported to this project.

Equipment

Lack of equipment was highlighted in several cases both in the context of planned tracheostomies or for management of tracheostomy displacement. It is clear that ICUs managing potentially difficult airways must have appropriate equipment for such events.

Planning

One of the major learning points from reviewing cases in the NAP₄ project is that lack of anticipation of potential airway misadventures contributes to the lack of a systematic and logical plan for resolving the issue. Although 'standardised operating procedures' are common in other high-risk areas such as aviation, they have not been widely adopted in medicine. It may be the time to revisit our approach.

Teamwork

It is clear that communication and mutual co-operation between intensivists, anaesthetists and ENT surgeons is vital to the successful management of difficult airways. There were many examples of good teamwork during events that prevented progression to worse morbidity or mortality. In a minority of cases teamwork and communication was poor and contributed to events.

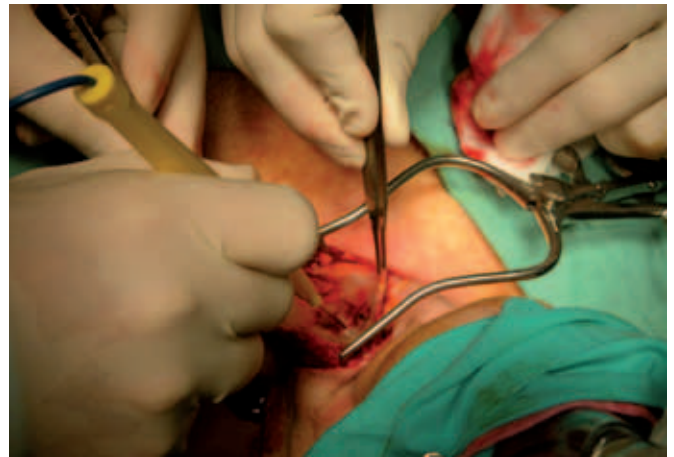
Ward based events

It is acknowledged that airway events occur during ward care of patients with tracheostomies. NAP₄ did not seek or review events arising on the ward. More than 5,000 tracheostomies are performed each year in the UK and only a minority of these patients are nursed only on ICU. It is worth remembering that in addition to those cases reviewed here there is no doubt, that during the period of NAP₄ data collection, numerous cases of tracheostomy-related harm will also have occurred to patients on the wards.

Learning points and recommendations

Cricothyroidotomy failure

As needle cricothyroidotomy fails frequently, tracheostomy (both surgical and percutaneous) is an important rescue technique for severe airway emergencies.



Recommendation: Training in tracheostomy, including as an emergency, should be prominent in both ENT and intensivist training.

Capnography

In cases of tracheostomy displacement recognition was delayed by a lack of capnography. Diagnosis of misplacement during formation of tracheostomy was also delayed for the same reason.

Recommendation: Capnography must be available at each bed space in the ICU and should be used continuously while patients are being mechanically ventilated.

Recommendation: Multidisciplinary staff training should focus on the recognition and interpretation of capnography.

Recommendation: Continuous capnography should be used during the performance of percutaneous tracheostomy.

Protocols and strategies

There was sometimes a failure of a logical and step-wise approach to managing airway events that occurred after accidental tracheostomy displacement or elective decannulation, especially out of hours.

Recommendation: Algorithms must be available for all staff for management of accidental decannulation of the trachea and a step-wise approach to management of the compromised airway. An example of such is included in Appendix 2.

Recommendation: There must be clear lines of communication for escalation of airway events to individuals with advanced airway skills. If individuals covering ICUs do not have advanced airway skills, they must know who to contact for help.

Movement and transfers

Transfers of patients with unstable airways are fraught with hazard. Equally, moving patients as part of routine care can lead to airway displacement.



Recommendation: All staff involved in the care of patients with tracheostomies should be alert to and receive training in maintaining the airway and in safe movement of the patient.

Obesity

Obese patients present additional problems. Tracheostomy tubes that are suitable for patients with normal body habitus may be too short or poorly designed for these patients.

Recommendation: Extra long or adjustable-flange tracheostomy tubes should be available for obese patients who have tracheostomies.

Recommendation: Appropriate bodies such as the Intensive Care Society should engage with manufacturers to redesign tracheostomies, recognising especially the general increase in body mass index in the patient population.

Equipment

Lack of necessary airway equipment repeatedly contributed to a poor outcome in patients whose tracheostomies displaced. Previous studies have shown that ICUs frequently do not have a similar standard of difficult airway trolley to the anaesthetic department in the same hospital.

Recommendation: Difficult airway trolleys must be available to ICUs and their contents familiar to staff.

Recommendation: The difficult airway trolley should have the same contents and organisation as the difficult airway trolley used in the theatre suite of the same hospital.

Recommendation: A flexible fibroscope should be immediately available on the ICU to check position of tracheal/ tracheostomy tubes and assist with fiberoptic intubation or percutaneous tracheostomy placement.

Staffing and teamwork

Team-working and involvement of senior staff are important in successful airway management in patients who may have complex compromised airways. This may

include patients with tracheostomy or complications of a previous tracheostomy.

Recommendation: Clear lines of communication are required between the various teams that manage airway problems related to tracheostomy (ICU, anaesthetic and ENT clinicians) in order to best manage such patients with potentially difficult airways. Mechanisms are also required within teams so senior staff are appropriately available and involved when adverse airway incidents occur.

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Headline

This project has identified the topics for training in airway management which will require extra emphasis. These include assessment of risk of impending airway obstruction or regurgitation and aspiration, appropriate use of supraglottic airway devices, care of tracheostomised or intubated patients in ICU, use and interpretation of capnography, and training in airway skills such as cricothyroid puncture and intubation through appropriate supraglottic airway devices. In addition, it has emerged that it is essential for the training programmes to address strategic planning for dealing with difficult airways, and Human Factors training including non-technical skills such as situational awareness and team training.

What we already know

Airway management is a key component of everyday clinical practice in anaesthesia, critical care and emergency medicine. Therefore, it is not surprising that it holds central position in the training programmes of these disciplines. In anaesthesia, the curriculum for training includes elements of knowledge of human anatomy, physiology and pharmacology, recognising patients at risk of difficult tracheal intubation, different equipment, different techniques and their use in clinical practice alongside acquiring competence in a number of skills and techniques of airway management in different routine and emergency clinical situations.

For trainees, the delivery of a curriculum related to airway management can vary in individual training schools or hospitals. Traditional lectures, skill testing on manikins or models, demonstration on patients, direct supervision and instructed assistance on patients are all variably used; and it is recognised that there is a need to ensure that individual skills of trainees and consultants are developed and maintained.¹ In recent years, training in a simulated environment is being promoted but access to training sessions in a high fidelity simulation centre is neither universally available nor always possible for a given airway technique. The Difficult Airway Society (DAS) has produced guidelines for management of unanticipated failed tracheal intubation (including progression to 'can't intubate can't ventilate' CICV), with others in preparation and soon to be released. The current guidelines cover many important clinical scenarios and give clear instructions regarding what to do when faced with such difficulty.² However, as

this report also shows, airway problems continue to occur even when the difficult airway is anticipated. This stresses the importance of continued education and training in airway skills. DAS, the College and many other regional and national organisations run dedicated educational and training programmes, which now include elements of team training and human factors.³

The last few years has also seen dramatic growth in the types and subtypes of equipment that can be used in airway management, whether routine or difficult. There are increasing numbers of published studies which have evaluated the new devices in experimental or clinical settings. The main growth in equipment has been related to supraglottic airway devices (SADs), flexible and rigid fiberoptic laryngoscopes and technology for improving visualisation of the larynx during laryngoscopy.

Despite these endeavours, which have emphasis on training in airway management and growth in equipment for airway management, adverse incidents during airway management, in routine or emergency clinical practice, continue to be reported to national incident reporting systems in or outside the UK.^{4,5} Although reports are good at providing evidence that airway management remains an area of concern for adverse events, the quality and the depth of information in these reports is usually insufficient for detailed analysis of individual or systemic factors which could have contributed to the incidents. Litigation-based analyses provide another source of information and these generally focus on events at the more severe end of the spectrum of harm, but again often lack case detail.^{6,7} This detailed knowledge, however, is extremely important in identifying the areas in which further emphasis may be required while planning training and continuing education in airway management. One of the aims of setting up NAP₄ was to gain this valuable knowledge.

Some recently publicised high profile cases have drawn our attention to how human factors may interact with clinical scenarios causing inappropriate task fixation of the clinicians, and leading to loss of situation awareness and adverse incidents.^{8,9} The scope of NAP₄ widens the study of systemic and individual factors related to airway management. In this chapter, we present a focus on the areas in the reported incidents in which the review panel highlighted education or training to be one of the factors contributing to the incidents.

Case Review

The NAP₄ data collection process, being a web-based reporting system, was well suited to collecting data on the mechanistic aspects of events (e.g. timelines, equipment and procedures used, complications identified). It was less well suited to identifying issues of training, interpersonal interactions and human factors. While efforts were made to identify this information at the review stage it is likely that relevant data will have been missed either by the process of reporting or review: numbers reported in this chapter are therefore an approximation.

In total, 80 events were recognised in which education and training was highlighted as one of the contributory factors. Further analysis showed a number of factors which were associated with the airway incidents in these cases. These are presented in Table 1.

In order to obtain further insights into where, and how, the issues related to training and education could have interacted with, or contributed to, the reported incidents we studied the free text scripts of the reported incidents to ascertain interactions between different risk factors; we attempted to identify possible patterns, or combinations of risk factors, which contributed to poor outcome. A number of patterns were recognised across the cases, and these are summarised in the following.

Inappropriate use of a standard laryngeal mask, in particular, in obese patients, or in patients at risk of aspiration, often by a trainee anaesthetist

We found a number of reports in which a standard laryngeal mask had not been used appropriately. Often these cases were managed by junior anaesthetists. The laryngeal mask had been used in obese patients who then developed

airway difficulties during or after surgery. As for example, in some reports, the airways of obese patients, some with undisclosed sleep apnoea, were maintained using a laryngeal mask for spontaneous or positive pressure breathing. The patients underwent surgery in lithotomy, lateral or supine positions for variable time periods; the airway deteriorated in these patients during surgery, or at the end of the surgery. Often the deteriorating airway prompted attempts at tracheal intubation which were complicated by trauma, gastric distension, inability to intubate, or aspiration of gastric contents with poor outcome. The lack of a back-up plan in some cases led to hurried and poor quality subsequent management of the airway after the difficulties were encountered.

There were also reports of regurgitation of gastric contents and aspiration whilst the laryngeal mask was in-situ – on reflection, these patients were at risk of regurgitation of gastric contents and aspiration, but the risk was either not suspected or was underestimated. As, for example, a laryngeal mask was chosen for maintaining the airway in a patient undergoing surgery for irreducible hernia, and the patient was not considered to be at risk of aspiration because they had bowel sounds present and had opened their bowels that morning. Another patient who aspirated intraoperatively had recently suffered with pancreatitis, was on nil-orally regime, and a laryngeal mask was used for airway management during emergency surgery for peripheral limb surgery. These cases, and similar ones such as Case 1, highlight how unreliable the clinical features such as presence of bowel sounds and opening of the bowel, and/or period of fasting can be in patients undergoing emergency surgery when assessing the risk of aspiration.

Table 1 Factors identified in the reported event in which training and education were highlighted as contributory factors

<p>Location of event</p> <ul style="list-style-type: none"> • Intensive care unit <p>Personnel</p> <ul style="list-style-type: none"> • Junior trainee anaesthetist <p>Patient factors</p> <ul style="list-style-type: none"> • Obesity • Maxillofacial anatomical abnormalities • Airway mass • Ankylosing spondylitis • Gastrointestinal obstruction • Inadequate reversal of muscle relaxants • Tracheostomised patients in ICU • Presence of stridor • Bleeding into airway or in the neck • Use of throat pack 	<p>Task factors</p> <ul style="list-style-type: none"> • Poor assessment • Lack of use of capnography • Inappropriate use of laryngeal mask • Non-use or delayed use of supraglottic airway device (SAD) for airway rescue • Lack of appropriate strategic planning (no Plan B) <p>Team factors</p> <ul style="list-style-type: none"> • Poor supervision of trainee(s) • Poor support for trainees • Lack of team training <p>Organisational factors</p> <ul style="list-style-type: none"> • Poor adherence to existing guidelines • Lack of appropriate equipment in ICU
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Learning point: Training emphasis on recognising the risk of regurgitation and aspiration – in emergencies and in sick patients the period of fasting can be an unreliable guide to an empty stomach. Devices and techniques that offer better protection than a standard laryngeal mask should be used where there is increased risk of regurgitation and aspiration. Also see Chapters 11 and 19.

Case 1

An elderly, previously fit patient was admitted with a several day history of abscess. The patient was septic, dehydrated and fasted for 48 hours. Urgent drainage of abscess was required. One anaesthetist assessed the patient and planned rapid sequence induction (RSI). At the time of surgery another anaesthetist attended and judged RSI was not required. After induction of anaesthesia a laryngeal mask was inserted and anaesthesia maintained with spontaneous breathing. On transfer to the operating table in theatre the patient regurgitated and aspirated gastric contents and desaturated. At intubation gastric contents were sucked from the tracheal tube. After surgery, the patient was transferred to intensive care, and eventually died.



Airway problem, lack of capnograph or poor interpretation of capnograph

Airway problems, in a patient with, or undergoing tracheostomy in ICU, were often not diagnosed; and lack of, or poor use of, capnography was considered to be contributory in these circumstances. There were reports where lack of capnography was considered contributory to missed diagnosis of misplaced tracheostomy tube during attempted percutaneous tracheostomy on ICU. In addition, there were reports of displacement of tracheostomy tubes where the lack of capnography contributed to delayed diagnosis.

We encountered some reports of oesophageal intubations, where the diagnosis was delayed due to unavailability, non-use, or poor interpretation of capnograph traces. At one extreme of the spectrum, the reported cases were of oesophageal intubation by a trainee anaesthetist who either failed to use capnography to confirm its placement, or ignored an abnormal or absent capnograph trace. There were also cases reported where capnography traces were abnormal and there were difficulties in ventilation (due to oesophageal intubation, or complete airway obstruction by aspirated blood) which were erroneously attributed to severe bronchospasm or anaphylaxis. Many of these patients died. In some cases, however, capnography traces, strongly suggestive of misplacement of the tracheal tube, prompted appropriate action. Although failure to use capnography was more common in ICU and the emergency department it should not be interpreted as a problem only of non-anaesthetic doctors. Cases of capnograph misinterpretation occurred in anaesthesia cases and several cases in both ICU and the emergency department involved anaesthetists.

Learning point: Training emphasis on interpretation of abnormal capnography trace – a flat capnography trace after tracheal intubation should be taken to mean absence of ventilation (tracheal tube misplaced or obstructed). Active steps must be taken to confirm the correct position and patency of the tube. During cardiac arrest and CPR, when the lungs are being ventilated, the capnograph trace is not flat but shows an attenuated expired carbon dioxide trace.

Case 2

A healthy middle-aged patient for elective minor surgery who was known to be atopic was anaesthetised by a locum consultant using induction with fentanyl and propofol. Facemask ventilation was impossible and was followed by hypoxia and cardiac arrest. Anaphylaxis was suspected, intubation attempted, revealing a grade 3 view at laryngoscopy which made visual confirmation of correct tracheal tube placement difficult. During external cardiac massage there was no end-tidal carbon dioxide trace: this was interpreted as due to bronchospasm and treated with adrenaline. The cardiac output was restored but the capnograph trace remained flat. The patient was re-intubated using a bougie and McCoy blade and transferred to ICU. The patient sustained a significant brain injury.

Unrecognised oesophageal intubation is discussed further in Chapters 6, 9, 10 and 12.

Risk of airway obstruction and lack of planning, equipment and/or appropriate personnel

This group of issues was a recurrent theme and seen in numerous reported cases. The review panel identified many events in patients with a known risk of developing airway problems, in whom lack of planning and/or facilities contributed to the poor outcome. Several reported incidents occurred after trauma or after maxillofacial or head and neck surgery: the patient then developed difficulty in breathing and stridor. These events occurred in all areas studied in NAP4 including emergency departments, ICUs and theatre recovery areas. Other examples include bleeding after tonsillectomy, loss of the airway after planned or accidental extubation following head and neck surgery, bleeding in the neck after carotid endarterectomy and patients with oral tumours, glottic masses, or dental abscesses developing stridor. The outcome of these patients ranged from good competent management of the airway to loss of the airway and death. The factors we identified that influenced outcome in these



cases were anticipation of the problem, multidisciplinary discussion, senior involvement, geographic considerations within the hospital, formation of an appropriate strategy (i.e. a co-ordinated combination of plans: as a minimum Plan A and Plan B), on-site presence of a surgeon capable of performing open tracheostomy and adequate resources and equipment particularly in ICUs. In patients with poor outcome it was more frequent to find: failure to follow simple text book teachings, lack of senior involvement and lack of appropriate planning.

Case 3

A young child was extubated following tonsillectomy. On arrival in the recovery area the child was cyanosed. Intubation was performed with an uncuffed tube but ventilation was impossible for some time until the trachea was re-intubated with a cuffed tube and a blood clot delivered. The child experienced profound prolonged hypoxia, asystolic arrest and irreversible brain damage.

Learning point: Training emphasis on inspection of the airway before extubation after surgery near or around the airway, and in the event of absolute obstruction prompt change of tracheal tube and/or rigid bronchoscopy is required.

Case 4

An elderly unfit patient was a grade 3 laryngoscopy when intubated for carotid endarterectomy. Surgery took more than four hours and was complicated by postoperative surgical site oozing. On ICU a surgical trainee reviewed the patient but planned no intervention. Soon after this, bradycardia developed followed by a PEA arrest, from which the patient was resuscitated. A junior anaesthetist used an i-gel to maintain the airway. The patient was awake after resuscitation but several hours later had a further cardiac arrest. At this time three different SADs all failed to rescue the airway, tracheal intubation failed repeatedly and the airway was secured by open tracheostomy, performed by a junior surgeon, after failed needle cricothyroidotomy. The patient died.

Learning point: Training emphasis on well-known problems where high index of suspicion and anticipation, planning for difficulty, timely senior input and urgent removal of airway compression from bleeding in the neck would be warranted. See also Chapters 9, 13, 17 and 18.

Guidelines, Human factors and Team factors

A number of cases were reported where, when patients undergoing rapid sequence induction developed CICV, strict adherence to DAS guidelines (i.e. airway rescue with a laryngeal mask and emergency cricothyroidotomy if laryngeal mask rescue failed) were life saving. However, there were some cases where emergency cricothyroidotomy or open surgical tracheostomy was performed without trying simple measures such as





laryngeal mask rescue. In some other cases, after having rescued the airway with a SAD, emergency open surgical tracheostomy was performed to secure the airway without trying to intubate through the SAD. Waking the patient was often not considered. The review panel felt that these cases pointed perhaps to lack of awareness of guidelines, lack of training in these skills or both. Cases occurred both in anaesthesia and on ICU (see also Chapter 13).

This project received a number of cases where, when faced with a CICV situation, anaesthetists continued multiple, seemingly unlimited, attempts at intubation, often leading to trauma and/or profound hypoxia. Typically, many of these patients presented with a known difficult airway or predictors of difficulty – a junior anaesthetist, and some consultants, would either ignore the risk and proceed with routine intravenous induction of anaesthesia followed by muscle relaxant, or would start with awake fiberoptic intubation or gas induction as plan A. When plan A did not go smoothly, they seemed to have no plan B and would continue with multiple attempts at intubation with unwanted consequences. What lacked consistently in these cases was an appropriate thought through plan B, which had been discussed with a senior and/or surgical colleague and prepared for, including senior involvement. The cases which had a favourable outcome more often had a clearly defined plan B (and plan C etc) which would invariably include planned surgical involvement and cricothyroidotomy or tracheostomy.

The review panel is of the view that lack of adherence to guidelines, failure to involve senior members of the team, failure to consider waking the patient, failure to involve surgical colleagues and persisting with multiple attempts at intubation after failure, as also highlighted by some recent high-profile cases, point to areas of human factors, situation awareness and team training which require emphasis in the existing training programmes. See also Chapters 12, 13 and 24.

Numerical analysis

Of the 80 incidents where training and education were considered to have contributed, 50 incidents occurred in operating theatres, 22 in ICU, eight in emergency departments. The primary airway was a tracheal tube in 43 patients, a SAD in 20, a tracheostomy in 12 and other in five. In relation to timing during anaesthesia, half of these incidents occurred during induction, and approximately one quarter each during maintenance or during emergence from anaesthesia and/or recovery. Among patient factors, obesity was most common: 29 of 80. Seventeen of 80 incidents occurred in patients with a recognised difficult airway (neck masses, stridor, intraoral tumours, dental abscesses) and where fiberoptic intubation should logically have been used but was not. Among other associated factors, equipment and organisational factors were identified in 38 and human factors in 45 of the 80 incidents.

Learning points

This project has highlighted a number of areas where lack of appropriate training and education was considered to have contributed to the airway incidents. Many of these areas are not new, and are well covered by a typical training programme curriculum. However, the project has captured several topics that require further consideration and emphasis, when planning the implementation and delivery of a training curriculum.

Assessment of risk, and planning

Assessment of risk of regurgitation and aspiration has emerged to be an important training issue. Factors such as obesity, the lithotomy position, semi-elective trauma surgery, and emergency surgery were noted in a large number of aspiration cases where choice of airway or technique was questionable.

Another area of assessment, which requires training emphasis, is that of impending airway problems after trauma or after maxillofacial, head, neck or intraoral surgery. These patients require a high index of suspicion and anticipation for airway problems, and training should cover appropriate steps that must be taken to avoid, diagnose and manage problems promptly if they occur. This requires senior input, surgical involvement, having a Plan A and a Plan B (i.e. a strategy) and prior organisation of appropriate resources and equipment. It must be emphasised to all anaesthetists that their responsibility does not end with transferring an 'at-risk' patient to recovery or ICU unless an appropriate plan has been put in place to diagnose and manage anticipated problems.

Another area which has emerged from this project in terms of emphasis on strategic planning in a training programme is the life-saving role of a scrubbed and ready surgeon, able to perform surgical tracheostomy, in a patient faced with a 'can't intubate can't ventilate' situation.

Care of tracheostomised and intubated patients in ICU

This has emerged as a major area for emphasis in training and education; this is in addition to providing adequate resource and equipment to deal with difficult airways in ICU. With increasing numbers of non-anaesthetists now being resident doctors in ICUs, training in airway skills must be accompanied by emphasis on anticipating difficulties, prevention, early diagnosis and prompt appropriate management including early involvement of senior assistance. These training programmes must include topics such as prevention strategies, the role of capnography, nursing involvement in recognition of complications, multidisciplinary team planning and communication, early involvement of a senior anaesthetist and ensuring availability of appropriate equipment and protocols in the ICU.

Appropriate use of supraglottic airway devices

The project has highlighted the need for emphasis in training on appropriate use of SADs. In particular, the use of SADs as a possible rescue airway in the 'can't intubate can't ventilate' situation needs to be reiterated. On the other hand, caution needs to be emphasised on their use in patients who are obese, at risk of regurgitation and aspiration, or those undergoing prolonged surgical operations. Different performance characteristics and probably safety profiles between different SADs also needs emphasis.

Use and interpretation of capnography

A major finding of this project is that capnography is underutilised in ICU, and this may be a training as well as resource issue. Failure to use capnography contributed to a substantial number of deaths. However, even in operating theatres, abnormal capnograph traces were either ignored or not interpreted appropriately. Training programmes must emphasise the crucial role that capnography plays in early diagnosis of misplaced and blocked tracheal tubes and/or airway problems; any significantly abnormal capnograph trace must trigger prompt action. A message that must be driven home is that unless the tracheal tube, or tracheostomy tube, has been visually confirmed to be placed in the trachea and confirmed to be patent, any abnormal capnograph trace should be taken to indicate misplacement or blockage of the tube, and this should be followed by prompt action.

Airway skills

The project highlights some key airway skills which require more in terms of training and education. In particular, cricothyroid puncture and subsequent ventilation failed in many of the reported cases, and one of the underlying factors could be lack of training in performing this procedure. Another skill which was either underutilised or failed in many of the reported cases was tracheal intubation

through a SAD. More emphasis should be placed on training in these skills, and use of simulators and bench models may have a role in enhancing this type of training.

Guidelines, human factors and team training

In our opinion, these areas are not comprehensively covered in most training programmes. Recent work in these areas highlights the importance of involving simulation centres, human factors experts and trainers from different disciplines in enhancing training. It is also known that training the whole team together, rather than individuals, is much more beneficial. When teams are trained together, the individual members help each other in reminding and adhering to guidelines, seeking further help, communication, making and executing plans and overcoming some of the human factors such as task fixation under stress. These factors emerged as recurring themes, and we believe that this is one of the most important areas of training, as highlighted by the present project, where further efforts and energies must be directed.

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Headline

We found instances of deficiencies in the undertaking or recording of an airway assessment, failure to undertake additional airway investigations and failure to review the investigations even when this would have been extremely useful. The anaesthetist was not always aware of a previous problem with airway management. Even when abnormalities were detected, the strategy adopted was not always likely to manage the problem successfully with textbook problems managed by unconventional approaches. Aspiration occurred in some patients judged to be at no increased risk, partly because the risk may be difficult to assess preoperatively but also due to wayward judgement. Serious adverse events occurred even when no problem with airway management had been anticipated emphasising the necessity for vigilance and a prepared strategy. There were instances of difficult situations managed well but, overall, airway management was considered poor in a high proportion of reports. Poor judgement was the commonest contributory factor identified by the person completing the report.

What we know already

'An anaesthetist must assess the patient before anaesthesia and devise an appropriate plan of anaesthetic management' – *The Good Anaesthetist*, Royal College of Anaesthetists, 2010.¹

'The preoperative assessment process should have identified and addressed problems with individual patients.' – *Pre-operative Assessment and Patient Preparation*, Association of Anaesthetists of Great Britain and Ireland, 2010.²

In the practice guidelines of the American Society of Anesthesiologists,³ the first two steps in airway management are evaluation of the airway and preparation for difficulty. Evaluation seeks to identify which airway device (facemask, supraglottic airway or tracheal intubation) offers the appropriate security of maintenance and protection of the airway and whether there is likely to be difficulty with the technique chosen. Since all plans fail at times, evaluation also identifies an appropriate back-up plan, including potential ease of emergency surgical airway. Airway management should always be described as a strategy (a combination of plans in a pre-defined logical sequence) which will aim to achieve good gas exchange and prevention of aspiration.

Both the ASA and Difficult Airway Society (DAS) have produced guidelines for management of the difficult airway in general and in specific situations such as failed intubation or 'can't intubate can't ventilate' (CICV).^{3,4}

An airway evaluation should be undertaken in all patients who may require airway support or an airway intervention. While this most commonly applies to patients undergoing surgery it includes patients in ICU or the emergency department. Even those undergoing a procedure under local or regional anaesthesia should be assessed in case of complications such as local anaesthetic toxicity or a high block, or conversion to general anaesthesia because of block failure or surgical circumstances. What constitutes an adequate preoperative airway evaluation is not defined in detail in practice guidelines but includes obtaining a history of previous difficulty; seeking medical conditions associated with difficulty such as rheumatoid arthritis or obstructive sleep apnoea; identifying previous surgery or radiotherapy to the head, neck or mediastinum; assessing whether the patient looks as though the airway will be difficult to manage; undertaking some bedside interactive tests; noting the availability of the cricothyroid membrane and considering the implications of the presenting disease. The bedside tests are not very good at predicting difficulty in the apparently normal patient⁵ but it is difficult to argue against their use since limitations in simple tests such as mouth opening or neck mobility may dictate strategy.



Rapid sequence induction; but what if the plan fails?



Prediction of difficulty with airway management (broadly tracheal intubation, supraglottic airway device (SAD) insertion, ventilation by facemask or direct tracheal access) allows the practitioner to summon help, assemble alternative equipment, undertake airway management in a more equipped area, secure the airway by awake intubation, undertake cricothyroidotomy or tracheostomy, offer regional or local instead of general anaesthesia or postpone elective surgery. Traditional indications for awake intubation are difficult direct laryngoscopy in association with difficult mask ventilation or increased risk of aspiration. Some authorities advocate awake intubation for isolated difficult direct laryngoscopy but the large numbers of alternative laryngoscopes designed for this problem are commonly employed under general anaesthesia.

When no difficulty is predicted the practitioner will manage the airway 'as normal' and rely on the prepared strategy to successfully manage unanticipated difficulty.

The resources necessary to implement a selected strategy are the appropriate knowledge and skills (or competence) to undertake the steps, an environment of readily available equipment and trained assistance, non-technical skills such as leadership, situation awareness and teamwork and the ability to learn from 'near-misses'. Equipment required to manage the airway is conveniently arranged in a tray or trolley near to the patient with more specialised equipment in a conveniently located advanced airway trolley. The contents of an advanced airway trolley should be decided locally but UK recommendations have been made.⁶ The selection and completion of a strategy for the unanticipated difficult or emergency airway requires the highest level of resource. The availability of rarely used equipment, competence in advanced techniques, team-working and human factors become more prominent in determining the outcome.

Working with this framework or model of airway management, we can predict that adverse outcomes associated with assessment and planning may arise in the following circumstances.

- An airway evaluation is not performed and difficulties are not predicted.
- Airway evaluation is imperfect in predicting difficulty and unanticipated problems arise.
- No airway strategy has been devised or pre-formulated.
- The airway strategy selected by a practitioner for a normal or difficult airway is inappropriate.
- The airway strategy may be considered best practice but fails in a some patients.
- An individual or team cannot complete the planned appropriate strategy due to inexperience, unfamiliarity or failure of technique.
- It is not possible to assemble the appropriate resources due either to time pressures, institutional or non-technical problems.

An individual anaesthetist can be expected, as part of their professional duties, to undertake an airway assessment, have pre-formulated strategies for the commonest problems and the necessary knowledge and skills to complete the strategy. However, we are more exposed dealing with emergency cases when time for assessment and decision-making may be limited or when the abnormality is an obstructed airway and the practitioner is not familiar with this clinical problem. Excellence in managing these cases will require the resources of experienced surgical and anaesthetic colleagues and assistants. Some adverse incidents indicate failure of the department or organisation to match the event with the necessary expertise. We must also remember that we are human and all plans fail at times.

Case review

Assessment

Specific fields on the reporting forms for anaesthesia incidents elicited information about airway assessment and whether problems with airway management were anticipated. It is clear that no airway assessment at all was undertaken in a number of reports. Two patients with no airway assessment recorded were undergoing surgery under 'sedation', most notably in a case report detailing profuse



bleeding during biopsy of a presumed tonsillar malignancy but also including aspiration in a patient undergoing upper GI endoscopy. The inclusion of these patients in the project illustrates the importance of an airway assessment even when general anaesthesia is not planned in case of complications, resuscitation or conversion to general anaesthesia. The panel were unfamiliar with the practice of tonsillar biopsy under sedation.

Case 1

An elderly patient weighing more than 100 kg presented for an elective video-assisted thoracic procedure. No airway assessment was undertaken and (consequently) no airway management problem was anticipated preoperatively. All bedside tests (mouth opening, neck movement, Mallampati grade, thyromental and sternomental distances) were recorded as 'not done'. After induction of anaesthesia, including muscle relaxation, direct laryngoscopy was very difficult with the report noting 'limited neck extension and prominent teeth'. Multiple attempts at intubation failed, the procedure was abandoned and a SAD inserted. On return of spontaneous breathing and awakening (after glycopyrronium and neostigmine) the SAD was removed but the oxygen saturations remained low. An oral airway failed to improve the situation and a nasal airway was inserted provoking nasal haemorrhage. After ten minutes with oxygen saturations in the 80s, the cardiothoracic surgeon inserted a percutaneous tracheostomy.

Of the reports in which difficulty with airway management was anticipated, the commonest predicted problem was with difficult direct laryngoscopy or intubation. Anticipated difficult facemask ventilation, difficult direct tracheal access, difficult supraglottic device insertion and difficult pre-oxygenation were also recorded. Each difficulty requires its own relevant airway planning. Two patients had a 'full-house' where all five elements of difficulty were anticipated and both developed problems in the postoperative period: Case 2 is an example. A history of airway problems was available in some reports (usually in the hospital notes) but in two reports the anaesthetist was not aware of the problem before inducing anaesthesia. In one report the fact that the patient was known to be difficult to intubate was recorded in different hospital notes. The patient, undergoing endovascular aortic repair, was anaesthetised as normal but direct laryngoscopy was very difficult. During a protracted sequence of attempted intubation the patient aspirated and the airway was rescued by SAD and blind intubation through it. The patient required ventilation for several days. The second case is described in Case 3.

Case 2

An obese, diabetic patient presented with floor of mouth swelling due to infection following dental extraction. All modes of airway management were predicted to be difficult. A consultant anaesthetist intubated the patient by awake fibreoptic intubation for incision and drainage. The patient became obstructed immediately after extubation in theatre (with the team still present) due to superadded haemorrhage into the floor of mouth/tongue. Repeat awake fibreoptic intubation was successful and a tracheostomy was undertaken by the consultant ENT surgeon.

Case 3

A patient weighing more than 150 kg (BMI 43 kg/m²) was referred from out of region for minor hand surgery but had declined a local anaesthetic technique. There was no mention of obstructive sleep apnoea (OSA) from the referring letter or patient. During anaesthesia the airway was managed uneventfully with a laryngeal mask: at the end of surgery the patient sat up and removed laryngeal mask then proceeded to obstruct leading to hypoxia and a bradycardic arrest. The situation was managed by suxamethonium, SAD and fibreoptic intubation aided by Aintree intubating catheter. The patient was admitted to ICU and was reviewed regularly. Supraglottic oedema/swelling was still present after three days and the patient underwent tracheostomy. Following the event hospital policy was amended so that specific questions are now asked about OSA at preoperative assessment.

When a planned awake (conscious sedated) fibreoptic intubation was carried out several reports described patients who were neither awake enough to look after themselves or sufficiently anaesthetised to allow intervention. Several reports described problems during use of remifentanyl to assist management of the airway: these included cases where over-sedation led to loss of the airway or where it did not increase co-operation but stopped respiration.

Case 4

A morbidly obese patient weighing 120 kg presented with post-thyroidectomy bleeding. Patient co-operation was thought to be a problem but the worrying array of predicted difficulties led the anaesthetist to attempt fibreoptic intubation with remifentanyl sedation. The airway was lost (attributed to sedation with remifentanyl) and facemask ventilation was impossible. Although the patient was not able to maintain their own airway and respiration, they were struggling and resisting insertion of a SAD. Rocuronium was administered but the surgeon had removed the skin clips and sutures and performed a tracheostomy before a SAD could be inserted. The patient made a full recovery.



In cases with multiple predicted problems successful management requires full assessment, clear planning, immediate availability of required equipment and the presence of senior anaesthetic and surgical specialists. The review panel considered that management of these complex cases in theatre, rather than the anaesthetic room, to be good practice.

Case 5

An adult patient was scheduled for panendoscopy of the upper aerodigestive tract and biopsy. The patient had minimal symptoms of upper airway obstruction and no special investigations were obtained. After induction of general anaesthesia, it was clear that a very extensive tumour of the glottis/epiglottis prevented intubation. The patient suffered a cardiac arrest during surgical tracheostomy but was successfully resuscitated.

Additional airway investigations may be very useful when a disease process distorts or narrows the airway. The most frequently reported investigation was flexible nasendoscopy. The anaesthetist did not commonly review the CT neck suggesting that, even in potentially difficult cases, helpful information may not be extracted from investigations by anaesthetists. It is conjecture as to whether this is due to lack of effort, difficulty in accessing or lack of expertise in interpretation. Failure to review the findings of fiberoptic nasendoscopy undertaken by the surgeon led one anaesthetist to underestimate the degree of epiglottic oedema in a patient scheduled for biopsy

of a base of tongue tumour. The patient had previously undergone radiotherapy for a malignant neck node and had continued to smoke. Following induction of general anaesthesia it proved difficult to ventilate by facemask, place a laryngeal mask or intubate by direct laryngoscopy. Fiberoptic intubation (in the now anaesthetised patient) proved impossible and the situation was rescued by surgical tracheostomy in the anaesthetic room. We would conjecture that the anaesthetist might have undertaken a different approach if they had knowledge of the nasendoscopic view.

Location and timing of surgery may dictate that specialist investigations, such as CT or MR scans, are difficult to arrange or inappropriate prior to intervention. However, flexible nasendoscopy may be performed by the surgeon and/or anaesthetist and with readily available equipment both can review the dynamic image together. In one report although the ENT specialist registrar had assessed the airway of a patient with advanced glottic/upper tracheal tumour by nasendoscopy in the emergency department, the consultant anaesthetist performed flexible nasendoscopy (with the flexible intubating fibrescope) again at the onset of care in the operating theatre. This led to the assessment that placement of a transtracheal catheter under local anaesthesia prior to intervention would be beneficial. In another similar case nasendoscopy performed immediately before planned anaesthesia identified an 'untubatable larynx' and led to abandonment of a plan to anaesthetise and a surgical tracheostomy was performed awake, without complications. It was clear that some other patients would have benefited from special airway investigations but these were not performed.

Data were collected on whether there was an increased risk of aspiration and the clinical reasons for making this assessment. The problem of aspiration is explored in more detail in another chapter in the report (Chapter 19). Some judgements on risk of aspiration were poor, most notably leading to an anaesthetist undertaking surgery for an incarcerated hernia with a first generation SAD followed by fatal aspiration.

Planning

Three broad problems were seen when planning airway strategy.

The first problem was failure to match the strategy to the assessment. Even with a textbook abnormality such as the combination of difficult direct laryngoscopy with a risk of aspiration or difficult facemask ventilation, the anaesthetist induced general anaesthesia in co-operative patients. Other examples were patients with a high-risk of aspiration managed by SAD.



Case 6

A 115 kg patient with sleep apnoea, limited cervical spine mobility and tracheal deviation was scheduled for thyroidectomy. General anaesthesia was induced with remifentanyl, propofol and sevoflurane. It was not possible to see the vocal cords at direct laryngoscopy and after repositioning it was not possible to ventilate the patient either. Cricothyroidotomy was not possible and the airway was secured by difficult tracheostomy. Saturations were < 60% for 20 minutes.

Case 7

A non-obese adult with trismus was scheduled for removal of infected mandibular plate during daylight hours. The anaesthetist assessed the airway and anticipated that problems would be present in this airway compromised by pharyngeal oedema, radiotherapy and infection. The specific problems identified were difficult facemask ventilation, difficult direct laryngoscopy/intubation, difficult SAD insertion and difficult direct tracheal access. Patient co-operation was not expected to be a problem. After identification of all these warning signs anaesthesia was induced and rocuronium administered. After unsuccessful attempts at fibreoptic intubation and with difficult ventilation (oxygen saturations falling to 25%) the airway was eventually rescued by difficult surgical tracheostomy.

Case 8

An adult patient with ankylosing spondylitis required surgery during daylight hours for intestinal obstruction. Difficult direct laryngoscopy and risk of aspiration were predicted by the consultant anaesthetist. The patient was managed by a rapid sequence induction with propofol, suxamethonium and cricoid force. When intubation by direct laryngoscopy was not possible rocuronium was administered and attempts were made to intubate through a SAD with a flexible fibrescope. When this also failed further relaxant was administered and the laparotomy was carried out with a SAD. The induction process took one hour.

The second problem was failure to have a prepared strategy – there was no Plan B in case of failure of the primary technique. Sometimes the decision to select a particular primary plan (for example to use a SAD) was made because of a limited repertoire of skills. In circumstances where difficulty in laryngoscopy is predicted it may be appropriate to avoid intubation attempts and manage the airway by facemask or SAD. However when such a strategy is chosen it must be remembered that the presence of anticipated risk for one airway device (e.g. intubation) is also a risk factor for failure of other techniques (mask ventilation, SAD). Such a plan is not acceptable without a well formulated strategy for rescuing the airway if the chosen technique fails. This strategy should take into account factors such as impeded access to the airway (e.g. patient position) and the likelihood of failure of the primary

technique (e.g. patient movement, positioning, prolonged surgery, advanced uses of primary technique). Involvement of more than one individual to manage such high-risk cases and a clear plan for summoning senior help should be in place. Organisational planning requires that colleagues communicate with each other to ensure an individual with appropriate skills manages patients with an airway that may become difficult to manage.

The third problem area in planning was whether to stabilise a deteriorating patient in the emergency department or ICU or make a dash for the operating theatre. The operating theatre may be seen as a place of safety but it may be preferable for the airway to be secured without or prior to transfer. There were several cases of deterioration and loss of airway even during relatively short transfers: the consequences included deaths, brain damage and the requirement for several immediate surgical airways. There is a period of increased risk during transfer and we suggest that cases from this project should be used to test institutional readiness to manage critical airways in the emergency department or ICU. Such strategies require that resuscitation rooms and ICU should be ready for advanced airway techniques and surgical tracheostomies with adequate provision of advanced airway equipment, appropriate personnel who are able to respond and high quality assistance. These have all been found to be wanting in cases described elsewhere in this report (see Chapters 6, 9, 10 and 23).

Case 9

A 120 kg patient presented to the emergency department with acute epiglottitis. Intubation in the emergency department failed and the patient was transferred to theatre with a SAD in place and saturations of 80% on 100% oxygen. A cannula cricothyroidotomy was attempted but the situation deteriorated and CPR was initiated. A surgical tracheostomy was inserted and the patient made a full recovery.

Case 10

A middle-aged obese, bull-necked man was in ICU after major neck surgery including fusion. During the first postoperative night he developed neck swelling and stridor and required surgical exploration for bleeding. The airway was not secured in ICU and the patient had a respiratory arrest during transfer to theatre. Intubation failed and the airway was barely rescued by SAD. As no surgeon was immediately available a needle cricothyroidotomy was attempted, but this failed. Eventually a tracheostomy was inserted.

Numerical analysis

There were 133 anaesthesia reports. Difficulty with airway management was anticipated in 66 and not anticipated in 67. Of the 66 reports in which difficulty with airway management was anticipated, the commonest

problem was difficult direct laryngoscopy or intubation (56 reports), followed by difficult facemask ventilation (21), difficult direct tracheal access (18), difficult supraglottic device insertion (ten) and difficult pre-oxygenation (eight). Two reports had all five elements of difficulty, six reports had four elements and seven reports had three elements of difficulty.

Patient co-operation was recorded as anticipated to be a problem in 14 reports. In 28 reports an airway assessment was not recorded and in a further nine reports this field was left blank indicating that in 23–28% reports the written anaesthetic record contained no information about the airway. When performed, the commonest bedside tests were Mallampati (normal in 52, abnormal in 35 reports), neck movement (normal 59, abnormal 24) and mouth opening (normal 65, abnormal 20).

Additional airway investigations were obtained in 21 reports, most commonly in head and neck disease, with flexible nasendoscopy the commonest procedure (15 reports) followed by CT neck (seven), chest X-ray (six) and MRI neck (three). The anaesthetist reviewed the CT neck in only two of the seven reports in which it had been obtained.

The risk of aspiration was judged to be not increased in 83 reports but in at least nine of these patients the root cause of poor outcome was aspiration. In 43 reports there was judged to be an increased risk of aspiration due to intestinal obstruction (eight), gastro-oesophageal reflux (eight), recent ingestion (seven reports), delayed gastric emptying (seven) and pregnancy (four). Other reports highlighted the risk of aspiration of blood from upper airway bleeding.

A history of airway problems was available in 41 reports and the anaesthetist was aware of this in all except two reports. In those patients with a previous airway problem the commonest method of communication of the difficulty was through the hospital notes (32 reports), supplied verbally to the patient (14) or supplied to the general practitioner (six).

No patient reported to the project had a Medicalert bracelet.

Poor judgement was the commonest influential factor identified by the person completing the form (74 reports); in comparison defective training (14) and defective knowledge (11) were less common. Airway management was considered by the panel to be poor in 65 of all reports in the project.

Discussion

Airway assessment underpins selection of an airway strategy and failure to assess the airway is a failure in professional duty. In some reports no airway assessment was recorded and in most of them no bedside tests were

done indicating a failure to assess the airway. Without an airway assessment there can be no plan other than carrying on 'as normal'. Features in a history or examination such as prominent teeth, limited neck extension and obesity are likely to be evident on standard preoperative assessment. Where specialised surgery requires specialised anaesthetic techniques, even in the face of potential airway difficulty there are a variety of means for providing satisfactory surgical conditions (e.g. one-lung separation in the presence of a predicted difficult airway).⁷ Failure to assess the airway, followed by airway difficulty and patient complications was always described as poor management by the reviewing panel.

In many patients without any obvious problem with the airway, life-threatening events may still occur at any phase of surgery including extubation and recovery. From this project we would select aspiration, laryngospasm, unanticipated difficult direct laryngoscopy, failed intubation at rapid sequence induction and CICV as the core primary problems for which the anaesthetist should plan. The problem of unanticipated difficult direct laryngoscopy is common enough to allow recommendation that all anaesthetists should be competent in an alternative technique of intubation. In elective situations, the anaesthetist should remember that waking the patient up is an option when more serious airway difficulties arise and is the preferred option by the patient.

The management of a patient considered at risk of aspiration should be different from one without this risk. Establishing the level of risk is an important part of preoperative assessment, for failure to protect the airway adequately will lead to aspiration with a possible fatal outcome. It is not always clear-cut but our interpretation of the relevant cases in this project is that much more trouble results from failure to protect an airway by intubation than is caused by trying to intubate. The role of the second generation supraglottic devices in managing 'borderline' patients is unknown but they should at least be considered preferable to SADs without any channelling of regurgitant material.

If there is an aspiration risk with no predicted airway difficulty, the textbook management in the UK is a rapid sequence induction. This is one of the specific situations covered by a guideline of the Difficult Airway Society. The strategy is initial attempted intubation by direct laryngoscopy and, if this fails, immediate resumption of oxygenation (with facemask or other techniques as needed) and allowing the patient to wake up. Reviewing the case reports we would comment that it seems allowing the patient to wake up is a difficult choice to make but it is an error to continue intubation attempts unless surgery is immediately urgent. After awakening, the patient can be managed by alternative means. If the airway is known or predicted to be difficult when there is a risk of aspiration,



the textbook management (if general anaesthesia is essential) is awake intubation. If the anaesthetist in charge of the patient cannot undertake an awake intubation, and time permits, the appropriate path is to involve an appropriate colleague.

The reluctance to manage some airways by awake conscious sedated intubation led to problems and occasionally the flexible fibroscope was used after induction of general anaesthesia and muscle relaxation. In cases where multiple primary and rescue techniques may be difficult, textbook teaching would highlight this as a clear indication for an awake fibreoptic intubation. Once the patient is anaesthetised and paralysed the 'airway space' diminishes, there is no movement of gas or bubbles to guide the intubator to the larynx, the position of the patient cannot be altered, the patient cannot sniff to tense the palate and improve the nasopharyngeal view and the time for endoscopy is limited by the onset of desaturation in the apnoeic patient: this is further discussed in Chapters 14 and 18. When rescue oxygenation via the neck is also assessed to be difficult this multiplies the risk of general anaesthesia (see Chapter 13). Securing the airway awake should always be considered when direct tracheal access will be difficult. It must be appreciated that the sedation or local anaesthesia used for 'awake' intubation may destabilise the airway. This is particularly true if lack of compliance is due to hypoxia or hypercarbia. If the primary plan fails rescue oxygenation may be needed. If this involves surgical tracheostomy the management should start in the operating theatre with the team assembled.

Maintaining spontaneous respiration and avoiding muscle relaxation is ingrained within UK anaesthesia culture but we would question the drugs sometimes used to undertake inhalational anaesthesia. The textbook manner is a volatile agent (usually sevoflurane initially) in oxygen. Can a technique using propofol, remifentanyl and a volatile agent really be classed as a sensible approach? The risk of producing an apnoeic patient caught in an inappropriate level of anaesthesia seems too high for us. There is no chance of awakening and consideration must be given to urgent muscle relaxation. Obstructive sleep apnoea features in a number of reports. It is characterised by obstructed breathing during sleep. It is unlikely to be any different during inhalational induction of anaesthesia.

Some patients would have been better managed if additional investigations had been obtained or if the investigations available had been reviewed by the anaesthetist. It is easy and conducive to team-building for the anaesthetist and surgeon to jointly review imaging or perform flexible nasendoscopy. Occasionally information about previously encountered airway difficulty was not known to the anaesthetist. This problem is inherent where information about a single patient exists in different sets of

notes or in notes in different hospitals. Whenever possible the patient should be informed of the problems so they may tell subsequent anaesthetists.

Learning points and recommendations

- A quarter to one-third of anaesthesia patients had no recorded airway assessment.
- Mallampati grading, mouth opening and neck mobility were the most commonly performed bedside interactive tests.
- The commonest predicted problem was difficult direct laryngoscopy or intubation.
- Nasendoscopy was the commonest additional airway investigation.
- The risk of aspiration was not always assessed and some of these patients aspirated.
- Awake intubation would have prevented some described adverse events.
- Deficiencies in judgement are more commonly cited as influential in adverse events than deficient knowledge or skills.
- An airway plan suggests a single approach to management of the airway. A strategy is a co-ordinated combination of plans, which aim to achieve good gas exchange and prevention of aspiration. Anaesthetists should approach airway management with strategies rather than plans.
- Some responses to airway events suggested that anaesthetists and others managing the airway lacked good knowledge of published guidelines and some responses lacked structure and logic.

Recommendation: All patients should have an airway assessment performed and recorded before anaesthesia. This involves bedside interactive tests.

Recommendation: All patients should have their risk of aspiration assessed and recorded before anaesthesia. The airway management strategy should be consistent with the identified risk of aspiration.

Recommendation: Awake intubation should be used when it is indicated. This requires that anaesthetic departments and individual anaesthetists ensure such a service is readily available.

Recommendation: All anaesthetic departments should have an explicit policy for management of difficult or failed intubation (e.g. formal adoption of the Difficult Airway Society guidelines as departmental policy) and for other airway emergencies. Individual anaesthetists should use such strategies in their daily practice.

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CHAPTER 18

Head and neck pathology



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Headline

There were 72 cases reported to the project in which the airway problem was in association with an acute or chronic disease process in the head, neck or trachea. These cases account for approximately 40% of all cases reported to NAP₄. Approximately 70% of the reports were associated with what might be termed an obstructed airway. The death and brain damage incidence in this group was: anaesthesia 13%, ICU 50%, emergency department 14% which closely mirrors the NAP₄ group as a whole. The review panel suggested that airway management might be considered poor in nearly one-third of these case reports. A number of airway themes related to head and neck pathology emerged from these data including:

- 1 adequate assessment and planning
- 2 location – anaesthetic room or operating theatre
- 3 airway deterioration following multiple attempts at direct laryngoscopy
- 4 flexible fiberoptic intubation attempts can fail
- 5 inhalational induction with maintenance of spontaneous ventilation can fail
- 6 emergency cannula cricothyroidotomy commonly fails in an emergency
- 7 bleeding after head and neck surgery makes the airway even more difficult to manage
- 8 extubation and early recovery are times of risk for head and neck patients.

What we already know

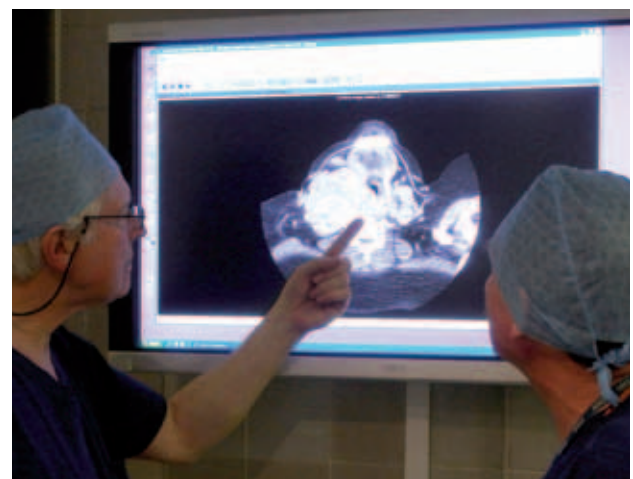
Airway management presents particular difficulty when a disease process, airway oedema or neck haematoma has narrowed or distorted the airway. Problems may arise at the start of anaesthesia but also at the time of extubation or in the recovery phase. It is helpful to differentiate those patients on scheduled operating lists requiring anaesthesia for biopsy, drainage, debulking or resective surgery from emergency patients who are admitted with advanced airway obstruction and require immediate intervention to ensure a secure airway.

For planned or urgent surgery an appropriate airway strategy (combination of plans) can be formulated only with careful preoperative assessment to determine the nature, degree, location and implications of airway narrowing

or distortion. Acute airway obstruction usually presents with prominent signs and symptoms due to untrained respiratory muscles failing to maintain alveolar ventilation. Stridor is prominent and should always be considered an indication of significant airway problems. In chronic obstruction, with respiratory muscle conditioning, there may be few signs or symptoms despite an airway diameter of only a few millimetres. A pitfall for the unwary is failure to take seriously enough the airway of a patient breathing quietly at rest. In chronic obstruction there is usually ample time to perform MR or CT scans to delineate the extent of disease pathology and nasal fibre-endoscopy (nasendoscopy) to inspect the upper airway. Management should start with all relevant preoperative imaging being reviewed jointly by the surgeon and anaesthetist prior to formulation of an airway strategy. The strategy will be affected by the site of the narrowing, its severity and the nature of the abnormality. Of particular importance is the availability or otherwise of the cricothyroid membrane or upper trachea for emergency oxygenation.

The primary airway management plan in elective or scheduled surgery should consider

- whether facemask ventilation and intubation by direct laryngoscopy are likely to be difficult
- whether the airway should be secured in the awake patient
- whether the surgeon requires a tubeless technique
- back-up plans if the primary technique fails



Joint assessment of CT scans assists anaesthetic planning



- the need for supplemental oxygen
- an assessment of patient co-operation (as emphasised by the ASA in their difficult airway algorithm).¹

While the above considerations are equally important in the emergency situation, additional factors influence outcome when the major focus of intervention is to secure the airway urgently to preserve life. The patient may be deteriorating rapidly in a location without appropriate resources or trained assistance, imaging may not have been possible and the level and nature of obstruction unknown, senior help may not be available, high skill levels are required to successfully accomplish intubation or cricothyroidotomy with abnormal anatomy or a struggling patient and rushed decision-making often leads to poor individual and team performance.

The 1998 Confidential enquiry into Peri-operative death (CEPOD) study² looked at deaths in association with the obstructed airway. It concluded that senior anaesthetic and surgical input were required early, local protocols were sensible and awake fiberoptic intubation or tracheostomy under local anaesthesia should always be considered even if subsequently rejected as inappropriate. There is no consensus as to the best primary plan in conditions such as deep neck infections or airway malignancy and there are advocates of awake fiberoptic intubation,³ tracheostomy under local anaesthesia⁴ induction of general anaesthesia by the inhalational route with avoidance of muscle relaxants,⁵ the intravenous route with muscle relaxants⁶ or prior insertion of a transtracheal catheter under local anaesthesia prior to any other intervention.^{7,8}

Our uncertainty about the best method of managing the 'obstructed airway' is in part due to failure to appreciate that the site of obstruction (oral cavity, tongue base, supraglottic, glottic or infraglottic) has a great influence on the efficacy and suitability of various techniques. The flexible fibroscope is very useful for tongue base lesions



(with normal glottis) but much less so for tight abnormal glottic narrowing. We also have a historical bias in the UK towards inhalational induction whenever there is an airway problem. Recent work shows quite clearly that for adult subglottic stenosis (extrathoracic, awaiting reconstruction) intravenous induction, muscle relaxation and positive pressure ventilation is superior to maintaining spontaneous respiration.⁶ Even when 'experts' are presented with the same case scenario, it is interesting to read the degree of thought required to prepare an airway strategy and the different approaches advocated.^{9,10}

Safe airway management is dependent on establishing the best airway plan for any given circumstance considering the experience of the anaesthetist, surgeon, equipment and team available.¹¹ While the primary plan may be directed at a specific goal (i.e. tracheal intubation) the back-up plan(s) may have the same or a different one (i.e. effective oxygenation, waking the patient). The back-up plan is just as, if not more, important and often discussion about the best primary airway plan has obscured or diverted attention away from the fact that the safety of airway management resides in the 'whole strategy'. It requires the same level of thought as the primary plan and to be competent the team needs to firstly recognise that the primary plan is not working, secondly communicate this, and finally act to institute the back-up plan at the correct time.

For example, the best airway plan for a patient with a manageable laryngeal tumour might be attempted direct laryngoscopy and the back-up plan rigid bronchoscopy and jet ventilation. With numerous attempts at direct laryngoscopy swelling, airway distortion, oedema and bleeding may make rigid bronchoscopy impossible. If however the back-up plan had been instituted earlier it may have been successful. Similarly, another group may decide the back-up plan should be direct tracheal access with cannula cricothyroidotomy. However if the cannula is not



immediately available and or the team lack familiarity with high pressure source 'jet' ventilation this may lead to failure of the back-up plan. The back-up plan needs to start at the correct time with the appropriate equipment, personnel and location to have the best chance of success at establishing alveolar ventilation. The tendency to start management in the anaesthetic room may not be a logical approach when the rest of the team are in the operating theatre.

Hospitals which normally undertake head and neck surgery have the 'luxury' of experience in dealing with critical airways, particularly the availability of skilled surgical expertise. Their results should compare favourably with other hospitals where surgical tracheostomy is rarely performed. Here, combined teaching and practice sessions and reflection will provide the opportunity to learn from near misses.

No plan is always successful and experience, adaptability, skill and fortune may determine the outcome when a prepared strategy has been unsuccessful. Reading the case scenarios in this chapter, which are all of adverse outcome, we have used the following scheme in assessing whether there are learning points from the described management and outcome.

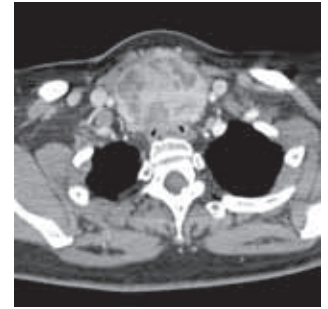
- Was the preoperative assessment, including imaging, adequate?
- Was preoperative imaging reviewed by the surgeon and anaesthetist?
- Were the primary and back-up plans pre-formulated and compatible with the patient's presentation?
- Was the back-up plan activated at the correct time?
- Was there evidence of good team work?
- Was specialised equipment and experience to use it available when needed?
- Was senior anaesthetic and surgical input apparent at an early stage?

Case review

We have tried to organise the enormous amount of data from these 72 cases by breakdown into various groups by location or timing of airway event. It should be re-iterated that undergoing planned primary surgical tracheostomy under local or uncomplicated general anaesthesia were not qualifying airway events for this project.

Induction of anaesthesia for diagnostic or resective surgery

There were 21 reports of difficulties encountered at induction of anaesthesia. In one of these, the problem was caused by an unanticipated subglottic stenosis in a patient having surgery elsewhere on the body. In all other cases the surgery was to the head, neck or trachea. The largest group (13 reports) were in patients with upper



aerodigestive tract tumours, with another three reports in patients with infection. Other surgery planned (one each) was thyroidectomy, re-siting a displaced long-term tracheostomy tube, control of intra-oral bleeding after hanging, posterior cervical stabilisation and to re-establish velopharyngeal function.

Case 1

A young adult patient had been admitted urgently after pulling out a long-term tracheostomy tube (inserted following upper airway trauma). A small standard tracheal tube had been inserted through the stoma and the patient had come to theatre for reinsertion of a tracheostomy tube. The plan was to remove the tracheal tube over a Cook Airway Exchange catheter but a test 'jet ventilation' prior to extubation caused bilateral tension pneumothoraces and significant surgical emphysema. The patient was rescued by bilateral chest drain insertion and tracheostomy with a variable-flange tracheostomy tube. The patient was admitted to ICU and made a full recovery.

Most patients were managed during the hours 08.01–18.00 with a consultant anaesthetist present. Obesity was not generally a factor for the 13 patients with advanced upper aerodigestive tumours most of whom were men aged 41–60 years. The youngest patient was Case 1 and the oldest Case 2.

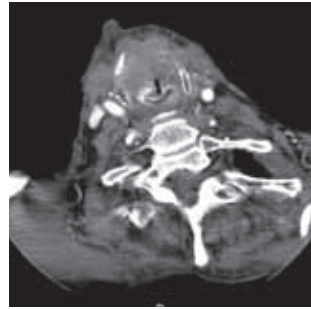
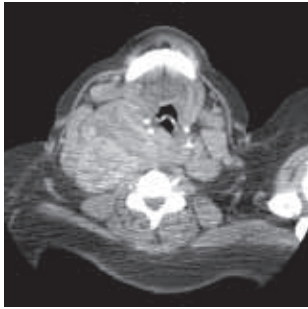
Case 2

An ASA 3 elderly patient was scheduled for panendoscopy and biopsy of a presumed airway tumour. Preoperatively, the patient appeared comfortable, with mild stridor and was able to lie flat without any distress. No airway investigations had been undertaken and general anaesthesia was induced. The tumour obscured the larynx, intubation and mask ventilation were impossible and the patient suffered a cardiac arrest from gross hypoxia. The ENT surgeon performed an urgent surgical tracheostomy and the patient was resuscitated. The patient died several months later from inoperable disease.

When a condition is chronic, training of respiratory muscles can lead to minimal symptoms despite a very narrow airway that may be difficult to instrument and that may compromise ventilation once anaesthetised.

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Without adequate assessment of such patients some will inevitably present with difficult or impossible to manage airways and lead to avoidable death and brain damage. Assessment forms part of professional duty. Some patients with advanced disease are only suitable for tracheostomy under local anaesthesia and such an option should not be judged a professional failure. In Case 2 the LR noted that in retrospect 'this was the only safe option'.

The airway was anticipated to be difficult in all but two patients. The first patient, an obese middle-aged patient, had an unanticipated sub-glottic stenosis (possibly from a previous smoke inhalation injury). Tracheal intubation was eventually managed with the aid of a fibrescope through a supraglottic airway device (SAD). The second patient is Case 3.

Case 3

A middle-aged, but not obese patient was scheduled for biopsy of a suspected tumour of the base of tongue. The patient had undergone radiotherapy to the head/neck following the discovery of a malignant neck node four years previously and had continued to smoke. The consultant anaesthetist did not expect any particular problems. However, after induction of general anaesthesia, on attempting laryngoscopy no recognisable laryngeal structures could be seen and mask ventilation was difficult. A satisfactory airway could not be achieved with a SAD. Fibreoptic endoscopy showed an 'inflamed and swollen epiglottis' and fibreoptic intubation was not successful. The patient had an emergency surgical tracheostomy in the anaesthetic room with satisfactory maintenance of oxygenation via facemask ventilation.

A high level of suspicion is needed in patients with upper airway tumours. Previous radiotherapy often worsens the situation and should be seen as a 'red flag'. The airway may be very difficult after induction of anaesthesia.

Case 4

A patient presented for microlaryngoscopy with stridor. Awake fibreoptic examination showed tumour in the upper trachea. After tracheal intubation ventilation became difficult. A tracheostomy was formed to assist ventilation but did not help. Distal tumour in the trachea prevented ventilation. Bilateral pneumothoraces developed. The patient died.

Table 1 Events during Maintenance (females 5, males 3)

Age	Weight	Qualifying event	Outcome	Surgery being performed	Problem	Resolution
Child	normal	ESA	Full recovery	Removal inhaled foreign body	Failed removal, sudden hypoxaemia	Surgical tracheostomy, FB removed
Elderly	underweight	Death	Death	Biopsy tumour upper airway	Intubation success but failed ventilation	Surgical tracheostomy, failed ventilation
Adult	obese	ESA/ICU	Full recovery	Tonsil biopsy under sedation	Bleeding, failed intubation/ventilation	Cricothyroidotomy followed by tracheostomy
Elderly	obese	ICU	Death	Upper GI endoscopy under propofol boluses	Presumed aspiration	Intubated, to ICU, late death
Elderly	underweight	ICU	Death	Palliative tracheostomy	False surgical tract, bleeding, intraluminal tumour	Difficult tracheostomy, to ICU, late death
Adult	uncertain	ESA/ICU	Full recovery	Planned arytenoidectomy	Desaturation during supraglottic jet ventilation	Surgical tracheostomy
Elderly	normal	Brain damage	Full recovery	Planned tracheostomy	Failure tracheostomy insertion, cardiac arrest	Resuscitated, successful insertion tracheostomy
Elderly	underweight	ESA	Full recovery	Laser resection of laryngeal tumour	Failed supraglottic ventilation	Failed needle cricothyroidotomy, surgical tracheostomy



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Table 2 Events in Recovery (female 4, male 4)

Age	Weight	Operation	What happened	Resolution	Outcome
Elderly	uncertain	Neck dissection, flap	Airway obstruction	Reintubation, to ICU	Full recovery
Child	normal	Tonsillectomy	Obstruction, blood clot in trachea	Failed resuscitation, despite reintubation	Death
Adult	normal	Septoplasty	Post obstruction pulmonary oedema	Reintubation to ICU	Full recovery
Adult	normal	Nerve repair	Bleeding	Back to theatre, failed intubation, cricothyroidotomy	Full recovery
Elderly	underweight	Bronchoscopy and laser	Massive haemorrhage	Surgical tracheostomy	Death
Adult	normal	Radical neck dissection, flap	Bleeding, stridor	Failed intubation, surgical tracheostomy	Full recovery
Adult	normal	Biopsy tracheal tumour	Bleeding, oedema	Return to theatre, then ICU admission	Full recovery
Elderly	underweight	Laser resection glottic tumour	Stridor	Return to theatre, surgical tracheostomy	Full recovery

Pre-operative imaging may identify multiple lesions in the respiratory tract and therefore enable appropriate planning for their management. Without it, unexpected and perhaps unmanageable complications may occasionally arise.

Events during maintenance of anaesthesia

In eight patients the problem occurred during the maintenance phase of anaesthesia/surgery (Table 1).

Case 5

An adult patient underwent biopsy of a tonsillar mass under local anaesthesia with deep sedation, resulting in profuse bleeding of considerably more than one litre. Both ventilation and intubation failed due to the bleeding. Severe hypoxaemia developed leading to bradycardia. The airway was rescued initially by emergency needle cricothyroidotomy followed by surgical tracheostomy.

When airway surgery takes place and bleeding or excess secretions are a possibility, airway control is necessary. Either the patient must maintain their own airway or the anaesthetist (or surgeon) must take over the airway. Performing potentially bloody airway surgery during heavy sedation is rarely likely to be a good primary plan. Oxygen delivery may be compromised and the ability to rescue a deteriorating airway is likely to be considerably compromised by both the effects of sedation and surgery/bleeding in the airway.

Another elderly patient was admitted with advanced post-cricoid carcinoma and bilateral recurrent laryngeal nerve palsies. Although intubated successfully under general anaesthesia for surgical tracheostomy, problems with ventilation developed during surgery possibly due to tumour in the trachea. The patient required rigid bronchoscopy and insertion of an airway exchange catheter into the trachea to provide a landmark to enable the second

surgeon to find the trachea and complete the procedure. The patient went to the ICU and recovered initially but died later from disease progression.

Multiple lesions in the respiratory tract may lead to problems intra-operatively as well as at the start of surgery.

Events at extubation or early in recovery

Five case reports concerned events at extubation and were managed in theatre. Three were after laser surgery to the airway (arytenoidectomy, tracheal stenosis and laryngeal surgery) and were managed by re-intubation or tracheostomy under local anaesthesia and overnight admission to ICU. Another case report detailed laryngospasm and probably aspiration of blood at extubation after tonsillectomy requiring reintubation and transfer to ICU. The final such report, in a 100 kg diabetic patient, was of loss of the airway at extubation, after drainage of a submental abscess which followed dental extraction. The airway was managed by awake fiberoptic intubation (FOI) for the incision and drainage procedure, and prompt awake FOI was also successful when the airway was obstructed after extubation. A tracheostomy was then undertaken and the patient transferred to ICU.

Eight patients developed problems in recovery with airway management completed in recovery or requiring transfer back to theatre (Table 2). There was one death in a child following tonsillectomy, ascribed in the report to aspiration of a blood clot. This is described in detail in Chapter 21.

Of the events in this project occurring at extubation or in recovery a disproportionate number involved surgery to the airway. Head and neck pathology may not be resolved by surgery. Debulking surgery should improve the calibre of the airway but after diagnostic biopsies without debulking the airway may be more swollen and oedematous. Residual anaesthesia leaves the airway 'at-risk' until the patient

Table 3 Events when securing the airway in theatre environment

Disease	Obstructed airway	Airway Management	Outcome
Base of tongue tumour	Yes	Failed awake FOI and Airtraq intubation, cricothyroidotomy for oxygenation, formal tracheostomy under LA	Full recovery
Floor of mouth tumour	Yes	Failed inhalational induction, surgical cricothyroidotomy then surgical tracheostomy	Full recovery
Post extensive tumour resection	Yes	Failed awake FOI, surgical cricothyroidotomy in anaesthetic room, then surgical tracheostomy	Full recovery
Transglottic tumour	Yes	IV induction, failed intubation, failed cricothyroidotomy, died in anaesthetic room	Death
Oral cancer, radiotherapy	Yes	Failed inhalational induction, needle cricothyroidotomy then surgical tracheostomy	Full recovery
Thyroid cancer	Yes	Transtracheal catheter under LA prior to awake FOI, barotrauma with test jet, intubated, tracheostomy	Died from disease
Vocal cord palsy	Yes	Inhalational induction, failed intubation, SV maintained, surgical tracheostomy	Full recovery
Acute epiglottitis	Yes	Inhalational induction, failed intubation, SV maintained, surgical tracheostomy	Full recovery
Assault, airway obstruction	Yes	IV induction, unable to insert laryngoscope blade, surgical tracheostomy	Full recovery
Acute epiglottitis	Yes	Failed intubation in emergency department, large-cannula cricothyroidotomy followed by surgical tracheostomy in theatre	Full recovery



is fully awake and the presence of blood in the airway may cause coughing, laryngospasm or aspiration. Active bleeding may lead to airway compression or compromise. The emergence and recovery period is a high-risk period for these patients and the team should remain immediately available until the patient is safe.

Reoperation from the ward

Three events were reported in adult patients who returned to theatre after elective head and neck surgery, requiring emergency re-operation. The first case is Case 6. A second patient developed stridor two days after carotid endarterectomy. Inhalational induction led to airway obstruction and failed intubation, the airway was maintained by a ProSeal LMA whilst a surgical tracheostomy was performed. The third patient (BMI 40 kgm⁻²) returned to theatre for evacuation of a neck haematoma following thyroidectomy. The primary plan was awake fiberoptic intubation but the airway was lost through oversedation. Bag-mask ventilation was not possible and the already scrubbed surgeon proceeded successfully to immediate tracheostomy.



Case 6

A patient bleeding after radical neck dissection returned to theatre in the early hours of the morning. The patient was asymptomatic apart from a dull ache and previous laryngoscopy was grade 2. The anaesthetist undertook a rapid sequence induction in the anaesthetic room. At laryngoscopy the tissues were completely oedematous and the larynx was not visible. A blind attempt in placing a bougie failed. A prepared fibroscope was inserted but again no landmarks could be recognised. Ventilation via a SAD failed and a large-cannula cricothyroidotomy was performed. However, ventilation was still not possible. The patient was rushed into theatre for a surgical tracheostomy with an intubating LMA in place but before intubation through this was started the thiopentone and suxamethonium used at induction wore off enabling the patient to awaken. A difficult awake tracheostomy was undertaken and the patient made a full recovery.

After bleeding into the neck there may be compression but there will be oedema: these airways can be predicted to be considerably more difficult to manage than during the original surgery. Knowledge of ease or difficulty at that time is useful only in indicating that it will now be more difficult still. Opening a wound to relieve haematoma may reduce compression but will not resolve airway oedema. The airway is likely to remain difficult to manage.

Anaesthetic management in the theatre environment to secure the airway

There were ten patients who were managed by an anaesthetist when the primary aim of management was to secure an 'at-risk' airway (see Table 3). Six of these patients came direct from the emergency department. Some of the patients were transferred in a critical condition: e.g. Case 7.

Case 7

A 120 kg adult patient with rheumatoid arthritis and obstructive sleep apnoea was admitted to the emergency department with acute epiglottitis. Intubation in the resuscitation room failed and the patient was transferred to theatre with a SAD in place. Oxygen saturations were 80% breathing 100% oxygen. A Melker large-cannula cricothyroidotomy was inserted with some difficulty. Pulseless electrical activity (PEA) developed and a surgical tracheostomy was placed as resuscitation continued. The patient made a full recovery.

Cases in the NAP₄ project should be used by hospitals to test their readiness to manage critical airways. In some hospitals it will be preferable to equip the resuscitation room to undertake emergency surgical tracheostomy to avoid perilous transfers.

Patients managed in the emergency department

Five patients in this cohort were admitted via the emergency department and were not managed in theatre: Case 8 is an example. Other cases:

- A patient with airway oedema, presumed due to anaphylaxis, managed successfully by emergency tracheostomy.
- A middle-aged adult with known laryngeal cancer and severe stridor managed by failed minitrach and then surgical tracheostomy.
- A patient with facial trauma sustained during a seizure required intubation due to a low GCS. Intubation failed due to oropharyngeal bleeding obscuring the view. A percutaneous dilatational tracheostomy successfully secured the airway.
- A patient, on warfarin with an INR >10, with stridor after a traumatic cervical vertebral fracture requiring airway rescue. An enlarging retropharyngeal haematoma caused failed direct laryngoscopy and required surgical cricothyroidotomy. Resuscitation was unsuccessful and the post-mortem confirmed tracheal compression from haematoma.

Case 8

An adult patient with maxillofacial trauma required a CT scan under general anaesthesia. An unsupervised junior anaesthetist attempted a rapid sequence induction but was unable to intubate or ventilate. There was no SAD available to rescue the airway. A needle cricothyroidotomy was attempted but failed and the patient had a hypoxic cardiac arrest. A surgical airway was inserted and the patient resuscitated. A more experienced anaesthetist intubated without difficulty.

These cases illustrate quite clearly the need for emergency departments to be prepared to manage airway obstruction and also failed airway management. Expertise and equipment to perform emergency surgical airway should be available.

Patients in ICU at the onset of problems

There were ten case-reports in which the events started in ICU. The majority were patients after head and neck surgery (six) or after securing the airway (two). Generally the problems were either deterioration in a patient who required intubation, or blockage/displacement of the tracheal tube or tracheostomy.

Case 9

An elderly patient underwent tracheostomy under local anaesthesia in theatre to relieve supraglottic airway obstruction due to tumour. The patient was transferred to ICU but in the early hours of the morning the tracheostomy became displaced. It proved impossible to intubate the patient using direct laryngoscopy and reinsertion of the tracheostomy took a considerable time due to massive surgical emphysema. The patient suffered hypoxic brain damage and subsequently died.

Case 10

A middle-aged patient had a tracheostomy placed in theatre during bilateral neck dissection and free flap. About 24 hours later in ICU there was a sudden inability to ventilate through the tracheostomy. Reintubation, guided by flexible fibroscope, was attempted through the tracheostomy site as well as through a laryngeal mask. The situation was made more difficult by surgical emphysema and tension pneumothoraces, the patient suffered severe brain damage and died.

In these ten reports five died or sustained brain damage as a result of the event indicating a high incidence of poor outcomes in patients with head and neck disease in ICU/HDU. Inadvertent displacement of a tube in a difficult airway is a very challenging event. Successful management requires a prepared strategy, experienced personnel and readily available equipment at all times. These issues are also explored in Chapters 6, 9, 16 and 23).

Numerical analysis

There were 72 cases reported to the project in which the airway problem was in association with an acute or chronic disease process in the head, neck or trachea. The 72 reports were garnered from 55 anaesthesia, ten ICU/HDU and seven emergency department forms and represent more than one-third of all cases reported to the project. Approximately 70% of the reports were associated with what might be termed an obstructed airway.

Qualifying airway events included death or brain damage in 13 cases, emergency surgical airway in 50 and unexpected ICU admission in 27. The outcome at time of form completion was death in 17, partial recovery in two, full recovery in 51 and not recorded in two cases. In the anaesthesia group there were six deaths and one case of brain damage due to the event.

Problems at induction of anaesthesia for diagnostic or resective surgery formed the largest group (21 case-reports), with other case-reports during extubation/recovery (13) and maintenance of anaesthesia (eight). In addition there were problems in ten patients at 'induction' in theatre when the aim was primarily to secure the airway

and in another three patients transferred to theatre from the ward for re-operation following planned surgery. Seven patients presented to the emergency department and were managed either entirely there (five) or transferred to theatre (two). One patient died. The most common problem in the ten ICU patients was obstruction or displacement of a tracheostomy tube. Five of these patients died.

The review panel suggested, on the submitted material, that the airway management might be considered poor in nearly one-third of case-reports.

Discussion

Airway management themes for head and neck pathology

Whilst analysing this large group of patients with head and neck pathology a number of consistent themes emerged. Some of these themes have been described in the literature by those experienced in dealing with head and neck pathology. However, this project amplifies any individual or institutional experience and represents probably the largest prospective dataset of airway problems in patients with head and neck pathology.

Approximately 70% of the reports in this chapter were in patients with an obstructed airway. This included patients with stridor but also those patients (fewer in number) with a chronic disease process and airway narrowing but no stridor. Here we try to group cases by initial airway management plan, noting its success and the back-up plan when it failed.

Individual reports used one or more of the techniques described to manage the airway and may therefore appear in more than one discussion of techniques. It is also important to recognise that this dataset includes only those patients who developed airway problems with a given technique and does not give us information on the number of successful uses of that technique.

Direct laryngoscopy and airway deterioration

A consistent theme to emerge from patients with head and neck pathology was the deterioration in the airway following single or repeated attempts at direct laryngoscopy. Head and neck tumours can be friable, necrotic, oedematous and cause considerable airway distortion. This combination not only makes direct laryngoscopy difficult but can cause bleeding, soiling, increasing oedema, fragmentation of any tumour and dramatically worsen the ability to facemask ventilate between direct laryngoscopy attempts.

Following induction of anaesthesia and attempts at direct laryngoscopy the airway deteriorated with increasing



difficulty in ventilation in 13 patients. With repeated attempts the airway became impossible to ventilate in 15 patients. All these 15 patients subsequently required a surgical airway. Case 11 is an illustrative example.

Case 11

A middle-aged ASA 3, slim patient presented for elective clearance of infected tissue following pharyngeal surgery and radiotherapy. A consultant anaesthetist and consultant surgeon attended. Facemask ventilation, direct laryngoscopy, laryngeal mask placement and direct tracheal access were all predicted to be difficult. Facemask ventilation was optimal following induction of anaesthesia and muscle relaxation but deteriorated after four attempts at direct laryngoscopy with increasing bleeding, oedema and secretions. Ventilation became impossible and a surgical tracheostomy was performed.

It is important to recognise for patients with head and neck pathology that the airway may deteriorate with attempts at direct laryngoscopy and ultimately can lead to total airway obstruction. Persisting with the same failing technique has no logic and has been well documented to lead to an increase in major complications.¹² These data emphasise the importance of ensuring that early attempts at intubation are optimised (best patient preparation, best position, best laryngoscope blade, best intubator) and imply that when direct laryngoscopy fails this should be accepted, announced and alternatives that have been included in the airway strategy (whether alternative methods of achieving intubation or alternatives to intubation) should be pursued.

Inhalational induction and maintenance of spontaneous ventilation

Another theme that emerged from the project data was the deterioration in the airway following inhalational induction and subsequent inability to maintain spontaneous ventilation.

Following induction of anaesthesia, there was no compromise to spontaneous ventilation in four patients. In 12 patients the airway was compromised and spontaneous ventilation became more difficult with oxygen desaturation. In 11 patients spontaneous ventilation became impossible, either because the airway deteriorated further or after direct laryngoscopy attempts were made. Cases 12–14 are examples.

It is important to recognise that inhalational induction techniques with maintenance of spontaneous ventilation in patients with head and neck pathology can and do fail. Some anaesthetic techniques were questioned. The use of propofol, remifentanyl and an inhalational agent (all together) was associated on more than one occasion with a patient too light to allow airway manipulation but no longer breathing. In some cases when the airway was lost there

was either reluctance to use (or even an active decision to avoid) muscle relaxants and controlled ventilation. This persisted despite respiratory distress, airway obstruction, hypoxia and a peri-arrest state in some cases. It was apparent in these cases that the patient did not 'rapidly awaken' when airway compromise arose and it was frequently not apparent what the 'plan B' was, or indeed if there was one.

Case 12

A young fit and slim adult presented with a dental abscess and facial swelling. Inhalational induction and maintenance of spontaneous ventilation with sevoflurane was planned. Following induction airway obstruction and laryngospasm occurred. No muscle relaxant was administered, airway obstruction persisted with desaturation. Direct laryngoscopy and laryngeal mask ventilation failed. Airway obstruction and inability to ventilate required a surgical airway.

Case 13

An elderly, ASA 4 patient presented with stridor, due to invasive thyroid carcinoma. Inhalational induction and maintenance of spontaneous ventilation with sevoflurane was planned. Following induction airway obstruction and laryngospasm occurred. No muscle relaxant was administered; direct laryngoscopy revealed a grade 2 laryngeal view, attempted intubation resulted in trauma and oedema with no ventilation. A surgical airway was required.

Case 14

An elderly, ASA 3 patient who was known to have a grade 4 direct laryngoscopy view due to oral carcinoma and radiotherapy, presented as an emergency with stridor. Inhalational induction with halothane failed, ventilation was impossible and the patient deteriorated to PEA cardiac arrest requiring CPR. Attempted fiberoptic intubation failed and the airway was successfully rescued with a surgical airway.

Flexible fiberoptic guided intubation in the presence of head and neck disease

The use of flexible fiberoptic intubation techniques for the management of patients with a difficult airway is universally recognised. However, in this group of head and neck patients with airway problems flexible fiberoptic guided intubation failed in the majority of patients in which it was attempted. Of 23 attempts to use flexible fiberoptic techniques 14 failed and nine were successful. In those patients where fiberoptic techniques were unsuccessful a surgical airway was usually required.

Two patients with a known difficult airway had awake flexible fiberoptic intubation for surgery. Following extubation airway obstruction developed in these two patients and both had repeat successful awake fiberoptic intubation by the same anaesthetist.

Asleep flexible fiberoptic intubation through a SAD was successful as a rescue technique in six patients with head and neck pathology including vertebral body fracture, haematoma, pharyngeal oedema, pharyngeal bleeding and following vocal cord biopsy. Asleep fiberoptic intubation without a SAD was successful in one patient in this group.

Of the 14 failures with this technique four were attempted awake and ten patients asleep. Awake failure was due to an inability to either identify the glottic inlet or an inability to pass either the fiberoptic scope or tracheal tube. Asleep fiberoptic failure in ten patients was as a result of repeated attempts, inability to identify the glottic inlet, inability to pass the fiberoptic scope or the tracheal tube, bleeding and airway obstruction.

From this project it is not possible to say how successful or unsuccessful awake or asleep fiberoptic intubation techniques are in patients with head and neck pathology, because most successful attempts would not have presented here. It is however important to recognise that flexible fiberoptic guided intubation attempts, either awake or asleep, can and do fail in head and neck patients. If fiberoptic intubation is a primary plan there are good theoretical reasons for performing this while the patient is awake to maintain spontaneous ventilation, prevent hypoxaemia, maintain the 'airway space' required for fiberoptic visualisation, maintain a gas-flow which often helps when trying to locate the glottis and to retain the patient's ability to vocalise, move or reposition which may assist at various stages of the procedure. Nevertheless a plan B is still required.

Cannula cricothyroidotomy for airway rescue

Cannula cricothyroidotomy is well recognised as a rescue tool for the 'can't intubate, can't ventilate' (CICV) scenario and can be divided into fine bore (<3 mm) and large bore (>3 mm) techniques. Fine bore devices require high pressure source 'jet' ventilation and large bore devices (especially those >4mm) may allow positive pressure ventilation with a 'bag' or other low pressure source. Data on the type of cricothyroidotomy device was in some cases absent and so detailed analysis between devices was not possible.

The project methodology was designed to capture all CICV scenarios in head and neck patients during the study year. Even though this is unlikely to have been achieved the current data probably represents the best information in the literature to date, on the efficacy of cannula cricothyroidotomy for CICV in clinical practice. The reports indicate that in real clinical situations the techniques are successful in less than half these patients. Of 27 uses of cannula cricothyroidotomy in head and neck patients 12 were successful (by both large and small bore devices) and 15 failed. Failure of cannula cricothyroidotomy was due to misplacement, inability to place, fracture, kinking, blockage, dislodgement and barotrauma.

It is important to recognise that cannula cricothyroidotomy has a significant failure rate in CICV, and for head and neck patients a surgical tracheostomy is often required.

The subject is discussed further in Chapter 13.

Location and teamwork

There were several reports of events, including death, in the anaesthetic room even in patients with a severely obstructed airway. It would have been preferable for the management to start in the operating theatre with the whole team briefed and ready to execute the prepared strategy. It cannot be easy for a surgeon, without warning, to rush into an anaesthetic room and undertake a surgical tracheostomy. The anaesthetic room may be small or narrow with suboptimal lighting, unavailable diathermy and limited assistance.

Case 15

A patient with an advanced transglottic tumour required tracheostomy prior to radiotherapy. Anaesthesia was induced with total intravenous anaesthesia in the anaesthetic room and intubation attempted unsuccessfully by rigid videolaryngoscopy. Rapid oxygen desaturation developed and both facemask ventilation and needle cricothyroidotomy failed. A late peri-arrest attempt at intubation was made by the surgeon. The patient died in the anaesthetic room.

Some cases started without the surgeon immediately available and scrubbed for reasons best described under planning, communication and human factors. Amongst the key elements required for high quality management of patients with head and neck pathology are sound planning, clear communication and good teamwork. Deficiencies in these were noted to be at the core of some events in this group, while in others excellence in these factors led to prompt rescue of impending disaster.

Awake versus anaesthetised tracheostomy

There were several reports in which the review panel judged tracheostomy under local anaesthesia to be the 'obvious' strategy but anaesthesia was induced first. With fewer opportunities for junior surgical staff to perform routine ICU surgical tracheostomies there will inevitably be less experience when undertaking a surgical tracheostomy under local anaesthesia.¹³

Summary

Head and neck cases comprise a third of all cases reported to the project. That in itself indicates the high-risk nature of these cases and that they may present great difficulty to the teams managing them. A number of reports with adverse outcome were well managed with complimentary comments from the panel. Very many difficult cases are skilfully and successfully managed without complication and none of these would have been reported to this project.



We have tried to summarise our learning points from the major complications reported, in the hope that it may inform the process whereby individuals, departments and institutions learn from near-misses.

We posed, in the section entitled 'what we already know', a number of mechanisms of adverse outcome and found examples of all in the cases examined. It is over ten years since the head and neck CEPOD report was published and there is worrying evidence of failure to learn important lessons from that report. If we are to minimise adverse outcomes in head and neck cases there must be strategic direction jointly from senior anaesthetic and surgical organisations to devise and adopt recommendations for good practice.

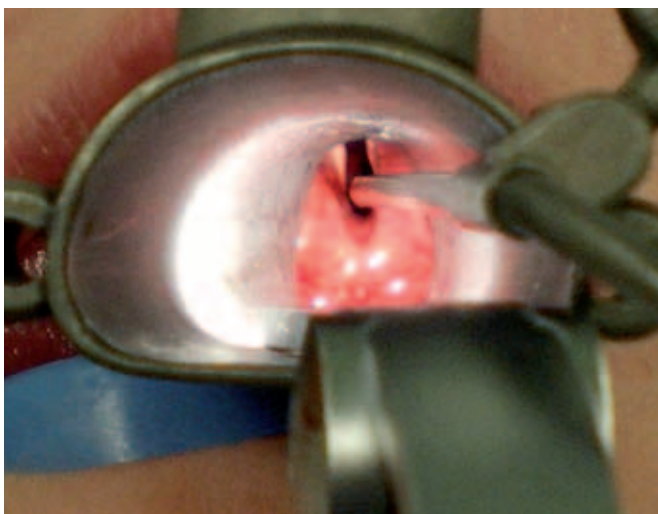
Learning points and recommendations

Patients with upper airway tumours and those with previous radiotherapy are a challenging group of patients to manage. Disease progression, infection and the consequences of radiotherapy such as an increased tendency to oedema may further complicate these patients.

Assessment and planning

This project has identified omissions in pre-operative assessment in these complex cases in particular where further investigation of the airway by CT, MR or nasendoscopy, was either not performed or on occasion it was performed but the results not viewed by the anaesthetist.

Recommendation: Anaesthetists who attend patients with head and neck pathology should be familiar with CT, MR and nasendoscopy of the airway and should use it when available to add useful information in planning anaesthetic airway strategy.



Recommendation: In patients with increased risk available airway investigations should be reviewed jointly by the surgeon and anaesthetist.

Recommendation: To assist planning the airway strategy the level of airway obstruction should be determined whenever possible: at least whether it is tongue-base, perilaryngeal or subglottic and whether the laryngeal inlet is affected.

Recommendation: If no additional investigations have been performed (or performed recently) consideration should be given to awake flexible nasendoscopy in the operating theatre to reassess the situation prior to starting anaesthesia.

Failure

All techniques may fail in these complex cases.

Recommendation: Successful management of these cases requires not one plan but a series of plans pre-formulated into an 'airway management strategy'. This strategy should be agreed by the anaesthetist and surgeon prior to starting. The theatre team should be briefed on the strategy and the necessary equipment and personnel assembled.

Location

The anaesthetic room is usually poorly designed for managing a complex airway problem involving several teams. It hinders communication, teamwork and efficient performance of procedures.

Recommendation: The anaesthetic management of any case which may involve surgical tracheostomy as a rescue technique should start in the operating theatre. Consideration should be given to anaesthetising all complex head and neck cases in the operating theatre.

Techniques

Multiple attempts at direct laryngoscopy in patients with head and neck pathology can lead to total airway obstruction.

Recommendation: Multiple attempts at direct laryngoscopy in patients with head and neck pathology should be avoided.

Fibreoptic techniques

Flexible fibreoptic intubation attempts, either awake or asleep, in head and neck patients can and do fail.

Recommendation: When patient factors make fibreoptic intubation the preferred option in patients with head and neck pathology consideration should first be made to performing it awake. The airway strategy should accept it may fail, particularly when performed in an unconscious patient.

Inhalation induction

Inhalational induction techniques with maintenance of spontaneous ventilation in patients with head and neck pathology can and do fail.

Recommendation: When inhalational induction is the primary plan for cases involving head and neck pathology the airway strategy should accept it may fail with loss of the airway. A clear rescue plan, that does not assume the patient will wake, should be in place before anaesthesia starts.

Cannula cricothyroidotomy

Emergency large or small bore cannula cricothyroidotomy, when undertaken in earnest, commonly fails.

Recommendation: When emergency cricothyroidotomy is included as part of the airway strategy for cases involving head and neck pathology success should not be assumed. The airway strategy should accept it may fail.

Patients bleeding into the neck after head and neck surgery

The airway can be predicted to be considerably more difficult to manage than during the original surgery.

Recommendation: Anaesthetic management of these patients is predictably difficult and difficulty may affect all approaches to the airway. Senior anaesthetists and surgeons must be involved. While opening wounds to relieve haematoma may reduce airway compression it will not resolve resultant airway oedema and the airway is likely to remain difficult to manage.

Extubation and recovery

Extubation and early recovery are times of risk for these patients.

Recommendation: For cases with head and neck pathology the team managing the patient should not disperse until the patient is clearly managing their own airway and is safe.



A massive thyroid such as this may cause airway compromise

ICU

ICU is a hazardous environment for patients with head and neck pathology who develop complications.

Recommendation: The maintenance of a clear airway in patients admitted to ICU requires continuous preparedness for insertion of a tracheal tube or tracheostomy in difficult circumstances. As in theatre this requires an airway strategy (ability to recognise and diagnose the problem, the right equipment and personnel to respond with a series of pre-formulated, logical and sequential plans).

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Headline

Aspiration was the commonest cause of death in anaesthesia cases reported to NAP₄. One in five of all reports described aspiration of gastric contents as a primary or secondary event (17% primary, 5% secondary). Aspiration of gastric contents accounted for 50% of anaesthesia-related deaths. In addition to the deaths many of those who survived did so only after a prolonged period of time on Intensive Care. Aspiration of blood clots led to two cardiac arrests including one death. Aspiration was associated with incomplete assessment of aspiration risk and a failure to alter anaesthetic technique when aspiration risk was present. An excess of the cases involved emergency surgery and trainee anaesthetists. There were clear examples of aspiration occurring at induction when classical indications for rapid sequence induction were present and it was not used. A significant number of aspirations occurred during maintenance while a standard laryngeal mask was in place. The overall impression in these cases is of failure to identify risk and a failure to use available precautions to reduce the risk of such events: these include rapid sequence induction for higher risk cases and the use of second generation supraglottic airway devices rather than first generation devices for patients at lower risk. Aspiration and its prevention should remain major concerns for all anaesthetists.

What we already know

Aspiration of gastric contents is recognised to be an important complication during anaesthesia. In 1956 a study of 1,000 deaths associated with anaesthesia reported that 'regurgitation and vomiting' was the largest single cause of death.¹ The surgery most frequently associated with these complications was strangulated hernia repair. Soon afterwards, in 1961, Sellick described the technique of 'cricoid pressure'² which evolved into what in the 1960s was a well established technique of 'rapid sequence induction' (RSI).

Numerous reports have examined the incidence of aspiration during anaesthesia and the quoted incidences vary widely. Without searching for extremes of incidences it is possible to find large historical studies that have reported rates of anaesthesia-associated fatal aspiration from one in 45,000³ to one in 240,000.⁴ In 1993 in a study of more than 400,000 cases Warner et al reported a risk of aspiration of approximately one in 4,000 during elective surgery and one in 900 during emergencies.⁵ One interesting aspect of this study

was that almost two-thirds of aspiration events occurred either at the time of intubation or within a few minutes of extubation: clearly placement of a tracheal tube does not eliminate risk of aspiration and this study indicates that the periods of insertion and removal of a tracheal tube may themselves be high-risk. These studies predated widespread introduction of the classic laryngeal mask and since then a meta-analysis estimated the frequency of aspiration with a laryngeal mask during elective use to be one in 5,000.⁶

Aspiration of blood is generally considered to be less hazardous than aspiration of gastric contents. However aspiration of large formed blood clots into the trachea may cause complete obstruction (known in ENT surgery as the 'coroner's clot'). A degree of protection from aspiration of blood may be achieved by a cuffed tracheal tube, a correctly placed laryngeal mask or a throat pack, each having strengths and weaknesses. Of note the laryngeal mask may have benefits over the tracheal tube in protecting from airway soiling when the bleeding comes from above.⁷

Although not all universally accepted as being effective, some methods used to decrease the risk of aspiration or to minimise its consequences include:

- avoidance of general anaesthesia by use of regional anaesthesia
- routine pre-operative starvation
- nasogastric tube insertion and stomach drainage before (or during) anaesthesia
- premedication with prokinetics drugs, antacids, H₂-blockers and proton pump inhibitors
- tracheal intubation (routine and following rapid sequence induction)
- use of second generation supraglottic airway devices.

Recognising and quantifying risk of aspiration

Many risk factors for regurgitation are generally accepted: typically involving either failure of the lower oesophageal sphincter (hiatus hernia, known reflux, oesophageal disease) or excessive gastric volume. Gastric emptying is decreased by many factors such as pain, opioid medications, disease processes of the bowel and systemic diseases such as diabetes or chronic renal impairment. The risk of regurgitation is increased in patients with a high body mass index. Certain patient positions,

notably being head down or in lithotomy will increase the likelihood of regurgitation as does light anaesthesia and inadequate reversal of neuromuscular blockade at the end of anaesthesia, as laryngeal competence may be impaired without complete reversal.

If the world were purely black and white, patients could be readily dichotomised into those with risk and those not at risk. Taken to its logical conclusion those patients 'not at risk' would be 'without risk' and thus have zero risk of aspiration. Clearly the world is not black and white but has infinite shades of grey. More realistically the risk of aspiration is a spectrum. During an early study on the ProSeal[®] the author was required to insert a gastric tube in patients in the study whose airway was being managed with a ProSeal. Despite recruits for this study only being starved, healthy, low-risk patients with no recognised risk factors for aspiration several patients had significant gastric residues with volumes up to 200 ml. Asai published an editorial in the *British Journal of Anaesthesia*⁹ in response to a case series that described three major adverse outcomes (including one death) after aspiration during classic laryngeal mask use.¹⁰ The authors of the case series identified risk factors for aspiration in 19 of 20 patients in the literature reported to have aspirated while a laryngeal mask was in place. Asai's editorial listed 27 risk factors for aspiration, many of them generic such as 'drugs reducing gastric emptying'. To summarise, there are many risk factors for regurgitation and aspiration, it is highly likely that a large proportion of the population have at least one. As illustrated above, aspiration may also be a risk in patients with no identifiable risk factors. Aspiration risk is therefore a grey area, with a spectrum of risk from very high to low. Some patients it must be recognised have an *intermediate risk*.

Rapid Sequence Induction

In patients considered at additional risk of regurgitation or aspiration, RSI (despite a lack of clear definition) has been a staple of anaesthetic practice for 50 years. In recent years RSI has come under considerable scrutiny and some criticism; with some authors even arguing for its abandonment.^{11,12} It is accepted that RSI increases the risk of failed intubation (around 8-fold), it is also accepted that cricoid pressure may be poorly taught, poorly performed and sometimes ineffective. Vanner and Asai in an excellent editorial described both the limitations of RSI and a strategy for attaining most benefit from RSI, without blind obsession with it leading to patient harm.¹³

In practical terms RSI requires training, practice, good communication between those involved and an understanding of its limitations. When intubation is *difficult* cricoid pressure (more accurately cricoid force) should be reduced to prevent excessive force, or even removed. If, despite these actions, intubation *fails*, oxygenation

becomes the priority and cricoid force should be removed. One reason to remove it is that insertion of a SAD which may be part of airway rescue requires that the post-cricoid space is not compressed.^{14,15}

A recent publication from the American Society of Anesthesiologists Closed Claims Practice group reports that cricoid force was 'used' in half of claims relating to aspiration:¹⁶ whether this indicates poor technique or intrinsic inadequacy of the technique is open to debate. Claims for aspiration in which cricoid force was applied were settled for lower awards than those in which it was omitted.

Supraglottic airways

It has been variously argued that use of a supraglottic airway device (SAD) will reduce lower oesophageal sphincter tone by triggering the swallowing reflex and if reflux then occurs, channel material into the larynx. In an early study on the classic laryngeal mask a rate of 25% of regurgitation and soiling of the inside of the device was reported.¹⁷ However over time it has become accepted that the risk of aspiration with a classic laryngeal mask is low.⁷ Cadaver evidence identified a high oesophageal seal in those SADs that plug the top of the oesophagus¹⁸ and indicate that the laryngeal mask and others provide considerably greater protection from regurgitant fluid than does the unprotected airway.¹⁹ What is perhaps more relevant is that poorly positioned SADs in combination with controlled ventilation, or ventilation at high pressures via a standard laryngeal mask will lead to gastric inflation, and the risk of regurgitation.²⁰

More recently a group of SADs (second generation SADs) have been developed to try to reduce the likelihood of aspiration (ProSeal LMA, LMA Supreme, i-gel, Laryngeal Tube Suction II).²¹ While current evidence suggests that several of these devices may be more effective than the classic laryngeal mask in protecting the airway from aspiration^{22,23} proof of benefit of second generation SADs compared to a standard laryngeal mask or tracheal tube, is probably unattainable due to the low incidence of aspiration in elective surgery. The role of SADs in patients with modestly increased risk of aspiration therefore continues to be debated.

Alongside good technique the most important factor in minimising the risk of aspiration when using a SAD is good case selection (a form of 'clinical judgement'). A recent survey illustrates both the spectrum of perception of risk of aspiration and the variation in clinical judgement as to what is sensible and safe airway management (see Table 1).²⁴

The surveyed anaesthetists were asked how they would manage the airway of a patient presenting for knee arthroscopy with varying symptoms from a known hiatus hernia. The patient was assumed to refuse regional



CHAPTER 19

Aspiration of gastric contents and of blood

Table 1

	Laryngeal mask	ProSeal	Non RSI tracheal intubation	Modified RSI	Standard RSI
Asymptomatic	93 (62)	4 (4)	1 (21)	1 (9)	1 (5)
Post-prandial heartburn	73 (42)	4 (2)	7 (26)	12 (17)	4 (13)
Post prandial reflux	48 (22)	2 (2)	15 (26)	18 (31)	15 (20)
Supine reflux	12 (9)	1 (0)	12 (11)	31 (44)	44 (37)
Treated symptomatic reflux	70 (37)	9 (1)	15 (28)	5 (22)	2 (12)

anaesthesia. The question was posed both for a patient with a body mass index below 30 kg m⁻² and above 35 kg m⁻² and the figures in the Table represent: percentage in non-obese (percentage in obese).

Case review

Assessment of risk

The NAP₄ questionnaire specifically asked about risk of aspiration. An increased risk of aspiration was recorded in 35% of all patients rising to 42% and 50% in obese and morbidly obese patients, respectively.

Eleven of 83 patients judged to be at no increased risk had a primary aspiration. Of 23 patients with a primary anaesthesia-related aspiration, 11 were judged to have no increased risk and in two no assessment was made. Using Asai's list of risk factors of aspiration, above,¹⁶ it is arguable that at least nine of these 11 patients, including three who died, were at increased risk of aspiration. Factors included: recent trauma, recent ileus, recent pancreatitis, pain, recent opioids, obesity, light anaesthesia and chronic renal failure. Including secondary aspirations 27 of 29 patients who aspirated during anaesthesia had identifiable aspiration risk factors.

As the intended airway was a first generation SAD in 14 of the 23 patients who aspirated it seems an increased, sometimes markedly increased, risk of aspiration only rarely led to a change in airway management plans.

Case 1

An elderly patient was anaesthetised for fractured neck of femur surgery by an experienced anaesthetist. The patient had recently had pseudo-obstruction, though symptoms had now settled. The airway was managed with a laryngeal mask. During maintenance of anaesthesia, the patient regurgitated and aspirated. The patient was intubated but after surgery remained hypoxic and required ICU admission.

Case 2

An ASA 3 patient was anaesthetised out of hours as an emergency by a junior trainee. The patient had disseminated colonic cancer and minor surgery, in the lithotomy position, was planned. A laryngeal mask was used for airway management. Immediately after transfer into theatre faeculant matter was regurgitated and aspirated. The patient was intubated and the lungs suctioned. Initially the patient was stable and surgery proceeded. The final part of surgery was upper GI endoscopy and during this further airway soiling took place. The patient deteriorated rapidly and was kept intubated overnight. Multi-organ failure developed in the next hours and treatment was withdrawn.

In some cases poor communication between anaesthetist and surgeon appeared to contribute to the lack of aspiration protection. Opportunities for discussion of appropriate airway management need not be limited to anaesthetists and certainly it is appropriate for anaesthetic assistants, as part of the team caring for the patient, to 'speak-up' when an airway management choice is made that seems at odds with the risk of the surgical condition. The WHO checklist has a specific question about aspiration risk and should add a barrier to unsafe practice.

Case 3

An elderly obese patient was anaesthetised by a trainee for repair of a strangulated hernia performed by a consultant surgeon. Oxygen saturation was 88% on air before surgery. Routine intubation was planned but the patient aspirated at induction of anaesthesia and oxygen saturations fell to below 70%. The patient was admitted to ICU and developed ARDS and then multi-organ failure. The presence of intestinal obstruction was not communicated to the anaesthetist by the surgeon. Active vomiting on the ward was not communicated to the anaesthetist by the ward nurse. Nor did the anaesthetist extract this information.



There were cases where communication of risks between anaesthetists was seen to fail. This might have been due to failure of handover, inadequate documentation, failure to review the previous entries or an error of judgement on behalf of one of the clinicians.

Case 4

An elderly patient presented with a severe abscess. An initial anaesthetic assessment suggested sepsis, dehydration and an RSI in theatre was planned. During preparation for anaesthesia there was a change of anaesthetist. The latter anaesthetist judged RSI was not indicated. Following induction a laryngeal mask was inserted. During transfer from anaesthetic room to operating theatre the patient regurgitated and aspirated. Because of desaturation the patient was intubated. Chest X-ray confirmed signs of aspiration. The patient was admitted to ICU and subsequently made a full recovery.

Aspiration before airway management

Two patients aspirated after induction before any airway manipulations: both reports described similar clinical pictures.

Case 5

A very junior trainee anaesthetised an elderly patient who had been in hospital for management of pancreatitis, though symptoms had considerably settled and the patient was starved. The patient was anaesthetised after midnight for peripheral surgery to stop bleeding. A laryngeal mask was inserted and regurgitation occurred immediately, before any ventilation attempts. The patient was intubated and admitted to ICU where they had a prolonged stay complicated by pulmonary infection and pancreatic pseudocyst formation.

Case 6

A young, starved patient with obese body habitus and receiving PCA opioid analgesia was listed for fixation of a lower limb fracture sustained during polytrauma 24 hours earlier. Immediately after induction, with a laryngeal mask planned, the patient sustained a substantial aspiration and profound hypoxia. The patient was admitted to ICU. During a prolonged ICU stay the patient developed ARDS and a persistent neurological injury.

Aspiration when RSI indicated

In several cases the review panel highlighted the lack of RSI. Patients who aspirated who did not have a RSI included patients:

- nil by mouth and recovering from pancreatitis (laryngeal mask)
- for trauma surgery and with recent ileus (laryngeal mask)
- for surgery on an irreducible hernia (laryngeal mask)
- needing repair of an incarcerated femoral hernia (routine tracheal intubation)

- with disseminated colonic cancer requiring EUA (laryngeal mask)
- and numerous trauma patients (various).

While some may argue about the classical indication for RSI in the latter two cases, in this list the first five appear to have clear classical indications for RSI. In the majority no concession was made to the increased risk of aspiration. In most of these cases there was either a failure of assessment, a failure of interpretation of the assessment or poor judgement.

Case 7

An elderly ASA 3 patient with diabetes and controlled gastro-oesophageal disease presented for repair of an irreducible abdominal hernia. The patient had bowel sounds and normal bowel action. The patient was anaesthetised by a consultant anaesthetist with a laryngeal mask for airway management. During maintenance the patient aspirated causing airway obstruction. The patient was intubated. At the end of surgery the patient was extubated but deteriorated and required re-intubation and ICU admission. Further deterioration on ICU was rapid and the patient died the same day.

Case 8

An elderly ASA 3 patient with heart failure presented for repair of an incarcerated abdominal hernia. The patient was mildly hypoxic breathing air before surgery. The patient was anaesthetised by a very junior anaesthetist, as an emergency, in the early hours of the morning. RSI was planned but immediately after induction the patient either vomited or regurgitated, and aspirated gastric contents. The report was incomplete and it was unclear whether cricoid force was applied. Surgery was completed and the patient was extubated. The patient deteriorated during the next day and required intubation and ICU admission. The patient made a full recovery after several days on ICU.

Aspiration during laryngoscopy or RSI

Two aspirations occurred during RSI: one primary and one secondary.

Case 9

An elderly ASA 3 patient required an emergency laparotomy for small bowel obstruction, out of hours. The patient had a BMI >35 kg m⁻² and a hiatus hernia. A nasogastric tube had not been passed. The anaesthetist planned an RSI, modified by the addition of an opioid during induction. The patient was induced and while cricoid was in place 'vomited' copiously such that the airway was obstructed and the larynx could not be seen. Attempted rescue with facemask and laryngeal mask failed and profound hypoxia developed. A cannula cricothyroidotomy was promptly and successfully placed, enabling re-oxygenation and then intubation. Surgery was completed and the patient made a full recovery after a short period on ICU.



In cases such as case 9, placement of a nasogastric tube might have allowed emptying of the stomach and reduced the risk and extent of aspiration. This used to be a standard practice but was not observed in any reports submitted to NAP4.

When aspiration occurs during RSI it is often difficult to determine if cricoid force was applied correctly. It is known that excessive cricoid force worsens laryngeal view and contributes to obstruction of the airway, while too low a force fails to protect the airway: both are forms of poorly applied cricoid force. It is recognised that the quality of cricoid force is improved by training, practice and by simulation (e.g. depressing a capped 20ml or 50ml syringe a predetermined level to mimic the application of 3 kg force).

Case 10

A prolonged emergency caesarean section complicated by severe haemorrhage required that a spinal anaesthetic was converted to a general anaesthetic. Three attempts at intubation by anaesthetic registrars failed, followed by failure of rescue with a standard laryngeal mask. Cricoid pressure was released during these attempts. During facemask ventilation the patient aspirated leading to severe hypoxia. After further failed attempts to secure the airway with a ProSeal LMA and Bonfils laryngoscope, intubation was successful with a McCoy laryngoscope and blind placement of a bougie. The patient was admitted to ICU for management of aspiration and consequent lobar collapse. She was discharged within a week.

When intubation fails at RSI the patient remains at risk of aspiration; while it is appropriate to release cricoid force to attempt intubation and for placement of a rescue SAD, this risk remains. The removal of cricoid force requires a sucker in hand and constant attention.³³ Airway rescue with a device that may reduce the risk of regurgitation becoming aspiration, such as a second generation SAD, is logical and supported by the available evidence.

Failed intubation was associated with secondary aspirations. Several occurred after brief inadvertent oesophageal intubation.

Case 11

An obese patient undergoing vascular surgery in the radiology department had a previous difficult intubation though this was unknown to the anaesthetist. After routine induction laryngoscopy was grade 3 and intubation was briefly oesophageal before being abandoned. An i-gel was placed and ventilation recommenced. Gastric contents were then noted in and around the i-gel. A nasogastric tube was passed and almost half a litre of fluid suctioned. The patient was subsequently intubated (via the i-gel). The patient was ventilated on the ICU for several days before recovering.

Aspiration and the laryngeal mask

There were 11 cases in which aspiration occurred after placement of a standard laryngeal mask. In at least four cases it was judged that the use of a laryngeal mask was likely inappropriate. In five cases the aspiration occurred during transfer or waking raising 'light anaesthesia' as a contributory cause of aspiration.

Case 12

A young obese patient with chronic renal impairment was anaesthetised by a locum consultant for a minor elective procedure. The patient had a routine intravenous induction in the anaesthetic room and a laryngeal mask was inserted. The patient 'briefly' received nitrous oxide and a volatile before this was discontinued and the patient was transferred to theatre. While transferring to the operating table the patient coughed, regurgitated and gastric contents appeared in the laryngeal mask tube. The laryngeal mask was removed, ventilation was initially obstructed then improved. There was brief profound hypoxia. The patient was intubated, surgery completed and due to continuing hypoxia was transferred to ICU. The patient made a prompt full recovery.

The NAP4 census indicates that second generation SADs account for approximately 10% of overall SAD use, with the i-gel used more than twice as often as the ProSeal. In a small series, such as this aspiration cohort, it is difficult to detect robust patterns. Amongst SAD-related primary aspirations there were 11 with a laryngeal mask in place and one with an i-gel. The secondary SAD-related aspirations involved one laryngeal mask and one i-gel. In 14 reports risk factors for aspiration were identifiable in 13. In four the use of a SAD appears very ill-advised.

It is not possible, from the reports, to determine whether the SADs were well inserted or effectively placed and whether this contributed to aspiration episodes.

Supervision, training, staff

Junior anaesthetic staff working alone were involved in many of these events, and some appeared to make poor judgements about aspiration risk. Cases often took place out of hours when this was not apparently clinically indicated. Several are described above.

These facts raise concerns about training, supervision and perhaps wider issues of culture, hospital organisation and departmental support for trainees.

Miscellany

In one case aspiration occurred when the airway had been secured by awake fiberoptic intubation but an incompletely inflated tracheal tube cuff failed to prevent aspiration after induction of general anaesthesia.



Almost a third of aspirations were treated with bronchial lavage and several with blind antibiotics. The benefits of either have not, to the best of our knowledge, been demonstrated.

Aspiration of blood

There were five cases of aspiration of blood related to anaesthesia: one was fatal, two led to ICU admission. Three were judged to be secondary events complicating lost airway during inhalational induction, surgical bleeding and airway trauma during laryngeal mask insertion.

Two cases were primary events and are notable for their similarity. Both occurred during recovery. One followed dental surgery in a sick cardiac patient: after extubation there was hypoxia and despite re-intubation ventilation was impossible and cardiac arrest occurred. A flat capnograph during CPR was not correctly interpreted. Ten minutes after cardiac arrest, tracheal suction removed copious clots and ventilation was then possible. The patient was admitted to ICU and made a slow but full recovery. In the second case, details of which were incomplete, a child had an uneventful tonsillectomy. On arrival in recovery the child was noticeably cyanosed, and was re-intubated with an uncuffed tracheal tube, but ventilation was not possible. There was a prolonged period of impossible ventilation and severe hypoxia during which severe bronchospasm was considered. Ventilation became possible after re-intubation with a cuffed tracheal tube and suction removed a large blood clot, however cardiac arrest had occurred. Despite successful management of the cardiac arrest the child suffered brain damage and subsequently died. The report did not clarify whether capnography was used in recovery, nor how it was interpreted, if it was.

In a related case a throat pack was not removed at the end of surgery, there having been a change of anaesthetists during the case. The patient obstructed in recovery to the point of needing re-intubation before it was identified.

Although on this occasion it was not used primarily to prevent aspiration, the case is a reminder of the importance of documenting and removing such packs when they are used to prevent aspiration, or any other purpose.

There was one case of aspiration of blood on ICU, this was a secondary event. A patient had blood loss in excess of one litre after removal of a percutaneous tracheostomy that had been placed to aid weaning from mechanical ventilation, 24 hours previously. The tracheostomy was replaced and although the patient had a prolonged ICU stay because of aspiration of blood, recovered. In two other patients bleeding in the lower airway (one caused by intubation and one by trauma led to harm, but these are not included in our analysis of aspiration (see Chapter 9).

Numerical analysis

Review of the project database identified a total of 42 aspiration events (23% of all events reported to NAP₄). Of these 34 occurred during anaesthesia (26% of events), six on ICU (17%) and two in the emergency department (13%). There were nine deaths (eight gastric aspiration, one blood) and two cases of brain damage (both gastric aspiration): all in anaesthesia cases.

There were 36 events describing aspiration of gastric contents (29 of which required ICU admission) and six of blood (three of which required ICU admission). Two cases of aspiration were so severe that the larynx was so obscured that an emergency surgical airway was attempted.

Aspiration of gastric contents

Twenty-five were reports of *primary aspiration* where the problem occurred without apparent warning, 23 occurred during anaesthesia and two in the emergency department.

Eleven were *secondary aspirations* of which two occurred during routine difficult intubation, and one during difficult RSI. In two cases inadvertent (recognised) oesophageal intubation preceded aspiration. One case complicated laryngospasm during attempted ProSeal placement in a patient with a known difficult airway in whom muscle relaxants were intentionally avoided. Two cases occurred during maintenance, one following inadvertent tracheal tube displacement and one during emergence when the patient obstructed a laryngeal mask by biting it.

Secondary aspirations reported from ICU included two associated with inadvertent extubation and two after failed intubation (one including unrecognised oesophageal intubation).

Anaesthesia

During anaesthesia primary aspiration of gastric contents led to eight deaths and two cases of permanent brain damage. Aspiration of gastric contents therefore



accounted for eight of 16 (50%) of anaesthesia-related deaths and ten of 19 (53%) outcomes of death and brain damage. Aspiration is therefore the leading cause of these outcomes in NAP₄ anaesthesia cases.

The mechanism of death in all cases was hypoxia and this often occurred many days later on ICU. In one case aspiration was so gross that the patient died in theatre and in another a few hours later, but these were exceptions. Of those patients who survived but required ICU admission there was a dichotomy of outcomes, approximately half made a very prompt recovery (six discharged <48 hours) and the others required prolonged periods of time on ICU: seven ventilated for more than three days with several developing ARDS and two spending more than 30 days on ICU.

All deaths and brain damage occurred in primary aspiration events.

The timing of primary aspiration events during anaesthesia is shown in Table 1.

Table 2 Timing of primary aspiration of gastric contents

Before induction of anaesthesia	
After tracheal tube placed by fiberoptic intubation	1
Before airway management	
Before airway management (LM planned)	2
During airway management	
During LM placement	1
After inserting Guedel before intubation	3
During laryngoscopy	1
RSI at time of laryngoscopy	1
Maintenance	
No airway	1
LM in place	11
i-gel in place	1
Emergence	
During emergence with LM in place	1

Of these 23 events the intended or used airway was a laryngeal mask in 13, and i-gel in one, a tracheal tube in eight and none in one.

Hypoxia at the time of the event was less of a problem than for many airway events reported to NAP₄. Only eight of 23 (35%) patients had oxygen saturations below 80% during a primary aspiration event, compared to 58 of 92 (63%) in non-aspiration events, where a minimum saturation was reported. Worsening hypoxia, often with cardiovascular failure requiring inotropic support, frequently developed several hours later. Those that did have profound hypoxia at the time of the event tended to have massive aspiration and airway obstruction.

More than two thirds of patients were elderly (aged >61), two thirds were ASA 1–2. Only one patient was assessed as having a difficult airway.

Of these 23 patients eight (34%, compared to 25% of the population) were obese and five overweight. Of note 15 of the patients who aspirated had hypertension (65%): the rate of hypertension in those who did not aspirate was 35/110 (32%).

Sixteen of the 23 (and 21 of 29 if secondary aspirations are included) surgeries were either urgent or emergency surgery: 21 of 29 (72%) of those who aspirated and 40/104 (38%) of those who did not were urgent or emergency surgeries.

Trainees anaesthetised 15 of the 29 (52%) of the patients who had a primary or secondary aspiration and 22% of patients reported to NAP₄ who did not aspirate. Put another way 43% of reports to NAP₄ by trainees and 15% of reports by consultants, described aspiration.

Twenty-one of 23 had an assessment of risk of aspiration performed and in 11 of these this was reported as 'no increased risk of aspiration'. Of those who aspirated the reporter stated that four had intestinal obstruction, two delayed gastric emptying, one reflux and one a hiatus hernia.

When aspiration occurred early in the case on 14 occasions the team continued with surgery and one was aborted. In five cases bronchial lavage was reported.

Of the six secondary aspirations all had clear risk factors for aspiration. The chosen airways were four tracheal tubes (one RSI), one laryngeal mask and one facemask then ProSeal. All made a full recovery. Four occurred at induction, one during maintenance and one emergence. The patients included one pregnant patient and one child. Three patients required an attempt at emergency surgical airway, one of which was successful.

The reporter indicated a root cause for 12 of the primary aspirations and this was defective judgement in ten.

Airway management of the 23 primary anaesthetic aspirations of gastric contents were assessed as good four, mixed seven, poor eight, not assessed four. Four of the deaths were assessed as poor airway management and one mixed.

ICU

There were no primary aspiration events reported from ICU. Of the six secondary aspirations five involved gastric contents and one blood. Three patients died but the contribution of the aspiration relative to the primary event is difficult to determine.

Blood

Anaesthesia

Aspiration of blood in anaesthesia cases involved two primary aspirations and three secondary aspirations and. Airway management in these five cases was a laryngeal mask in one and tracheal tube in four. There was one death, one surgical airway and the remaining three were admitted to ICU. There were four adults and one child. Three of these cases involved intra-oral surgery and one maxillofacial surgery. One occurred at induction, one during maintenance and three during emergence/recovery.

ICU

This case occurred when a percutaneous tracheostomy was removed 24 hours after insertion. There was profuse bleeding and secondary aspiration. The patient required an extra week of ventilation.

Discussion

In this project aspiration was the single commonest cause of fatality in anaesthesia events accounting, in all its forms, for 26% of all anaesthesia cases and 50% of anaesthesia deaths. While the absolute incidence of such events is rare, these data emphasise the importance of aspiration as a major contributor to airway-related morbidity and mortality in anaesthetic practice.

Establishing the level of risk of aspiration is an important part of preoperative assessment, for failure to protect the airway adequately will lead to aspiration with a possible fatal outcome. The management of a patient considered at risk of aspiration should often be different from one without such risk.

The diagnosis of aspiration can sometimes be difficult and conditions such as post-obstructive pulmonary oedema may need to be considered when new hypoxia is observed. However in almost all cases observed in NAP₄ a clear, witnessed aspiration event was reported. This often caused airway obstruction as well as subsequent hypoxia.

Case review identified failure to assess a minority of patients for aspiration risk, apparent failures to recognise the importance of some risk factors and a failure to alter airway management strategy accordingly. In particular there were clear cases where a high-risk of aspiration was present (e.g. bowel obstruction) and RSI was not performed and others where an increased risk was identified but no apparent concession was made to this: the airway being managed with a standard laryngeal mask. Such judgements may be prone to hindsight and outcome bias. However, various strategies are available to reduce the risk of aspiration in high and lower risk patients: in NAP₄ some deaths occurred without these precautions being used.

It is not always clear-cut, but our interpretation of the relevant cases in this project is that much more trouble results from failure to protect an airway by intubation than is caused by the process of intubation. The same, in terms of reports to this project, applies to RSI. The role of the second generation SADs in managing 'borderline' patients is unknown but they should at least be considered preferable to SADs without any channelling of regurgitant material.

Learning points and recommendations

The main lesson from this chapter is that aspiration of gastric contents remains the most frequent cause of airway-related death during anaesthesia and it may complicate apparently straightforward anaesthesia. Importantly most aspirations occurred due to failure to recognise risk factors for aspiration and failure to adjust the anaesthetic technique accordingly.

Assessment

Assessment was sometimes performed by doctors of insufficient seniority. Some assessments appeared poor and in others risk factors were identified but anaesthetic technique was not changed.

Recommendation: Anaesthetists must assess all patients for risk of aspiration prior to anaesthesia. This applies particularly to urgent and emergency surgery. Where significant doubt exists, the higher risk should be assumed.

Recommendation: The airway management strategy should be consistent with the identified risk of aspiration. Where reasonable doubt exists it is likely to be safer to assume increased risk and plan accordingly.

Aspiration before any airway management and during induction

Induction is a high-risk period for aspiration and this may occur before or during airway management.

Recommendation: No matter how low the perceived risk of aspiration, when anaesthesia is induced, the equipment and skills should exist to detect, and promptly manage, regurgitation and aspiration.

Failure to use RSI when indicated

NAP₄ has identified several cases where the omission of RSI, although there were strong indications for its use, was followed by patient harm, or death from aspiration. There were no cases where cricoid force was reported to lead to major complications. Rapid sequence induction with cricoid force does not provide 100% protection against regurgitation and aspiration of gastric contents, but remains the standard for those patients at risk.



Recommendation: On balance, rapid sequence induction should continue to be taught as a standard technique for protection of the airway. Further focused research might usefully be performed to explore its efficacy, limitations and also explore the consequences of its omission.

Aspiration during RSI

Aspiration was noted in a single case during RSI with cricoid force applied.

Recommendation: To maximise the likelihood of good quality cricoid force being applied, those who perform cricoid force should be trained in its methodology, should practise at regular intervals and should consider the use of simple methods of simulation.

Aspiration and the laryngeal mask

The single most frequent setting in which aspiration was reported was during the maintenance phase of laryngeal mask anaesthesia, in patients with risk factors.

Recommendation: If tracheal intubation is not considered to be indicated but there is some (small) increase or concerns about regurgitation risk a second generation supraglottic airway is a more logical choice than a first generation one.

Aspiration at the end of anaesthesia

Aspiration at emergence or in recovery is a risk period.

Recommendation: Where aspiration has been recognised as a risk at induction, steps should be taken to reduce the risk of aspiration at emergence.

Aspiration of blood

The diagnosis of aspiration of blood clots at the end of intraoral surgery may be missed if it is not specifically considered.

Recommendation: Anaesthetists caring for patients undergoing intra-oral surgery should be educated in the prevention, detection and management of blood clot aspiration.

Recommendation: Where a capnograph trace is flat (indicating absence of ventilation: the tube therefore displaced or obstructed) and there has been blood near the airway, active measures should be taken to exclude inhaled blood clot. These may include bronchial suction, changing the tracheal tube, fiberoptic inspection or rigid bronchoscopy.

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Headline

Seventy-six (45%) of 171 adult patients reported to NAP4 were obese, these included 53 (40%) of 133 anaesthesia-related events. Fourteen (8%) of reported events occurred in morbidly obese patients. As 24.5% of the adult UK population is obese and less than 2% are morbidly obese the rate of reporting of obese adults to NAP4 was more than twice the expected rate of those patients with a BMI < 30 kg m⁻² and of morbidly obese adults the reported rate was four times higher. Failure to recognise obesity as a risk for airway complications and to change technique appropriately contributed to many of these events. Failure of standard rescue techniques, in obese patients contributed to others.

What we already know

Obesity is a major problem in developed countries and in 2008 24.5% of the United Kingdom (UK) population were obese as defined by a body mass index (BMI) of >30 kg m⁻².¹ Between 1991 and 2008 the number of obese people in the UK increased by 10% and this trend continues. Currently less than two percent of the adult population is morbidly obese.¹ Obesity rates in children, although also rising, are lower than adults.¹

Implications for airway management

Obesity has major implications for airway management: it is a risk factor for developing diabetes, hiatus hernia, and gastro-oesophageal reflux, all of which make regurgitation and aspiration more likely. Obesity and obstructive sleep apnoea (OSA) are recognised indicators of potential difficulty with facemask ventilation and the American Society of Anesthesiologists (ASA) task force indicated that a thick or short neck are non-reassuring indicators of difficulty with tracheal intubation.² When difficulties arise with airway management, rescue techniques such as an emergency surgical airway are accepted to be more difficult and time consuming to perform in the presence of obesity.

Response to hypoxia

An increased body mass requires additional oxygen to meet metabolic requirements but simultaneously obesity reduces

lung compliance and elevates the diaphragm leading to a lower functional residual capacity and consequently reduced oxygen reserves. Importantly during periods of apnoea this oxygen reservoir is more rapidly depleted in obese than non-obese subjects.³ Oxygen reserves should be maximised before intubation and extubation. This can be done with thorough pre-oxygenation,⁴ the use of CPAP⁵ and the adoption of the reverse Trendelenburg position before intubation, or the upright position before extubation.⁶

Assessment, planning and alternative strategies for anaesthesia and intubation.

Prediction of airway difficulty is an important but inexact process.⁷ Preoperatively, it is essential to detect those cases where there is an obvious problem so the safest anaesthetic strategy can be selected.

Where appropriate, use of local or regional anaesthesia may avoid airway management problems altogether. If neuraxial anaesthesia is used, block height and quality should be checked thoroughly before surgery to prevent the need for urgent airway intervention to manage block failure.

Awake intubation may be needed to secure the airway before induction in cases of extreme obesity or where mask ventilation or tracheal intubation is expected to be difficult. Options to reduce the likelihood and consequences of aspiration include rapid sequence induction (RSI) and drugs that reduce the volume and increase pH of gastric contents. Routine use of ramping⁸ as an alternative to the traditional position for tracheal intubation may improve the success of direct laryngoscopy (Figures 1 and 2). Unless it interferes with surgery ramping should be left in place to facilitate bag-mask ventilation or re-intubation at the end of the procedure.

Postoperative care

Postoperative respiratory complications are more common in obese patients and patients with OSA or obesity hypoventilation syndrome may require nocturnal non-invasive respiratory support, particularly after surgery.

Organisational issues

The requirement for careful patient evaluation, consideration of options for anaesthesia and full discussion with the patient can take a considerable time. If a patient requires a minor procedure it may not be appropriate for



the morbidly obese patient to follow the usual patient pathway and these patients should be pre-assessed.⁹ In the UK, same day admission for even major surgery is becoming the norm, prior anaesthetic assessment is sometimes omitted. It can be very difficult to perform an adequate preoperative anaesthetic assessment with thorough discussion if time is limited. Similarly if the available operating time does not allow for the anaesthetic interventions such as awake intubation, or loco-regional anaesthesia clinical pressures may lead to the adoption of higher risk techniques rather than safer but more time consuming alternatives. All professionals providing care for this challenging group of patients need to be aware of these problems and good communication is essential.

Figure 1 Supine patient without ramping



Figure 2 The thorax, shoulders, head and neck are supported to align the external ear with the sternal notch in the horizontal plane. Support may be provided with pillows a proprietary device.



Case review

A number of themes were identified that, though not confined to obese patients, are either particularly important or more prevalent in this group. This chapter focuses on obesity in anaesthesia-related cases. Obesity in cases reported from ICU and the emergency department is discussed in the relevant chapters (Chapters 6, 9 and 10).

Assessment and preparation

Co-morbidities were common in this group of patients (see numerical analysis section below). Serious complications were observed in several patients with OSA. In some cases airway assessment was either not performed or not recorded and in others indicators of potential difficulty were recognised but ignored. In some patients with apparently normal airway assessment problems arose unexpectedly.

Case 1

A middle-aged patient weighing > 150 kg (BMI >40 kg m⁻²) who had hypertension and ischaemic heart disease was admitted for minor hand surgery. The patient had OSA diagnosed more than ten years previously but did not use a prescribed CPAP mask. The patient was admitted under 'choose and book' from out of region, was not accompanied by hospital notes and the GP referral did not mention OSA. At pre-assessment the history was not offered or elicited. Clinical examination of the airway demonstrated no abnormality. The patient was extremely needle phobic and refused local or regional anaesthesia. General anaesthesia via a laryngeal mask was uneventful until the end of surgery when, in the presence of a junior trainee, the patient awoke suddenly, removed the laryngeal mask and developed total airway obstruction. Hypoxic cardiac arrest followed. Suxamethonium was administered and a partially patent airway restored with a laryngeal mask. This was then used as a conduit for fiberoptic intubation over an Aintree Intubation Catheter. After external cardiac massage and five minutes with low oxygen saturations the patient was admitted to the ICU, for seven days. The patient subsequently required an elective tracheostomy but made a full recovery.

Regional anaesthesia

Many of the obese patients reported to this project required relatively minor procedures which might have been suitable for regional or local anaesthesia alone. These included carpal tunnel decompression, trigger finger release, breast biopsy and a number of perineal procedures. Regional anaesthesia might have prevented a number of serious complications. However regional anaesthesia was also seen to fail. A parturient with a BMI of over 40 kg m⁻² developed pain during a spinal anaesthetic for an emergency Caesarean section. This necessitated conversion to general anaesthesia but at induction problems occurred, oesophageal intubation was suspected and the patient required re-intubation twice and ICU admission for airway trauma and aspiration.



In some cases back-up plans did not always seem to be well thought through. An obese patient required tonsillar biopsy; airway assessment indicated potential difficulty and the operation was performed under local anaesthesia with deep sedation. Bleeding and airway obstruction developed and the patient could not be intubated or ventilated. An emergency needle cricothyroidotomy failed and was rescued by emergency tracheostomy. In total there were five reports of complications arising from general anaesthesia induced to rescue failed or inadequate regional anaesthesia in obese patients, contrasting with only one in non-obese patients.

Case 2

A morbidly obese, middle-aged patient with no recorded co-morbidities was listed for urgent perineal surgery. Preoperative assessment showed reduced neck movement and abnormal Mallampati class, but mouth opening was normal. Anaesthesia took place outside working hours and was performed by a junior trainee. After pre-oxygenation with three vital capacity breaths and intravenous induction a laryngeal mask was inserted. Although oxygen saturation was above 95% and ventilation was possible there was a poor airway seal and capnograph trace. The patient was transferred to the operating room. Manual ventilation became difficult and the patient's peripheral oxygen saturation fell. The airway was repositioned and propofol was administered to treat laryngospasm, without improvement so the laryngeal mask was removed. Bag-mask ventilation with an oropharyngeal airway failed. Help was requested urgently, intravenous suxamethonium was administered and two-person bag-mask ventilation was attempted. Laryngoscopy (grade 2) was performed and a tracheal tube was passed with the aid of a bougie, but ventilation was still difficult. There was minimal expired carbon dioxide and no improvement in oxygen saturation despite ventilation. At this point cardiac arrest occurred, help arrived and external cardiac massage was started. The absence of expired carbon dioxide was attributed to a low cardiac output. Resuscitation attempts failed and were abandoned. Oesophageal intubation was not excluded during resuscitation attempts.

General anaesthesia

Airway management: In some cases the chosen airway management technique appeared inappropriate for the patient's clinical condition or no back-up plan was considered.

Case 3

A middle-aged patient with OSA and a BMI of 35 kg m⁻² required a total thyroidectomy. The patient had limited cervical spine mobility, tracheal deviation and it was noted that a surgical airway would be difficult. A gaseous induction was performed using a combination of sevoflurane, propofol and remifentanyl. Direct laryngoscopy view was grade 3 and during repositioning the airway became obstructed with impossible mask ventilation despite a 6-handed technique. Several attempts at fine and large bore needle cricothyroidotomy were made but all failed. The airway was finally secured after a difficult tracheostomy. The patient spent 20 minutes with an oxygen saturation of less than 50% and received elective ventilation to manage anticipated cerebral hypoxia. The patient recovered fully.

Aspiration (see also Chapter 19): Examples were seen of obese patients who aspirated gastric contents despite an absence of risk factors. Others with risk factors for aspiration were anaesthetised with standard (disposable) laryngeal masks. An obese patient with intestinal obstruction was anaesthetised without rapid sequence induction for urgent laparotomy and aspirated gastric contents.

Awake intubation

There were several cases where AFOI would have been entirely appropriate but was not used. Failed AFOI complicated the management of others, failure usually resulted from lack of co-operation, airway obstruction or bleeding. Sedation may have been responsible for lack of co-operation, airway obstruction or apnoea in some cases. In one challenging case, AFOI of an obese obstetric patient in labour, was attempted under remifentanyl sedation. Intubation was abandoned due to poor co-operation and the patient was attended by a midwife. Soon afterwards the patient suffered a cardio-respiratory arrest and required urgent airway management which was achieved with an intubating laryngeal mask.

Supraglottic airway devices

Supraglottic airway devices were frequently used for anaesthesia and as rescue devices. The nature of inclusion criteria for NAP4 means that failures predominate, and failure of SADs to restore airway patency and provide effective ventilation was observed. There were also cases where these devices restored oxygenation or enabled tracheal intubation. A classic LMA or similar was used in most cases and in relatively few reports were the newer i-gel or ProSeal LMA used as rescue devices. Standard laryngeal masks were used for patients up to 155 kg in weight. The intubating laryngeal mask was used successfully following both failed emergency surgical airway and failed AFOI. There were several reports where fibreoptic-assisted intubation was performed through a

SAD but there were other examples where this failed or was not attempted and tracheostomy performed instead (see Chapter 13).

Spontaneous ventilation

There were several reported events in obese and morbidly obese patients during spontaneously breathing anaesthesia in the Trendelenburg or lithotomy position. Airway intervention was required intraoperatively but these events progressed rapidly to severe hypoxia and total airway obstruction. A middle-aged patient with sepsis and multiple co-morbidities including obesity was anaesthetised by a Trust Grade anaesthetist for the drainage of an extensive perianal abscess. This was performed in the lithotomy position. The patient became more difficult to oxygenate during the procedure. Eventually total airway obstruction developed and rescue mask and laryngeal mask ventilation was ineffective. The patient required rescue intubation which was difficult, requiring three attempts. Intubation led to airway bleeding. The patient was transferred to the ICU and went on to make a complete recovery.

Emergency surgical airway

There were several problems observed during emergency surgical airway in obese patients in which obesity may have been causative. In one patient a fine bore cricothyroid cannula kinked and prevented effective ventilation. In another a Quicktrach was too short to reach the trachea and required dissection of the front of the neck before it could be inserted. Normal tracheostomy tubes were also found to be short and adjustable flange tubes were needed for emergency tracheostomy formation in several cases.

End of surgery and recovery

Obese patients appear to be at greater risk of airway obstruction, hypoventilation and perhaps regurgitation at extubation (e.g. Case 1). Pre-oxygenation prior to extubation or emergence will 'buy time' if complications do arise. Emergence should be recognised as a period of increased risk for these patients.

Case 4

A middle-aged morbidly obese patient with a BMI $>40 \text{ kg.m}^{-2}$, complicated by asthma and undiagnosed hypertension was admitted as a day case for a biopsy. Anaesthesia was induced by a senior trainee who then inserted a disposable laryngeal mask. When the operation was over, in the recovery area the patient bit down onto the laryngeal mask producing complete occlusion. The patient's oxygen saturation fell to 44%, the laryngeal mask was forcefully removed and CPAP provided, but oxygen saturation remained below 70% for several few minutes. The nursing staff requested senior help and after a total of 20 minutes the patient was intubated. Pulmonary oedema complicated this episode of airway obstruction and the patient was transferred to the ICU for postoperative ventilation. The patient made a full recovery.

Post-obstructive pulmonary oedema (POPO) was a frequently reported cause of postoperative hypoxia. There were several reports where this was caused by laryngeal spasm but more commonly it followed airway occlusion by the patient biting on a supraglottic airway (SAD) or less commonly a tracheal tube. Airway occlusion in several events could have been entirely prevented by the use of a bite block.

Case 5

An acutely unwell, obese patient had emergency abdominal surgery. The patient was awkward to intubate and was extubated awake in theatre. Before extubation the patient bit and obstructed their tracheal tube, for less than 20 seconds. The patient was extubated and was stable before transfer to recovery, but after transfer became hypoxic despite a clear airway. The patient lost consciousness and sustained a cardiac arrest. Resuscitation was successful. Frothy secretions at intubation and subsequent chest X-ray indicated pulmonary oedema. The patient died on ICU. The reporter (who attended the patient) indicated the diagnosis was considered to be negative pressure pulmonary oedema. Based on other similar reports the review panel agreed this was a likely mechanism and diagnosis.

Organisational issues

Challenging patients with multiple co-morbidities were admitted to isolated sites, sometimes for same day surgery. Case 1 illustrates how failure to get relevant information may have important consequences. OSA is risk factor during induction, emergence and recovery and systems should be in place to specifically identify these patients in all hospitals.

Sometimes information was not passed from anaesthetist to anaesthetist or between ward staff and anaesthetists, in some cases the assessing anaesthetist recorded problems but this was not noted or ignored by the anaesthetist performing the anaesthesia. There were examples of serious complications in patients with morbid obesity whilst being anaesthetised by, or under the care of, very junior or



locum anaesthetists. Examples of the former were seen in Cases 1 and 2. A locum staff grade anaesthetist performed regional anaesthesia for a superficial wrist operation on a young, obese, diabetic patient. Analgesia was inadequate for surgery and general anaesthesia was induced. Airway obstruction supervened, tracheal intubation was difficult, as was mask and laryngeal mask ventilation. The patient suffered a hypoxic cardiac arrest but was successfully resuscitated after the airway had been secured. These patients may challenge even senior and experienced anaesthetists.

Numerical analysis

Seventy-seven of 184 patients (42%) reported to NAP4 were obese, including 76 (45%) of 171 adults and one of 13 children. Fourteen patients (8%) had a BMI of over $\geq 40 \text{ kg m}^{-2}$. The reports of patients with obesity and morbid obesity were therefore approximately two-fold and four-fold higher than those of BMI $<30 \text{ kg m}^{-2}$. As BMI was not always recorded it is possible the number of morbidly obese patients reported here is underestimated.

Deaths and persistent brain injury

Of 77 reports in obese patients 19 suffered death or brain damage due to the event. Of the 53 events in obese patients during anaesthesia there were four deaths and one persistent brain injury.

Emergency surgical airway

Twenty-five emergency surgical airways were performed on obese patients, 19 during anaesthesia events, two in ICU and four in the emergency department. One of these patients (in the emergency department) died from their airway event.

Further numerical analyses of the importance of obesity in events occurring in ICU or the emergency department are considered in the relevant chapters (Chapter 6, Chapter 9 and Chapter 10)

Events during anaesthesia

The proportion of females in this category was 49% (26/53) which is higher than in non-obese reports: 31% (25/80). There were more middle-aged and fewer elderly patients in the obese group compared to non-obese patients (Figure 1). ASA grades of obese and non-obese patients differed little (Figure 2).

Figure 1 Age distribution of reports with BMI >30

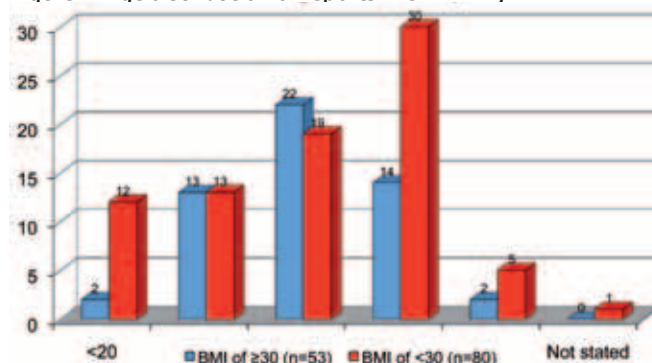
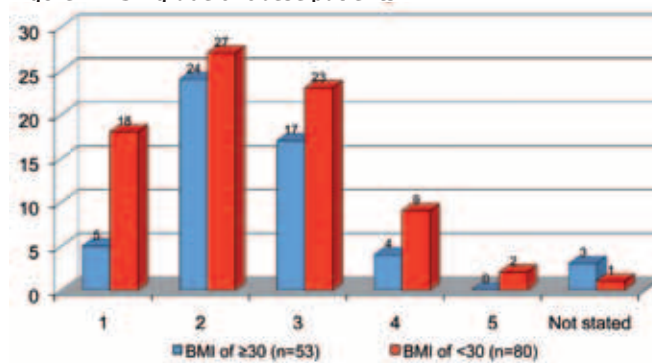


Figure 2 ASA grade of obese patients



The most common co-morbidities in reports describing obese patients were hypertension or ischaemic heart disease (25 reports), obstructive sleep apnoea (nine), diabetes (nine), and asthma (eight).

Airway assessment was not recorded in 17 patients and difficulty with airway management was anticipated in half of the cases reported (Table 1). An increased risk of aspiration was recorded in 35% of all patients and rising to 42% and 50% in obese and morbidly obese patients, respectively.

A consultant was less likely to be present at the start of anaesthesia in reports of events in obese patients (57%) compared to non-obese patients (68%).

In obese patients (compared to non-obese patients) events were less likely to be reported during maintenance (10% of events in obese patients, 26% in non-obese) and more likely during emergence (25% obese vs 10% non-obese).

Airway Test	Mallampati	Mouth opening	Neck movement	Jaw protrusion	Thyro-mental distance	Sterno-mental distance
Abnormal	17	10	10	6	4	2
Normal	19	25	23	17	12	9
Not recorded	17	18	20	30	37	42
Total	53	53	53	53	53	53

Table 1 Airway assessment

The primary anaesthetic plan in five (9%) events in obese patients did not include general anaesthesia but this was required either due to failure or complication of the initial plan. The primary (i.e. used or intended) airway differed little between reports in obese and non-obese patients (tracheal tube 64% of reports in obese patients vs 71% in non-obese, SAD 28% vs 25%, facemask 8% vs 4%). AFOI was attempted in six patients and failed in four due to lack of co-operation and airway obstruction.

The primary airway problem is shown in Table 2. Primary airway problems that occurred more often in obese patients than non-obese patients were SAD-related problems, and failed mask ventilation.

Table 2 Primary airway problem

Primary airway problem	Obese		Non obese	
Failed intubation	9	17.0%	14	17.5%
Difficult or delayed intubation	7	13.2%	8	10.0%
Aspiration of gastro-oesophageal contents	7	13.2%	15	18.8%
CICV - the can't intubate can't ventilate scenario	6	11.3%	8	10.0%
Extubation-related problems	6	11.3%	15	18.8%
LMA or supraglottic airway-related problem	5	9.4%	5	6.3%
Iatrogenic airway trauma	4	7.5%	5	6.3%
Failed mask ventilation	3	5.7%	1	1.3%
Tracheostomy related problems	1	1.9%	3	3.8%
Tracheal obstruction	1	1.9%	0	0.0%
Tracheal tube misplacement	1	1.9%	3	3.8%
Other	3	5.7%	3	3.8%

Evaluation of care

The proportions of obese patients whose airway management was rated as good, mixed or poor did not differ from the non-obese population.

Discussion

A major finding of this project is the over-representation of obese (2-fold) and morbidly obese patients (4-fold) in major airway events. This was observed in cases reported during anaesthesia and also in cases from ICU and the emergency department.

Several themes identified in the care provided to obese patients related to failure. These include failure of preoperative assessment, failure of regional anaesthesia, failure of awake fiberoptic intubation and failure of airway rescue techniques. These failures serve to emphasise the

challenges posed by this group of patients. There was an apparent failure to recognise obese patients as a high-risk group and adjust techniques appropriately.

Assessment

Preoperative assessment is the bedrock of safe anaesthetic practice, here problems are detected and a strategy is devised for their management. Planning should include identification of back-up plans to be deployed if the primary plan fails. In several cases no assessment of the airway was performed at all.

Several patients were admitted on the day of surgery after no preoperative assessment. Obesity is associated with multiple significant co-morbidities that may influence airway management including ischaemic heart disease, diabetes, asthma and notably OSA. Patients with potential for serious co-morbidities and airway problems require thorough evaluation. The options for anaesthesia need to be explained and discussed; sometimes this will necessitate changes to an operating list to allow more time, or to arrange for additional or expert colleagues to attend. These cannot be arranged quickly and time pressure may lead to hurried assessment, poor communication and hasty decision-making. It is inappropriate to admit these patients on the day of surgery, without appropriate preoperative assessment by a senior anaesthetist. Obesity needs full recognition as a high-risk condition even if the intended procedure is minor. As a minimum, patients with a BMI >40 kg.m⁻² or >35 kg.m⁻² with co-morbidities should have formal preoperative assessment.

Regional anaesthesia

Many of the obese patients reported to this project developed serious complications during relatively minor surgical procedures. The review panel considered that some serious or fatal complications might have been avoided by use of regional anaesthesia. However, when regional anaesthesia is chosen it can fail, or management of its complications may require airway intervention. Almost 10% of events in obese patients reported to NAP₄ occurred when regional anaesthesia failed, was of inadequate duration or led to complications, illustrating the need for full assessment and preparation in these patients before loco-regional anaesthesia. The WHO checklist provides an important opportunity, during surgery under regional or local anaesthesia, to communicate to the whole surgical team that complications or failure might necessitate urgent and difficult airway intervention.

General anaesthesia

There was evidence of a low level of anticipation of potential airway complications. In addition to poor airway assessment other examples included failure to assess aspiration risk and missed opportunities to optimise the patient with high quality pre-oxygenation before either induction or





extubation. The fact that the distribution of airway devices used in obesity did not differ from non-obese patients and that simple laryngeal masks were used in many morbidly-obese patients also perhaps indicates failure to respect the risks associated with airway management in obesity. Standard laryngeal masks predominated, with minimal use of second generation SADs. As obese patients have a lower pulmonary compliance and a greater potential for aspiration it is logical to select a SAD that is more likely to enable ventilation and protect against aspiration for these patients: this was not evident. Primary airway events involving SADs were more common in obese patients compared to non-obese patients, though numbers were small. Aspiration was identified as a significant cause of mortality in anaesthesia in this project. In reported cases of aspiration approximately one-third of the patients were obese, representing an excess based on population statistics.

Awake intubation

AFOI is a recognised technique for dealing with an anticipated difficult airway. Its safety lies in the fact that the airway can be secured whilst the patient is fully conscious

and breathing. AFOI was not used in several cases where it would likely have been a safer option than that chosen. In other cases AFOI was chosen but failed. Failure resulted from lack of co-operation, airway obstruction or hypoxia. The main benefit of AFOI is lost if excessive sedation is used and this was reported. Difficulty may arise in obese patients as they are more at risk of airway obstruction during sedation and selecting the correct dose of sedative may be difficult. Respiratory depression with remifentanyl likely contributed to a respiratory arrest in at least one patient who then required an emergency surgical airway. Supplemental oxygen should be delivered throughout AFOI and the patient should be attended by an appropriately trained individual during and after the event, even if it fails.

Emergency surgical airway

Problems were noted with needle cricothyroidotomy throughout the project in all groups and rescue surgical techniques were often required to secure the airway after failed cannula cricothyroidotomy. Specific problems in obese patients were kinking of fine bore cannulae and devices which were too short to reach the patient's trachea (wide bore cannula and tracheostomy tubes). Further research is likely needed to identify the optimal equipment and technique to use in obese patients.

End of surgery and recovery

A disproportionate number of problems at the end of anaesthesia occurred in obese patients. The end of anaesthesia, just like induction, needs to be carefully planned to minimise risk of harm. These patients might have benefited from active efforts to minimise risk at emergence with full reversal of neuromuscular blockade, thorough pre-oxygenation and optimal positioning before extubation and transfer. Use of drugs with a rapid offset may also be of benefit.

Postoperative airway obstruction was also seen in obese patients and post-obstructive pulmonary oedema was a reported cause of postoperative hypoxia (this is discussed in detail in Chapter 8). Causes include laryngospasm, occlusion of an airway lumen by patient biting and airway obstruction after removal of an airway. In difficult cases it is appropriate to plan extubation (with a back-up plan for failure) and to retain skilled staff to assist with re-intubation, airway rescue or an emergency airway until the patient is demonstrably safe. On occasion this may mean delaying the next case.

Organisational issues

Consistently, at all organisational levels, there was evidence in the reported cases of a failure to recognise and manage obese patients as a high-risk group. Challenging patients were admitted on the day of surgery, without appropriate assessment, to isolated sites. Poor



preoperative communication was noted. In some cases regional anaesthesia or AFOI might have been used if the anaesthetist had had more time to talk to the patient and plan anaesthesia. Junior anaesthetists managed cases alone and perhaps most significantly, consultant anaesthetists were less commonly present at induction of anaesthesia in reports involving obese patients than non-obese patients. Whether this simply represents the fact these cases are not considered high-risk or whether their absence was causal in the events, it is a finding of some concern.

Training

The review panel judged in some cases that the event could have been avoided by selection of an alternative technique, or if a chosen technique had been better performed. It is possible the anaesthetist lacked the necessary skills to manage the patient or failed to appreciate the potential hazards of the methods employed. These comments apply to actions such as failure to use available regional anaesthetic techniques, use of local anaesthesia and sedation in a patient with an 'at-risk' airway without securing the airway, failure of fiberoptic intubation, poor choice of airway device in high-risk patients and poorly planned emergence.

Learning points and recommendations

Many of these points are not new. As well as exploring new knowledge NAP₄ may be useful in illustrating or re-iterating what is already known.

- Airway problems are more common in obese patients and particularly in the morbidly obese.
- Obstructive sleep apnoea is associated with serious airway complications.
- Patients with morbid obesity are admitted as day-case procedures without pre-assessment by an anaesthetist.
- Failure of regional anaesthesia may necessitate general anaesthesia and sometimes this is urgent with fewer options than if general anaesthesia had been used at the outset.

- Awake fiberoptic intubation may be a suitable technique in obesity, particularly as failure is unlikely to lead to complications. However safety and success of the technique are compromised if sedation causes airway obstruction or apnoea.
- Supraglottic airways are useful rescue devices in this population but, like other airway management techniques, the rate of failure of SAD use may also be increased in the obese population. Device selection, for routine and rescue use, should be influenced by additional favourable features such as a gastric drainage port or higher seal pressure, which are particularly relevant for obese patients.
- Obese patient are particularly at risk of airway obstruction at the end of anaesthesia and harm from this was observed in this project.
- In the morbidly obese there is no such thing as a minor anaesthetic: the highest levels of organisation and preparation are required at all stages. All staff involved in the care of the patient including hospital management must be aware of this.

Recommendation: Hospital management need to be aware of the additional time and resources needed to safely anaesthetise obese patients.

Recommendation: Provision must be made for anaesthetists to evaluate obese patients before surgery. Morbidly obese patients and obese patients with significant co-morbidity should be formally assessed by an anaesthetist in a setting without time limitations.

Recommendation: Obese patients require thorough preoperative evaluation of co-morbidities. Evidence of OSA should be sought routinely.

Recommendation: Airway assessment should form part of the evaluation of all obese patients and should include an evaluation of possible rescue techniques.

Recommendation: Awake intubation should be considered in those patients in whom it would be difficult to establish rescue oxygenation or emergency surgical airway (e.g. those obese patients in whom the cricothyroid membrane or trachea cannot be identified).

Recommendation: If AFOI is chosen extreme care is required in titration of sedatives and monitoring, in order to avoid airway obstruction and periods of apnoea.

Recommendation: Failure of regional anaesthesia may necessitate general anaesthesia. Obese patients undergoing regional anaesthesia still require a strategy for airway management. Regional anaesthetic blocks should be thoroughly checked before surgery. All theatre staff must be aware of the hazards posed by intra-operative conversion from regional to general anaesthesia.



Recommendation: Pre-oxygenation, performed to high standards, should be used for all obese patients prior to general anaesthesia.

Recommendation: Organisations and individual anaesthetists should procure and use airway devices and techniques that meet the specific needs of obese patients. Safety should take priority in the decisions made.

Recommendation: The end of an anaesthetic in an obese patient should be planned. This includes pre-oxygenation before extubation and transfer to recovery. The possible need for re-intubation should be anticipated and planned for.

Recommendation: Anaesthetic training should emphasise the importance of obesity as a risk factor for complications of airway management.

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Dr Ann Black



Dr Tim Cook

Headline

Using a definition of age <16 years for children there were 13 paediatric cases referred to NAP4: 11 anaesthesia cases, one in ICU and one in the emergency department. Ten of the children were aged under ten and nine aged under four. These 13 cases represent 7% of all cases reported to NAP4 and 8.3% of anaesthesia cases. There was one death in each of the clinical areas.

Airway events occurred in a number of children with congenital developmental abnormalities that made airway management predictably difficult. Difficulties in airway management also occurred in a small number of healthy children, unexpectedly.

Areas of particular interest are unpredictable difficult intubation, often managed simply by multiple attempts, cardiovascular complications of airway management (bradycardia and cardiac arrest were frequent), problems occurring before, during or after patient transfer.

What we already know

Airway management in children is generally straightforward but can occasionally be an extraordinary challenge. The total number of children anaesthetised per year is unknown but anaesthesia and airway management are required for the vast majority of operations and many non-operative procedures as children and babies are less likely to be managed with sedation or regional techniques than adults. Sick children requiring airway management also present to emergency departments and to the approximately 300 UK Paediatric ICU beds. During the study year 2008–2009 children admitted to any of these areas, who had major airway complications, may have been reported to NAP4.

Many hospitals apply a lower age limit for elective admission of paediatric patients. The Royal College of Anaesthetists has recommended that anaesthetists managing children should have a regular commitment to routine paediatric work and that all departments should have agreed guidelines in place to manage elective and emergency paediatric workloads.¹ NCEPOD in 1999 advised that practitioners should not be involved in 'occasional paediatric practice'.² In a recent report on anaesthesia and ICU services, it was recommended that all departments should be aware of the limits of their expertise and have agreed guidelines in place to manage elective and emergency paediatric workloads.³ In addition there

should be local arrangements to ensure there are services in place to resuscitate, stabilise and if necessary transfer children to specialist centres.

Children and their families should receive expert paediatric care which is child and family focused.⁴ Resources should be made available to achieve this. Anaesthetists with a paediatric interest should have had a minimum of six months higher specialist paediatric anaesthesia training and should continue to have at least one regular paediatric theatre list. Anaesthetists with a predominately paediatric practice are expected to have had at least a year of specialist paediatric anaesthesia training.⁵

However, all anaesthetists are expected to be familiar with anaesthetising children and management of paediatric patients is part of the core competencies for anaesthetic training as stipulated in the curriculum of the Royal College of Anaesthetists at intermediary, higher and advanced level.⁶ Basic and advanced airway management forms part of this training. All post-CCT anaesthetists would be expected to be competent to manage children older than three years.

Several factors have made it inevitable that anaesthetic (and other) trainees now have less practical exposure to paediatric practice than in the past. As training has been streamlined and the European Working Time directive implemented, this has resulted in a reduction in practical experience gained by trainees.⁷ With the expansion of a consultant delivered service, and a reduction in trainee hours, the opportunities for experience with paediatric patients is limited and this is likely to affect skills and confidence in sub-specialty areas of practice. 'Hands-on' workshops and simulator-based training are increasingly used to address this training gap.

Nationally paediatric services have been centralised in recent years. There is a conflict between the desire to deliver services near to the child's home, which assumes paediatric services in all hospitals, and the desire to deliver the highest quality services concentrated in hospitals with the full range of specialist paediatric services. In anaesthetic-surgical practice there has been a particular decrease in the management of children below four years of age in district general hospitals (DGHs), due to planned reorganisations of both anaesthetic and surgical services. This trend applies particularly to emergencies. The shift in work patterns has been facilitated by new 'managed



clinical networks', where there are formal links between DGHs and regional centres.⁴ This reorganisation means that transfers of paediatric patients to centres which provide specialist services are now more common. Regarding airway management this is particularly relevant to adult and paediatric intensive care units (ICUs/PICUs). The majority of children under the age of 12 are now cared for in regional centres with paediatric specialists. If young children needing ICU care present to a DGH they will require transfer to a centre providing paediatric services. To support this there has been an expansion in dedicated paediatric retrieval services which have been a valuable addition to care.

Although the impact of these changes on paediatric anaesthetic and intensivists skills in a DGH, is unknown, a child presenting to a DGH Emergency Department with an airway problem will enter an environment with fewer paediatric anaesthetists, and trainees with lesser paediatric experience, than previously. The same will apply to surgical services. Many DGHs will now have no resident ENT staff and the service support may be provided from a remote location requiring transfer of either the doctor or the patient in an emergency. Similar arguments apply of course to nursing and anaesthetic support services. Should the child need immediate airway management or admission to ICU for ventilation it is likely that the anaesthetists and or intensivists, including many consultants, will have less experience in management of sick children and their airways than a decade ago. Dedicated paediatric rotas to cover such emergencies may or may not be in place.

Transfer of a sick child may be necessary for further definitive care, or simply to take the child to where the services are. Retrieval is generally reliable but the sickest children may require airway management before tertiary expertise is available and in these circumstances transfer without securing the airway is unwise. Retrieval teams are not always trained in difficult paediatric airway management and may rely on staff in the DGH to manage the child's airway before transferring them. Decisions about when to intervene and whether to transfer a sick child with a normal airway or a child with a potentially difficult/compromised airway require communication and careful decision-making of the highest quality. This may involve a paediatrician, an emergency physician and intensivists or anaesthetists at the DGH communicating with these and other specialist services at the tertiary centre.

We do not know the incidence of either difficult airway management or difficult intubation in the general paediatric population, but it is widely accepted as being considerably lower than in adult practice. Certain groups have been studied and the incidence of difficult intubation of 4.7% has been reported in children with cleft palate (with 7% in those younger than six months)⁸ and 1.25% in children with cardiac anomalies.⁹

Equipment also differs in paediatric practice. Innovations are often initially targeted at the adult market and development of smaller paediatric versions has perhaps lagged behind adult equipment developments. However in recent years there has been considerable activity with the introduction of several new paediatric supraglottic airway device (SADs) and laryngoscopes/intubating aids. Evaluation of paediatric airway equipment is often slow and much of the literature on the use of various innovative techniques or airway equipment is individual case reports or short series. There is a marked lack of evidence-based information on the management of even the routine paediatric airway.

Finally, there are some areas of practice which remain notably different between adult and paediatric practice. In adults it is routine to perform and document a formal airway assessment at the preoperative visit, while this is not so in paediatric practice. Most airway tests have not been validated for paediatric patients and are difficult to interpret with the varying ages and sizes of patients.¹⁰ The NAP₄ census noted a marked divergence between the management of the predicted difficult airway in adult and paediatric practice: in adult practice (which accounted for 91% of all such cases) management was 81% intravenous induction of anaesthesia, 9% inhalation induction and 10% awake fiberoptic intubation, while in children (9% of such cases) inhalational induction was used for 63% and intravenous for 37%, with awake techniques not reported at all.

Case review

Most paediatric cases reported to NAP₄ (11 of 13) were anaesthesia-related and involved young children (three infants and four under the age of four years). Several issues were raised though the cases are quite heterogeneous.

Difficult intubation

Two deaths were related to difficult intubation and four other cases involved difficult or impossible intubation. Two cases are described as Case 1 and 2, these occurred in the emergency department and ICU respectively.

Predicted difficult intubation occurred in several children with dysmorphic features. In one case difficulty at intubation identified during routine surgery, was due to an unexpectedly narrow trachea, in an otherwise normal child, a congenital abnormality which is extremely rare.

Harm arose due to repeated attempts to intubate the trachea without change of technique. In one case intubation was achieved after six attempts and in another multiple attempts led to trauma that required ICU admission (Case 3).

One death occurred from unrecognised oesophageal intubation in the emergency department (Case 1). The capnograph, which was in use, was not interpreted correctly and this is an important training issue.

Case 1

A small infant with a congenital neuromuscular disease presented to the emergency department in respiratory failure. Three attempts were made to intubate by a paediatric registrar from PICU. Clinical signs were used to confirm tube position. Capnography was in use but the flat capnograph trace was either not seen or not correctly interpreted. The infant had a hypoxic cardiac arrest and cardiopulmonary resuscitation was necessary for several minutes. When passing a nasogastric tube the tracheal tube was found in the oesophagus. The infant was transferred to ICU for further care but did not survive.

Case 2

A notably dysmorphic preterm neonate with respiratory problems was intubated, after considerable difficulty, by a DGH neonatologist and then transferred by a neonatal transfer team to a larger hospital. During a non-invasive procedure the tube was displaced when the head was moved and reintubation by a consultant neonatologist failed. Mask ventilation was only possible with a two person technique. Intubation was still not achieved after assistance from an ICU consultant and a consultant anaesthetist experienced in difficult paediatric airway management. A tracheostomy was planned and ventilation was just possible after insertion of a laryngeal mask. During transfer of the patient to theatres, which were not adjacent, the airway became obstructed, hypoxia and death followed.

Case 3

A young child due for routine surgery required unanticipated admission to PICU following iatrogenic airway trauma due to repeated intubation attempts. Mask ventilation was impaired and intubation difficult despite a good view of the larynx. Eventually a small tracheal tube was successfully passed.

Emergency surgical airway

An emergency surgical airway was needed in five paediatric cases reported to NAP₄: four were attempted, three succeeded and one patient (Case 2) died during transfer for an emergency tracheostomy. One baby for elective superficial surgery unexpectedly had marked subglottic stenosis. Tracheal intubation was impossible: the airway was managed on a facemask and an ENT surgeon performed an emergency tracheostomy: an example of excellent management all round. A second case involved an infant with croup who was being anaesthetised to secure the airway prior to transfer to a larger hospital. Laryngoscopy was easy but tracheal stenosis prevented intubation: hypoxia and cardiac arrest intervened and emergency tracheostomy was performed during CPR. The child recovered. The only cricothyroidotomy, and the

only paediatric emergency surgical airway performed by an anaesthetist, was a case of airway obstruction due to a massive regurgitation in an older child: the tracheal tube was dislodged during vomiting, aspiration of gastric contents occurred despite suction and intubation was impossible. The anaesthetist attempted to rescue the airway with a needle cricothyroidotomy but this failed (see also Chapter 13). A further attempt at re-intubation was successful and the child recovered. The final two Cases are Cases 2 and 4.

Case 4

A child inhaled a plastic pen top and was transferred from one hospital to another. A spontaneously breathing anaesthetic facilitated rigid bronchoscopy by an ENT consultant but removal of the pen top was very difficult and ultimately required an emergency tracheostomy. This required considerable co-operation and co-ordination between the anaesthetist and surgeons.

Events at the end of surgery and in recovery (blood in or around the airway)

There were three cases in which blood in the airway at the end of surgery contributed to an adverse airway event. One was a patient who, after tonsillectomy, was extubated and aspiration of blood caused first laryngospasm and then hypoxia from lobar collapse. The patient was admitted to ICU and recovered. The other two cases are described in Cases 5 and 6.

Case 5

An obese, young, dysmorphic child had minor intra-oral surgery with uneventful anaesthesia. Two senior anaesthetists attended. There was a small amount of bleeding into the pharynx before extubation. Immediately after extubation the child developed airway obstruction. Hypoxia was rapid and re-intubation was delayed by searching for a new tracheal tube (the first having been discarded) and by blood obscuring the laryngeal view. Bradycardia required a brief period of cardiac compression but after transfer to ICU the child made a full recovery.

Case 6

A young healthy child arrived in recovery after intubated tonsillectomy and soon after had a respiratory arrest. Despite re-intubation, ventilation was ineffective and hypoxia led to cardiac arrest. Bronchospasm was considered. Ventilation was only possible when, after a period of some time, the trachea was re-intubated with a cuffed tube and a blood clot was removed from the airway. Hypoxic damage had occurred and the patient died.

As can be seen a significant minority of cases of harm in children in this project were problems at the end of anaesthesia, a common finding throughout NAP₄. In these cases blood in the airway led to patient harm and in one case death.



Aspiration of gastro-oesophageal contents

Aspiration was a rare event in this cohort, being seen in only two reported cases. Both cases involved minor orthopaedic trauma surgery (closed fracture manipulations) on slim children performed out of hours, and use of a laryngeal mask. In both cases the aspiration occurred during surgery and both were significant. One case (described above) required attempted cricothyroidotomy to rescue the airway and one led to extensive airway soiling managed with rigid bronchoscopy and lavage. Neither child had additional risk factors for aspiration. Both children were admitted to ICU but made a rapid recovery and were discharged the following day.

Monitoring

Monitoring was generally of a high standard. In only two cases the review panel considered that monitoring might perhaps have been improved. The use of capnography was frequent, but not universal during anaesthesia (eight of 11 cases), except during events in recovery. Most anaesthetists used a combination of monitoring and clinical signs to determine correct placement of the airway device. In six cases some reliance was placed on clinical measures. In one case, outside theatres, a non-anaesthetist intubator apparently failed to appreciate the importance of a flat capnograph trace and missed an oesophageal intubation.

Transfers

Cases 2, 4 and 6 all illustrate issues related to transfer. Transfer may be hazardous because an airway has not been secured, or because an airway device used to secure a difficult airway may become displaced during transfer. Management of airway compromise 'in transit' is fraught with hazard as limitations of monitoring, patient access, equipment, assistance, personnel and environment all interact. NAP₄ had cases reported where a child with an 'at-risk' airway developed complications during attempted intubation for transfer, where a child with an 'at-risk' airway was transferred (successfully) without securing the airway, where a secure airway was lost during intra-hospital transfer and where an airway was lost after retrieval had been completed. Transfer issues therefore arose in around one in three of the cases reported to NAP₄: these events included one case of cardiac arrest and one death.

Training and staffing

Consultants were involved in the initial care of 11 of the 13 paediatric cases reported to NAP₄ and, if not already present, attended all events soon after they started. Frequently when additional help was requested another consultant or consultants were available to help manage the difficulties.

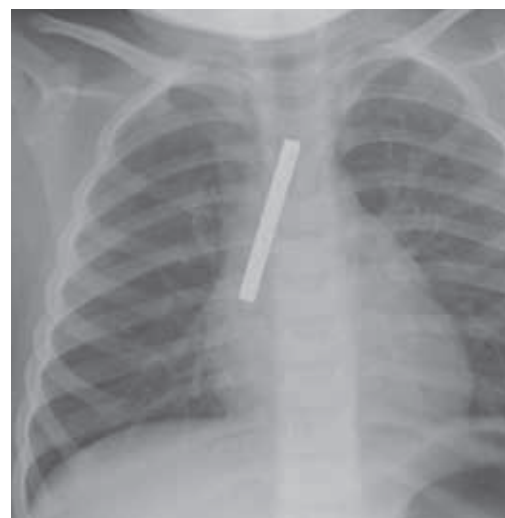
In one case oesophageal intubation occurred in emergency department and there was evidence the intubator, who was a trainee paediatrician, although using clinical signs to determine that intubation had been achieved correctly, did not correctly interpret the capnograph that was in use. There were several instances where multiple attempts at intubation either risked or caused airway trauma.

Numerical analysis

Thirteen paediatric reports met the criteria for submission to NAP₄. The two events occurring outside theatres involved infants both of whom had congenital abnormalities.

In three cases the outcome was death. This included the one patient in ICU, one in the emergency department and one in the theatre recovery area. Two of the children who died had severe co-morbidity.

The 11 events that occurred in theatres, involved three infants and four were aged 1–4 years. Males and females were equally represented. Eight of the 11 were ASA 1–2, one was obese. Four had congenital or acquired abnormalities. Four had airway assessment performed and two had a predicted difficult airway. Anaesthesia was administered by a consultant from the start in ten cases. Anaesthetic induction was gaseous in six cases and intravenous in five. Five events occurred at the induction of anaesthesia, two during maintenance, three at emergence and one in the recovery area. The primary airway device used during anaesthesia was a tracheal tube in eight, laryngeal mask in one and rigid bronchoscope in two. Monitoring was used for all cases: with capnography used for eight inductions. Primary airway problems were: failed intubation two, blocked airway three, airway trauma one, aspiration of gastric contents one, tube displacement one, problem at extubation three.



Nine children had a moderate level of harm, one no harm and three death. Overall airway care was rated good in two, mixed in five, poor in four and not commented on in two.

Discussion

It is anticipated that overall there has been an under-reporting of cases to NAP4 and this is likely to apply equally to children. However the varied nature of the cases reported gives us confidence that the main issues related to the care of children with acute difficulties in airway management have been included. The project has identified a small number of cases of poor outcome including permanent morbidity and mortality associated with the airway management of children.

Whilst it is unusual to have unanticipated airway difficulties in children the anxiety created by these cases is extreme. The incidence of difficulties with tracheal intubation in children is very low, and this project confirms that many difficult paediatric airways or difficult intubations are associated with recognised syndromal abnormalities.

Difficult intubation

Management of predicted difficult intubation in small dysmorphic children requires considerable skill and experience. When emergency intubation is required in such children the difficulty may be exacerbated. Options available in adult practice may be impractical or unavailable. Cases require very high levels of teamwork and communication. Case 2 highlights the precarious nature of the airway in babies with severe facial abnormalities, particularly micrognathia. When a difficult airway has been rescued it is vital that the airway is protected and the precarious nature of it might usefully be communicated to all those involved in the patient's care. Two deaths occurred outside the theatre setting: it has been noted in the review of adult cases that equipment in the emergency department and ICU often falls short of that in theatres. There was no evidence that this contributed in the cases described but the issue of availability of difficult airway management equipment is equally pertinent to paediatric practice.

While the techniques available for difficult intubation are more limited in paediatric practice, repeatedly using a technique which has already failed has little logic. Alternative techniques should be considered and with the recent development of more advanced paediatric SADs these may find an increased role in paediatric airway management in the future. Use of a SAD for airway rescue in children was seen only in one case in NAP4.

The importance of maintaining a wide range of small tubes (especially smaller than expected) is illustrated by several of the reported cases. On a related topic, one case was reported during an anaesthetic for a radiological

investigation in an infant: after intubation the small tracheal tube obstructed, due to excessive secretions, leading to hypoxia and brief cardiac arrest. Paediatric airways are small and the inserted tubes make them smaller, which can create problems rarely seen in adult practice. While this finding is well known, these cases serve as a reminder.

Emergency surgical airway

It must be acknowledged that paediatric ENT support may not now be available in all hospitals where children are anaesthetised. In the NAP4 cohort four children had an emergency surgical airway and in a further case this was planned. The cases described above reflect the benefit of having access to emergency ENT expertise. The use of direct transtracheal techniques are controversial in young children due mainly to technical difficulties.¹² Formal surgical tracheostomy is used in most cases and cricothyroidotomy, as a rescue technique, is very rarely employed in children. NAP4 has found a high rate of failure for needle cricothyroidotomy in adults (see Chapter 13) and it is likely the procedure in children will be even more demanding.

Events at the end of surgery and in recovery (blood in or around the airway)

Suction clearance of the airway before extubation should be performed routinely. When there is, or has been, blood in the airway during surgery it is essential that the airway is also inspected to ensure it is clear before extubation. Whether this is done by the surgeon, the anaesthetist or both is a matter for discussion, the important lesson is it must be done thoroughly for all such patients.

There are recognised alternative methods for protecting the airway from soiling at extubation and these include delaying extubation until the child is completely awake (on the basis that airway reflexes will have fully recovered), or using a laryngeal mask either after deep extubation or as an alternative to a tracheal tube throughout surgery. These latter techniques are likely used less in children than adults and remain controversial.

The cases also remind us that the anaesthetist's responsibility does not end when the patient is extubated or transferred to recovery.

Airway interventions including re-intubation may be needed after extubation or in recovery, and the relevant equipment, personnel and expert assistance should remain available until the need for them has clearly passed. In this regard keeping the child's tracheal tube (or an equivalent) until they are awake, as well as ensuring immediate availability of facemask and intubation equipment, both in theatre and recovery remain good practices.





Airway obstruction

Case 5 illustrates a case of complete airway obstruction. When, as in this case, ventilation is not possible despite clearing the upper airway the management is difficult. In NAP₄ (in adults) diagnoses of bronchospasm and anaphylaxis were more likely to be considered than tracheal tube blockage or displacement. Use of capnography, irrespective of the location of the event, may provide valuable diagnostic information. In such circumstances, particularly where blood or secretions may possibly obstruct the airway device or distal trachea, active efforts to diagnose mechanical problems include passage of a 'bronchial sucker' and suction, fiberoptic inspection, tracheal tube removal and rigid bronchoscopy. These have the potential to be life-saving.

These cases are undoubtedly very difficult to diagnose and manage promptly. Prior anticipation, management aimed at avoidance, use of appropriate monitoring to detect an event and equipment to manage it are perhaps the first steps.

Aspiration of gastro-oesophageal contents

The cases of aspiration, with others in this report (see Chapter 19) remind us that aspiration is a significant cause of airway morbidity, that trauma surgery is likely a risk factor and that a standard laryngeal mask cannot be relied on to protect the airway. Aspiration is not necessarily an unusual event in paediatric patients but previous work suggests children are much less likely than adults to have significant harm from this complication.¹¹

Cardiovascular complications of paediatric airway events

It is well recognised that hypoxia in children may lead to bradycardia and cardiac arrest. In NAP₄ in addition to the three deaths, four other events were complicated by bradycardia, three of which progressed to brief cardiac arrest requiring CPR. The need for those managing paediatric airways to be fully competent at paediatric advanced life support is re-emphasised.



Monitoring

In the recovery area monitoring should be such of such a level that airway events are detected as promptly as possible: this requires continuous oximetry and the one-to-one presence of a trained recovery nurse. Use of blood pressure monitoring and availability of ECG and capnography in recovery are areas where standards may fall short of those practised in adults. One child arrived in the recovery room 'obviously cyanosed': though other details were limited this suggested the patient was not monitored during transfer to the recovery area and the reality is that few patients are. Some would argue that formal monitoring should take place during transfer from theatre to the recovery area: this is a subject that remains controversial and for which this project has not identified a clear answer for either adults or children.

Transfers

Transfers are necessary and inevitable both within and between hospitals. All pose a risk to the airway and this is exacerbated where there is airway difficulty. Planning, communication and good management of the airway before transfer are essential. Senior involvement is required. The risks of transfers do not cease on arrival at the destination hospital.

Training and staffing

The high consultant involvement in these cases provides encouraging evidence of senior involvement and supportive team working. Whilst this is beneficial for patients it may also explain the difficulties trainees have in gaining experience in managing or observing such rare events. In only three anaesthesia cases was a trainee involved at the start of the case. In two cases an event was managed largely by a trainee, in one sub-optimally.

As a whole these cases reinforce the already known message that high quality paediatric airway management requires knowledge and practical skills but it also requires skills such as preparedness, planning, communication,

situation awareness and knowledge of when to stop or change plans. In many cases the clinicians involved in these cases showed evidence that all these skills were in use: however this was not universal.

Learning points and recommendations

Recommendation: Major airway difficulties in children are rare and many are predictable. However there is still a small incidence of unexpected difficulties with airway management and systems must be in place to deal with this.

Recommendation: Formal assessment of the airway was uncommon in this group of patients. The identification and validation of useful airway assessment tests in children would be beneficial.

Recommendation: Some children with congenital abnormalities are extremely difficult to manage and it was not possible to intubate their trachea despite the expertise of the staff. Alternative solutions may need to be actively sought. In a sub-group of these children the airway can only be adequately managed by tracheostomy.

Recommendation: Full monitoring at intubation is essential in paediatric patients. The observation of satisfactory chest expansion, auscultation and observation of the tracheal tube passing the cords, whilst useful clinical signs, must be supplemented with the correct use and interpretation of capnography whenever an artificial airway device is inserted. This applies outside the operating theatre as well as in it.

Recommendation: All staff managing the paediatric airway, in whatever clinical area, require training in practical airway skills and in the use of relevant equipment including capnography and other monitoring.

Recommendation: Theatres, ICU and emergency department areas where children are cared for should have advanced airway equipment rapidly available to manage airway difficulty in children. There should be a clear chain of responsibility so that anaesthetic input is requested early if any child is anticipated to have an airway that is difficult to manage.

Recommendation: All those performing advanced airway management for children should be competent in managing cardiac arrest in children.

Recommendation: During airway difficulty, especially in young children, there should be consideration of involving ENT specialists early.

Recommendation: Senior help must be asked for early if difficulties with management of a child's airway are identified.

Recommendation: Good practice guidelines should be available for management of children in post-anaesthetic recovery areas.

Recommendation: Transfers both within and between hospitals should be recognised as periods of increased risk for airway dislodgement and complications. Planning, equipment and staffing should be appropriate to manage such complications.

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Dr David Bogod

Headline

Four obstetric cases were reported to NAP4. All involved failed tracheal intubation at the time of emergency caesarean section and were admitted to ICU for observation of their airway and other reasons (e.g. aspiration, controlled ventilation following massive haemorrhage). In one patient a surgical tracheostomy was performed after delivery and in another there were two failed attempts at a cricothyroidotomy. All parturients were near term, three were reported to be obese, (two had a body mass index greater than 35 kg m⁻²) and the patients had complex obstetric, medical and anaesthetic issues. All occurred out of hours. Consultants were either involved from the outset or attended when the event occurred. Two case reporters commented on lack of support/insight from the non-anaesthetic staff in the delivery suite theatre. All mothers had live births and made a full recovery.

What we already know

The Confidential Enquiry into Maternal and Child Health¹ has consistently reported fatalities arising from difficult airway problems since its inception over 50 years ago. Fortunately the incidence of deaths in this category has fallen dramatically, probably largely as a result of the rise in regional anaesthetic techniques. There were 16 deaths from failed intubation, oxygenation, aspiration and airway problems in 1976–1978 in contrast to two cases in the last report of 2006–2008.

Algorithms on the management of the difficult airway do not specifically address the obstetric airway.^{2,3} This reflects the unique set of problems posed by the failure to intubate the mother's trachea: a conflict develops as the optimal and safe management of the mother may threaten the life of the fetus and vice versa and in this situation difficult choices may need to be made. The classification of degree of urgency of the emergency caesarean section⁴ goes some way to clarifying the risk to mother and fetus, making management plans more explicit, particularly to teams whose primary focus may be directed at delivering the baby: obstetricians, midwives, neonatologists etc.

After a failed intubation attempt, the overriding concern is maternal oxygenation and the patient should be woken up if continuation poses a risk to the mother. Trainees are taught to adhere strictly to this. More experienced anaesthetists

may continue anaesthesia with the airway maintained with a supraglottic airway device (SAD), if they consider the airway to be satisfactory, in order to facilitate rapid delivery of the baby. A recent paper described the successful use of the ProSeal LMA in 3,000 elective low-risk caesarean sections under general anaesthesia.⁵ However continuing anaesthesia with a SAD in an emergency situation may leave the mother at risk of aspiration of gastric contents and high levels of volatile agents exacerbate uterine relaxation and bleeding. The question then arises as to whether one should continue attempts to intubate the trachea in difficult circumstances where a stable airway could become unstable. This may be necessary even if the baby is safely delivered, as the procedure may be prolonged because of uterine atony, coagulopathy and postpartum haemorrhage etc. It is important to choose the best fitting SAD at the outset for manual ventilation, gastric suction and to facilitate tracheal intubation should that be required. Examples of failed intubation guidelines are available on the website of the Obstetric Anaesthetists Association.⁶

Recent concerns have been raised about the quality and duration of training of anaesthetic registrars dealing with this rare but serious complication.⁷ Furthermore the isolated nature of many delivery suites puts extra pressure on the anaesthetist and supporting staff, making the provision of skilled anaesthetic assistance essential. Numerous triennial reports have pointed out deficits in training on delivery suite and the necessity for prompt availability of senior staff.

Each year a small but consistent number of pregnant patients require admission to ICU. In 2010, ICNARC (intensive care national audit and research centre) reported that 2.5 per 1,000 deliveries are expected to require ICU care, often ventilatory support following pre-eclampsia and peripartum haemorrhage.⁸ In 2007–2008 there were 513 pregnant or recently pregnant patients admitted to ICU in the UK but the incidence of serious airway problems was not determined in this population.

In 2009 a national audit confirmed the incidence of difficult intubation of one in 250 general anaesthetics and the widespread use of SADs to manage this circumstance when this occurred.⁹ Obstetric anaesthetists should be familiar with a broad range of these devices, particularly those that provide protection against aspiration and aid insertion of a definitive airway required for prolonged ventilation: i.e. the i-gel™, ProSeal LMA™, Supreme LMA™, ILMA.

Case review

As only four obstetric cases were reported to NAP₄ all are described briefly here.

The cases describe:

- failed tracheal intubation, failed awake fiberoptic intubation, failed cricothyroidotomy
- gastric aspiration and need for a definitive airway
- supraglottic airway device insufficient for Peri-operative management of a complex case
- severe bronchospasm and lack of capnograph trace.

Case 1

An obese term parturient who was obese with a history of obstructive sleep apnoea in pregnancy was admitted to the delivery suite in the early evening. The patient had a lumbo-peritoneal shunt in situ. Prior neurosurgical advice recommended that labour and regional anaesthesia were contraindicated. The patient was initially attended for caesarean section by two trainees who made three unsuccessful attempts at intubation. The patient was woken up and a consultant anaesthetist attempted awake fiberoptic intubation: this failed due to poor patient compliance. There was no fetal compromise and the patient was allowed to labour in the operating theatre using entonox in the presence of a midwife. For poorly understood reasons the patient suffered a cardio-respiratory arrest: mask ventilation and airway rescue with a laryngeal mask, both failed resulting in a 'can't intubate, can't ventilate' (CICV) situation. Cardiac output was quickly restored. A 13G cricothyroid puncture was attempted twice and failed. Oxygenation and ventilation then intubation were eventually possible using an intubating LMA. The event lasted five minutes in total; oxygen saturations were below 70% for two minutes with the lowest recorded at 30%. A live infant was delivered by caesarean section and the patient extubated in ICU the following morning. She made a full recovery although there was the possibility of her having had a cardiac event during the period of severe hypoxia.

Case 2

A term parturient was admitted out of hours from a midwifery-led unit following prolonged second stage of labour. Delivery was by emergency caesarean section under successful intrathecal block but after delivery massive blood loss led to protracted surgery requiring conversion to general anaesthesia. There were three failed intubation attempts by relatively senior anaesthetic registrars and failure to rescue the airway with a laryngeal mask. Cricoid pressure was released during these attempts and, during facemask ventilation, aspiration of gastric contents occurred leading to severe hypoxia. There were further failed attempts to secure the airway with a ProSeal LMA and Bonfils laryngoscope, then eventual success with a McCoy laryngoscope and blind bougie placement. Total operating time was six hours. The patient was transferred to ICU for overnight ventilation and treatment of right lower lobe consolidation due to aspiration. No further complications occurred and she was discharged within a week.

Case 3

An obese term parturient presented in the evening with antenatal haemorrhage requiring a general anaesthesia for emergency caesarean section. Although prior airway assessment was normal, direct laryngoscopy by a consultant revealed a grade 4 larynx, and three intubation attempts failed. The airway was rescued with a laryngeal mask. The airway event lasted 45 minutes without oxygen desaturation and with delivery of a live baby. Following massive haemorrhage the mother became acidaemic, hypothermic and coagulopathic. A surgical tracheostomy (cuffed size 7.0mm id) was performed by an ENT surgeon, inserted on the first attempt without problems, and the patient was ventilated overnight on ICU. The patient made a full and rapid recovery.

Case 4

A morbidly obese smoker with asthma and recovering from a chest infection presented for emergency caesarean section. A spinal anaesthetic was performed by a staff grade but pain during surgery necessitated conversion to general anaesthesia. After induction of anaesthesia laryngoscopy was grade 2 but after intubation the capnograph was flat, indicating no expired carbon dioxide. Failed intubation was diagnosed twice and the tracheal tube removed. Ventilation of the lungs was possible when the tracheal tube was replaced by a laryngeal mask. After a third intubation, ventilation was possible and a capnography trace was visible. The baby was delivered safely and the patient required ventilatory support in ICU for five days but made a full recovery. The reporters ascribed the difficulty to severe bronchospasm following suxamethonium resulting in mistaken failed intubation.



Numerical analysis

NAP₄ received four obstetric reports. All involved emergency surgery at term and all required ICU admission after failed intubation. There were no deaths and no cases of resultant brain damage. One patient had a cardiac arrest during the airway event and one may have suffered an acute cardiac event due to prolonged hypoxia. All parturients delivered live babies and all mothers made a full recovery.

There were three obese patients: one of whom was morbidly obese.

One event occurred after failed (incomplete) regional anaesthesia and one after prolonged surgery meant regional anaesthesia became inadequate.

One patient was woken after failed intubation and three were not with on-going surgery likely making this option impractical.

Airway rescue with a SAD was attempted in all patients: in total on six occasions: four with a laryngeal mask (two successes, two failures), one with an ILMA (successful) and one with a ProSeal (failed).

There were no events where aspiration was the primary event, though in one case aspiration was a secondary event, complicating failed intubation.

There was one attempt to perform fiberoptic intubation, which failed. There were no attempts to intubate using the SAD as a conduit and one patient had a tracheostomy with an effective SAD in place.

Two emergency surgical airways were attempted: one surgical tracheostomy was successful while a needle cricothyroidotomy failed and was rescued by tracheal intubation.

Discussion

As there were only four obstetric cases reported to NAP₄ there is limited scope to draw robust conclusions and make firm recommendations, but there are useful learning points.

In 2007 there were approximately 720,000 deliveries in the UK. An extrapolation of the National Obstetric Anaesthesia Database (NOAD 2007) estimated 17,300 obstetric general anaesthetics.¹⁰ Using this data an approximate incidence of severe airway problems can be estimated at one per 4,348 obstetric general anaesthetics (95% confidence interval one in 1,700 – one in 16,000). The likelihood that not all cases have been reported means this is a minimum estimate and the true incidence may be up to four-fold higher. A simultaneous survey on failed obstetric intubation in the UK reported 33 cases (author's own unpublished data), giving a failed intubation rate in the order 1:500 general anaesthetics: in most cases anaesthesia was continued via a laryngeal mask.



In the year 2007–8 there were 513 obstetric admissions to ICU. The four cases reported to NAP₄ therefore likely indicate that airway problems constitute a very small proportion of the ICU admissions from delivery suite.

All cases presented in labour and had a general anaesthetic for out of hours emergency caesarean section or complications of caesarean section. The low number of reported cases is notable in itself and likely reflects the progress made in managing the obstetric airway in response to previous CEMACH reports. Three of the four patients were obese (two recorded as BMI >35kg.m⁻²) and while this might be a chance finding the prevalence of obesity in the general and obstetric population is increasing and may contribute both to primary airway events and those that occur after regional anaesthesia has failed.

The cases, which all involved failed intubation, highlight the need for regular airway training and skills updates for anaesthetists attending a group of patients with very specific airway issues. Interestingly in only one case was the recorded airway assessment abnormal (abnormal Mallampati view). It is notable that in the reported cases one followed inadequate spinal anaesthesia, one failed awake fiberoptic intubation and one prolonged surgery during which regional anaesthesia wore off: thus in none of these cases was general anaesthesia the primary plan for

airway management. All obstetric anaesthetists may be required to provide general anaesthesia, often when it is not 'plan A' to patients with a very short period of warning. As such they must have well practised skills.

When problems were predicted or occurred these were handled in a logical sequence: attempts at laryngoscopy were limited (usually to three), and were generally followed by attempts to rescue the airway with facemask ventilation, placement of a SAD and on one occasion, waking the patient. Despite this airway rescue techniques failed rather frequently. In one case awake fiberoptic intubation failed due to problems with sedation and compliance. This is a particularly challenging problem as the patient was also distressed by painful contractions. Use of alternative laryngoscope blades were not seen consistently in the reported cases, something of a contrast to non-obstetric cases. Rescue of the airway with a SAD failed in half the attempts and rescue surgical airway also failed on one of the two times it was attempted. These may illustrate both intrinsic difficulties inherent in managing the obstetric airway and problems due to the infrequency with which general anaesthesia is used in obstetric practice. As successful airway rescue would lessen the likelihood of cases meeting NAP₄ inclusion criteria, it must be acknowledged that the cases reviewed are unlikely to reflect normal success rates of these rescue techniques.

Waking the patient up after a failed intubation is a widely accepted practice in obstetric anaesthesia even when the fetus is in distress, as the mother's life is the priority. However this should not be an automatic reaction if difficulty is encountered, particularly if a SAD is successfully being used that can also aid intubation. Senior experienced staff need to be involved early to make decisions in difficult situations, e.g. failed block, ongoing surgery,

Figure 1 Ramping can be performed in obese obstetric patients for improved pre-oxygenation and laryngoscopy. The head and trunk are supported to align the external auditory meatus with the sternal notch in the horizontal plane



contraindications to regional techniques. Of note: in the first case report, great difficulties were encountered after the patient was woken up and these were ultimately rescued by a SAD that may have been used in the first place.

Aside from the case of failed fiberoptic intubation, it was noticeable that a fibroscope was not used either to intubate directly, intubate via a SAD or to check tracheal tube placement when it was in doubt. This may reflect the isolated nature of the delivery suite from main hospital theatres where fibroscopes are likely more available, but serious consideration should be given to having a fibroscope readily available for these difficult cases.

Suxamethonium is commonly used at induction in obstetrics. One case of airway difficulty was considered by the reporter to be severe bronchospasm in a brittle asthmatic following the administration of suxamethonium and intubation.

While this diagnosis is possible the awkward laryngoscopy followed by absent ventilation and 'flat capnograph' raise the possibility of oesophageal intubation (see Chapters 6 and 12). When oesophageal intubation is suspected, as it was by the anaesthetists in case 4, clinical signs may be misleading. There are other methods of confirming or excluding the diagnosis. Careful interpretation of capnography, use of bulb or syringe oesophageal detectors and fiberoptic inspection are all appropriate but were not used in this case. If the patient is considered to be at high-risk of a reaction to suxamethonium a modified rapid sequence induction with rocuronium may be used: the immediate availability of sugammadex would likely improve the safety of this option.

Skilled assistance is essential for safe obstetric anaesthesia. As these cases illustrate, airway difficulty in a complex obstetric patient can present at any time and may require advanced techniques. These cases all happened out of hours, all involved experienced staff having problems resolving difficult airway issues in sick emergency patients, two required a surgical airway and all required ICU admission. It is essential to have properly trained support staff available 24 hours a day to help the obstetric anaesthetist and this was reported as a problem area. On a related issue, in some cases vital equipment was not immediately at hand and this led to delays in obtaining the equipment and appropriate patient care; the remote location of the delivery suite was considered a factor in this.

There was often good communication between the members of the anaesthetic team. Despite all cases occurring out of hours and as emergencies, consultant anaesthetists were either present from the outset or attended promptly during the event. The reports described good anaesthetic teamwork. In contrast communication



between the different teams on delivery suite was not always as good. One reporter specifically commented on a lack of awareness of the non-anaesthetic staff of the seriousness of the incident and in another it was implied.

In one report, following failed intubation and failed sedated fibreoptic intubation in an obese patient with significant co-morbidities, the patient remained labouring in the operating theatre with a midwife managing a complex situation that included both recovery from sedation and ongoing labour. Cardio-respiratory arrest followed. This raises the general issue that those staff tasked with recovering patients after anaesthesia or sedation must have the requisite knowledge and skills and that recovery must take place in an appropriate environment.

Specialist advice given pre-operatively is often helpful in complex cases but it may also lead to confusion. A failed intubation occurred in a patient with a lumbo-peritoneal shunt whose neurosurgeon advised against labour and a regional technique. In retrospect the review panel were of the opinion that a regional anaesthetic was a viable option in difficult circumstances and that the neurosurgical advice may have excluded a possibly safer method of delivery. In complex cases multidisciplinary discussions are likely of value, and these should take place in the early antenatal period so that robust plans can be set in place.

The reported cases were complex and often involved multiple factors contributing to the event – good examples of the ‘Swiss cheese’ effect (see Chapter 24). In one case, despite recommended difficult airway management policies being followed, failed intubation was complicated by aspiration, there was evidence of poor communication between the teams and lack of availability of essential airway equipment. Contributory factors for the combination of airway difficulty and aspiration likely included omission of antacid prophylaxis, the physiological effects of the pregnancy, prolonged labour contributing to airway oedema, repeated laryngoscopy and (appropriate) release of cricoid pressure to facilitate intubation and enable placement of a laryngeal mask. This case also serves to remind that obstetric patients remain at risk of aspiration. Of note, when tracheal intubation problems occurred, the laryngeal mask was the first choice rescue SAD in all reported cases. It failed in two cases and succeeded in two. Given the prevalence of obesity in difficult airway problems, the need for ventilation and the risk of aspiration (especially in an obstetric population) a more advanced (second generation) SAD might be a better option at the outset. A standard laryngeal mask does not enable gastric drainage, is less likely to protect the airway from aspiration of gastric contents and is not the easiest SAD to use as a conduit for fibreoptic guided tracheal intubation. Other SADS may be better suited to all these roles as well as improving the success rate and quality

of controlled ventilation. While, an anaesthetist might reasonably in an emergency, attempt to secure the airway via any available SAD, with some planning the optimal device might be available and selected.

Learning points and recommendations

- Major airway complications in obstetric patients are rare but the physiology of pregnancy, active labour and isolated location may increase their complexity when they occur.
- Non-anaesthetic obstetric theatre personnel should be aware of the considerable difficulty of these cases.
- Three of the four obstetric patients reported to NAP₄ were obese and with medical problems such as asthma.
- In the event of a failed obstetric intubation it is not always possible to wake up the patient and convert to a regional technique (e.g. failed block, ongoing surgery) and this should be recognised in preparing failed intubation strategies.
- As consultants from other disciplines other than obstetrics and anaesthesia may not fully understand issues of choice of anaesthetic for parturients, decisions regarding the management of complex patients require close collaboration when forming initial and back-up plans.

Recommendation: Despite the relative infrequency of general anaesthesia for caesarean section, obstetric anaesthetists need to maintain their airway skills including strategies to manage difficult intubation, failed intubation and CICV.

Recommendation: Obstetric anaesthetists should be familiar and skilled with supraglottic airway devices for rescuing the airway: particularly those designed to protect from aspiration and to facilitate ventilation and/or intubation.

Recommendation: A flexible fibrescope may have several roles in the obstetric setting. Anaesthetic departments should provide a service where the skills and equipment are available to deliver awake fibreoptic intubation whenever it is indicated.

Recommendation: All staff working in the recovery area of a delivery suite including midwifery staff must be competency trained. Skills must be regularly updated.

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Headline

Healthcare organisations will predictably have a number of difficult intubations or airway difficulties every year (how many will vary depending on local circumstance) and will therefore need to have processes in place to deal with these difficult, potentially life-threatening events. Of the incidents reported to the project 72% were from an anaesthesia setting, 20% from ICU and 8% from the emergency department. Three-quarters of anaesthesia events took place during daytime hours and only 6% overnight (midnight–08.00), therefore skilled personnel should have been available for the majority of cases. In 90% of the cases it was reported that all equipment necessary to deal with the airway was available. In anaesthesia cases continuous capnography was widely used to confirm intubation. There was a single report of the use of a disposable carbon dioxide detector and there were no reports of the use of oesophageal detector devices. Capnography was used considerably less frequently in ICU and its omission led to patient harm and deaths.

Organisation

What we already know

The quality and safety of patient care has always been the focus for healthcare workers, but an increasingly high priority on improving patient safety has been seen in recent times both in the UK and across the world. All healthcare workers including medical staff make errors, with the majority of these being minor in nature. Historically, patient safety has been structured on the performance of experienced medical practitioners; however, increasingly the delivery of care is now more reliant on a multidisciplinary team. The communication and teamwork necessary for practitioners to provide effective and safe care has been assumed, but formal assessment and training in the elements of team performance has been generally absent from undergraduate and postgraduate education across all professions.

There is interplay of organisational, cultural and team factors that constantly threaten safety. These factors, often referred to as the 'system' are critical to performance, but all systems are operated by people. Improvement therefore depends on educating and empowering them. Because of this complex process and

the limitations of human performance it is reasonable to expect errors within healthcare delivery. The term 'human factors' has been applied to a multidisciplinary science which focuses on how humans interact with the environment in their workplace.¹ As a result of his personal experience, Martin Bromiley founded the Clinical Human Factors Group in 2007. This group brings together experts, clinicians and enthusiasts who have an interest in placing the understanding of human factors at the heart of improving patient safety.²

Healthcare organisations are complex and so to help reduce serious untoward incidents, such as major airway complications, they must be aware of such incidents and have a robust reporting and debriefing mechanism in order to learn from these events. Healthcare organisations should also ensure that clear lines of responsibility exist to manage these high-risk situations. The culture of individual blame is still dominant in healthcare and undoubtedly impairs the advancement of a 'safety culture'. In an effort to reconcile the twin needs for no-blame and appropriate accountability, the concept of a 'just culture' is being introduced. A just culture focuses on identifying and addressing systems issues that lead individuals to engage in unsafe behaviours, while maintaining individual accountability by establishing zero tolerance for reckless behaviour. It distinguishes between human error (e.g. slips), at-risk behaviour (e.g. taking shortcuts), and reckless behaviour (e.g. ignoring required safety steps), in contrast to an overarching no-blame approach still favoured by some.³

The successful management of airway difficulty demands a rapid and organised approach usually within a multidisciplinary team. Despite the immediacy of some crises many events will extend over a 24-hour period. Diagnosis and management should proceed without undue delay. Unnecessary delay leads to oxygen desaturation, potentially resulting in severe morbidity or death. The difficult airway presents a problem in which factors interplay between patients, the healthcare team, individual skills, equipment and the clinical area.

CHAPTER 23

Organisation and equipment

Case review

Although the scenarios are predominately present in the operating theatre (in this project 72% came from an anaesthesia setting) other areas contributed to the reported airway problems and need to be suitably prepared for this situation. After review of 184 reports organisational factors were judged contributory to the airway event in 42 (23%) and causal in one.

Case 1

An elderly patient was anaesthetised by a non-consultant for elective endovascular aortic reconstruction. A difficult airway was anticipated but the details of a previous airway problem during anaesthesia were recorded in a different hospital's notes and were unavailable to the anaesthetist. A grade 3 view of the larynx and pooling of saliva was noted: using a McCoy blade and a bougie the tracheal intubation was attempted but led to an oesophageal intubation which was promptly diagnosed. An i-gel was then inserted to manage the airway but gastric contents were soon noted around it and a gastric tube was inserted via the drain tube. The patient was intubated with a tracheal tube blindly placed through the i-gel. A chest X-ray confirmed aspiration, the patient was admitted to ICU and required ventilation for four days.

Case 2

An elderly patient with stridor required intubation for elective surgery. Neither CT nor MRI scan was performed pre-operatively. The patient was successfully intubated using an awake fiberoptic technique. During the fiberoptic examination tumour was noted to have invaded the trachea but a decision was made to carry on. Oxygenation became increasingly difficult. An emergency surgical tracheostomy was performed but this did not lead to improvement. Bilateral tension pneumothoraces occurred after use of a Manujet injector and despite these being drained hypoxia persisted resulting in the death of the patient. The obstructing tumour extended below the airway devices.

The availability of the patient's notes in Case 1, indicating previous difficulties may have led to a better management plan for anaesthetising this patient. The project data revealed cases in which preoperative assessment was inadequate and cases in which communication of the presence of an airway problem was lacking within the multidisciplinary team. Case 2 was felt by the reporter to be one in which poor multidisciplinary communication resulted in a poor initial treatment plan. Appropriate preoperative investigations and team discussion could have resulted in a different treatment option.

Difficult airways can present as a known problem or can be unanticipated. Fifty-five percent of cases related to anaesthesia were elective or scheduled cases. Preoperative assessment is therefore an important part of the surgical patient's pathway; organisations should ensure



that adequate facilities and trained personnel are provided for this vital function. Traditionally, anaesthetists have been responsible for determining whether a patient is 'fit for surgery'. However, in 2002 the National Confidential Enquiry into Peri-operative Outcome and Death (NCEPOD) report 'Functioning as a team?'⁴ suggests that preoperative assessment requires a team approach, this point is also endorsed by the Association of Anaesthetists of Great Britain and Ireland (AAGBI) in their 2010 guidance on Preoperative assessment and patient preparation.⁵ When a potentially difficult airway has been identified it is vital that good communication channels exist between those who perform preoperative assessment and the anaesthetist who will be responsible for carrying out the procedure, who must also visit the patient preoperatively to discuss, amongst other matters, the airway management options.

Anaesthetic departments should develop a standardised response to the diagnosis of a potential difficult airway. The Difficult Airway Society (DAS) recommend the use of an airway alert form to be carried by the patient.⁶ Case 1 illustrates how an alert of this type may have assisted



appropriate planning of airway management in this case. Anticipation of difficult airways is also important in other areas such as ICU and emergency departments, where the airway may be further compromised by illness, trauma or oedema. Other factors often exist within these areas that may compromise management of the difficult airway, such as the lack of relevant emergency airway equipment and appropriately trained staff to perform and assist with airway procedures.

Case 3

An elderly patient sustained multiple trauma with a subdural haematoma, face and chest injuries and an unstable upper cervical spine injury requiring halo fixation and ICU admission. Over an eight-hour period the patient became increasingly hypoxic and when intubation was attempted, by the intensivist, this failed. The patient was transferred to an anaesthetic room and intubation was then attempted by trainee anaesthetists. Gas induction was used and oxygenation was maintained. No ENT surgeon was initially available. Several airway management techniques were employed unsuccessfully and eventually the airway was established with a laryngeal mask. A tracheostomy was performed by a trainee ENT surgeon.

Case 4

An elderly patient with a BMI 40 kgm⁻² was in ICU after major cardiac surgery. Postoperatively the patient developed acute abdominal pain and distension with worsening metabolic acidosis. The patient had a known difficult airway. The patient was transferred to the CT scanner with non-invasive ventilation, but after the scan the patient had an acute deterioration resulting in cardiac arrest. Intubation was difficult, requiring two attempts and the position of the tracheal tube was confirmed clinically by three doctors. Capnography was not used. The resuscitation attempt was unsuccessful and after stopping the resuscitation attempts, fiberoptic bronchoscopy revealed the tracheal tube to be in the oesophagus.

Urgent intubation, re-intubation and patient self-extubation commonly occurs in ICU, especially with the increasing use of sedation breaks, therefore in situations where urgent intubation is required skilled personnel and the correct equipment are vital to avoid morbidity or mortality. The equipment necessary for intubation and difficult airway management must be the same as available in the operating theatre and includes capnography. Areas such as ICU must be as prepared for difficult airway management as the operating department (see also Chapters 6 and 9).

Systems and organisational structures need to ensure that those looking after critically ill patients have the skills to recognise and manage airway difficulties in a timely manner. Where this is not achievable, systems need to be in place to ensure those with the appropriate skills are

involved appropriately in time and place. The absence of airway management skills in those responsible for ICU and lack of appreciation of worsening hypoxia in a patient with a known airway difficulty can result in a controlled airway management problem becoming an emergency in which control may be lost and risk increased. Multidisciplinary teams are frequently needed to manage complex airway problems and these include ENT surgeons: planning and standard operating procedures should acknowledge such needs.

The transfer of hypoxic patients to another area adds a further risk to the patient. When a patient with a difficult airway, or one that might deteriorate is transferred outside the main area of care appropriate plans (including monitoring, equipment, personnel) must be in place to manage such deterioration, wherever possible to the same standards as would occur before transfer.

Equipment

What we already know

Many years ago in a seminal paper Cooper et al reported on the analysis of equipment failure and human error.⁸ In this article they observed that only 4% of critical incidents involved actual equipment failure and confirmed that human error was the dominant cause of equipment-related errors. In the intervening years as device reliability has increased the percentage of equipment errors is likely if anything to have decreased. Anaesthetic airway management, airway maintenance and tracheal intubation are usually easy procedures, but on occasions may be extremely difficult. A wide variety of equipment is available to assist in airway management, ranging from simple adjuncts, such as an oropharyngeal airway, to a plethora of supraglottic airway devices, specialist laryngoscopes, blades and tracheal tubes. The laryngeal mask airway has secured important niches in both routine and emergency airway management.⁹ Ten years ago Charters, in his British Journal of Anaesthesia Editorial on airway devices, concluded:¹⁰

‘Overall, development of airway devices up to the present time can be considered to have been somewhat empirical. The understanding of the physiological dynamics of the oropharynx is limited and variations in pharyngeal anatomy may be greater than has been previously considered. This is clearly an important area for anaesthesia research and airway device design in the future.’

Arguably not enough has changed since then, Beydon et al in 2010 concluded in their article on adverse events with medical devices that there needed to be a greater attention to the design of equipment and also inappropriate use was still prevalent when compared to reports from 1998.¹¹ In 2009 Thomas and McGrath reviewed patient



safety incidents with airway devices in critical care and recommended that there be minimum standards for the availability and checking of equipment.¹²

The increasing advances in medical technology have seen the need for healthcare professionals to be trained and competent in the use of an ever widening range of devices used to enhance patient care. However, the attainment and maintenance of competence in equipment and procedures such as difficult airway management has always raised debate regarding methods whereby competence at all levels is maintained and recorded.

The availability of the necessary equipment is very important in crisis management; the DAS website recommends an equipment list for routine and difficult airways. DAS also recommends that it is good practice to establish difficult airway trolleys. The Intensive Care Society (ICS) UK published 'Standards for the Care of Adult Patients with a Temporary Tracheostomy' in 2008.¹³ This document refers to the need for a designated difficult airway trolley in ICU. An audit reported in the Journal of the Intensive Care Society in 2010 (after many of the events reported to this project), concluded that the provision to deal with difficult airways in critical care across the UK was inadequate.¹⁴

Case review

Case 5

An elderly patient with a squamous cell carcinoma of the jaw who had a known grade 4 laryngoscopy view and difficult fiberoptic intubation was extubated in the ICU following jaw surgery. Forty-eight hours later he needed to be re-intubated. Oxygenation was barely maintained for an hour whilst the equipment was assembled for fiberoptic intubation and eventual percutaneous tracheostomy under local anaesthesia.

There is a need to have the difficult airway equipment in ICU. When a patient has a known difficult airway there is a need for clear management plans that can be used in the event of airway or respiratory deterioration. These require planning, communication and ensuring appropriate equipment and skilled personnel to carry them out are available.

Case 6

A patient developed respiratory failure in ICU one week after a craniotomy, intubation was carried out by two trainee anaesthetists however there was an unnoticed oesophageal intubation and the patient had a subsequent cardiac arrest. The resulting hypoxic brain injury led to the patient's death. The LR noted that capnography was not used.

Equipment used to monitor the airway on ICU should meet the standards that would be applied during anaesthesia. Thomas et al in an article in *Anaesthesia*¹² noted the apparent lack of capnography during airway incidents in ICUs. This has been confirmed in incidents reported in the NAP4 project (see Chapters 6, 9, 10 and 12); the reviewers judged that lack of capnography contributed to numerous airway events on ICU, poor interpretation of capnography also contributed to patient harm in ICU and under utilisation may contribute to lack of familiarity or expertise in its use. Absent or poor use of capnography likely contributed to or led to three-quarters of deaths on ICU that were reported to NAP4. Available airway guidelines (e.g. DAS guidelines for management of failed intubation and CICV) were frequently not followed and this was most notable in events occurring on ICU. All clinicians working on ICU should have formal training in routine and difficult airway management and this should include the use and interpretation of capnography.

Use of training programmes that incorporate high fidelity simulation, with other CPD strategies such as regular clinical exposure and appropriate purchase of advanced airway equipment – with the necessary training in its use – should be developed and supported throughout organisations where difficult airway management is likely to occur. Training and updating of skills is not only a requirement of medical staff working on ICU, but also a necessary requirement for staff assisting with airway management. Such airway training should incorporate an inter-professional element to help improve team-working and communication skills. There should be an agreed standard of competency for those assisting in securing airways. Levels of competence of staff assisting with airway management are designated to be the minimum level of those required by ODP and post graduate nursing programmes. This is an important factor to be considered by organisations, especially when managing airways outside of the operating theatre. The AAGBI's document on 'The Anaesthesia Team'¹⁵ states:



'Anaesthetists must have dedicated qualified assistance wherever anaesthesia is administered, whether in the operating department, the obstetric unit or any other area.'

The AAGBI recommended that anaesthetic directorates should nominate a consultant with a responsibility for equipment (the equipment officer).¹⁶ This safety guideline also recommended that safety and quality considerations be involved in all equipment acquisitions and training be provided for all users of equipment they may use. Further recommendations from this document included standardisation of equipment between areas; that the equipment is fit for purpose and easy to use; that a literature review inform the evidence base for purchase of equipment and as many users as possible participate in the evaluation of the equipment.

Learning points and recommendations

Recommendation: Because airway management is a fundamental anaesthetic responsibility and skill, anaesthetic departments should provide leadership in developing strategies to deal with difficult airways throughout the entire organisation.

Recommendation: The anaesthetic department should have an anaesthetist responsible for difficult airway management. The responsible person along with departmental colleagues should develop or adopt protocols for dealing with difficult airways in all areas of the organisation, ensure the purchase of suitable equipment to manage difficult airways and that regular multidisciplinary training for difficult airway management takes place.

Recommendation: As previously recommended by other organisations, a Medical Devices Management Committee should set, monitor and control the strategy, policies and procedures for Trust-wide management of medical devices. This will include risk assessment, evaluation and procurement, user training, maintenance, disposal and replacement. This committee should report directly to the Trust Board, where a named director should have overall responsibility for medical equipment.

Recommendation: Organisations should consider the minimal safe staffing and equipment levels required for establishing an airway and all associated complications in areas where airway management occurs. This should also involve development of training sessions and maintaining a record of staff training that allows for any deficiencies to be addressed via the appraisal process. This training should be recorded, and individuals should keep their own record of training for appraisal and continual personal development (CPD) purposes. An appropriate mix of staff should participate in selection of new equipment, training in the use of equipment, and reporting equipment associated incidents.

Recommendation: The availability of high quality guidelines from specialist organisations in the workplace near specially designated equipment may enhance safe management of these situations.

Recommendation: Relevant specialist organisations should consider national standardisation of difficult airway trolley contents for relevant areas. As a starting point a list of minimum advanced airway equipment that should be available in theatres, ICU and the emergency department would be welcome.

Recommendation: Those who work together should train together. Airway management involves a multidisciplinary team and there is evidence demonstrating that team training may improve outcomes¹⁷ in difficult situations. Research has shown that teamwork training may reduce technical errors by 30-50%.

Recommendation: Wherever possible, action plans for airway management should be developed between relevant staff involved. When airway incidents occur they should be followed by a debriefing session to allow all team members to feedback and allow future action plans and learning to occur.

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CHAPTER 23

Organisation and equipment

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Headline

NAP4 was not designed with a human factors analysis in mind. However there were enough examples of problems, which fell within the remit of human factors science, to highlight the importance of such issues and to raise awareness of the pivotal role human factors play in the prevention of error. In addition to the current chapter a follow-up study is underway that will attempt, by structured interview, to further explore human factors involved in the cases reported to NAP4.

What we know already

People working in the NHS are dedicated and conscientious and have worked hard to acquire clinical skills and knowledge. They are usually motivated by a genuine desire to reduce suffering and illness and yet, up to 10% of hospital inpatients suffer an avoidable adverse event.¹ Adverse incidents, accidents and mishaps in all safety-critical industries are caused by a combination of organisational and operational failures. The majority of adverse events are caused by errors, which can be identified and quantified using a systematic human factors analysis. Human Factors (HF) science uses knowledge of such failures to improve safety within the working environment. Recently, there has been an increasing recognition amongst medical practitioners of the importance of these human factors in error causation. While many anaesthetists may have some familiarity with HF science and some of its key concepts, we have yet to translate this awareness into improved safety in healthcare.

Human factors theory focuses on a range of topics associated with human abilities, behaviours and limitations in the context of workplace safety. The theory can be applied to system design and management and to the behaviour of individuals and teams who work within the system. It is crucial that both approaches are considered together to achieve success in building a robust safety culture.

System level

Human beings design systems, and knowledge of human factors can be applied to influence the design of facility layout, working environment, work-station ergonomics, equipment, alarms etc. Systems are also managed by human beings who in turn influence numerous variables such as organisational policies and protocols, rotas and

shift systems, staffing levels, job planning, task design and systems for transfer and sharing of information, all of which influence individual and team workload. System failures are found in abundance in healthcare but attention to the details of system design and management should enable managers to make allowances for human capability, and human failings, in complex working environments. Many of these system issues may seem to be too strategic and complex to be influenced by individual clinicians, but it is important that clinical input is included in all of the aforementioned areas if potential errors are to be avoided in the future.

As an example of anaesthetic system level HF planning many anaesthetic departments have started to try to address some of these issues (albeit in a limited way) by standardising airway equipment across theatre suites. Some have gone as far as organising their emergency airway trolleys to support DAS algorithms with separate drawers (labelled A-D) containing the equipment that would be needed for each part of the failed intubation drill.² Whilst this may seem intuitively sensible, it is important to realise that no robust scientific studies have been performed to determine if this approach actually improves adherence to guidelines, let alone outcomes. We must also recognise that there are hospitals in which equipment is not standardised and where anaesthetists will not know which piece of airway equipment they will be handed if an emergency arises.

Individual level

At an individual level, human factors theory describes the non-technical skills (NTS), which complement individual technical skills to facilitate safe and efficient performance of tasks. NTS include cognitive, social and personal skills such as effective communication, team working, leadership, decision-making, situation awareness and stress management. The most effective practitioners employ these skills to achieve consistently high performance.

NTS can be taught, practised and assessed alongside technical skills training in the workplace, but this requires assessors with the requisite knowledge and skills. Formal behavioural rating systems can be used to provide objective feedback against specific desired behaviours. The Anaesthetists' Non-Technical Skills (ANTS) System³ has been developed specifically for assessing NTS in

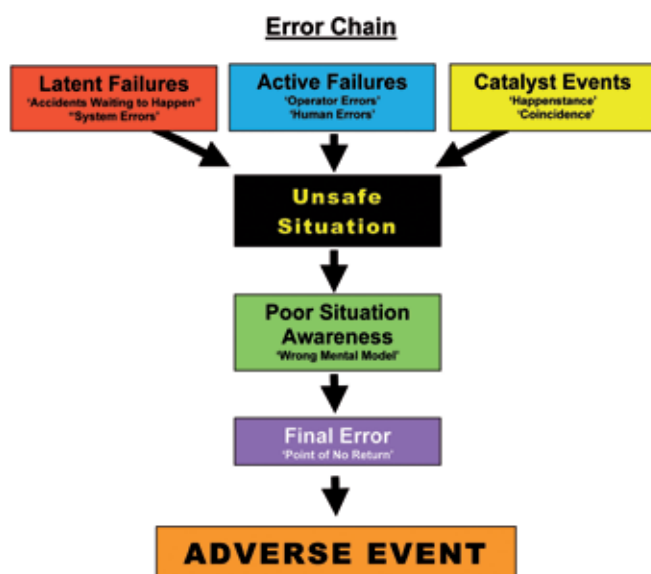
anaesthetists and provides a taxonomy of behaviours which are very specific for anaesthetic practice. ANTS is an excellent system for provision of feedback to all anaesthetists, whether in training or fully qualified, but is not suitable for multidisciplinary team training where a more generic system is more appropriate. The ANTS system also neglects some of the elements of leadership, which can be crucially important in emergency situations such as difficulty in maintaining control of the airway.

The taxonomies used in behavioural rating systems are useful for training, assessment, debriefing and incident analysis and can often appear to be deceptively simple. All taxonomies have their limitations and can never capture every aspect of performance. They require proper and systematic implementation into any organisation and the individuals who apply the rating system will require extensive training. Although individual performance can be improved, human error can never be totally prevented. Hence robust systems need to be developed in order to identify those errors that occur, before they cause harm.

Learning lessons from error in healthcare

Prior to the 1990s nothing had been published in the medical literature regarding clinical error or its prevalence. The results from the landmark Harvard Medical Practice Study^{4,5} were published in 1991 and for the first time it was recognised that the rate of error in medicine was much higher than had previously been acknowledged. A number of similar publications followed from around the world, showing similar rates of error. In June 2000, the United Kingdom Department of Health published the report *An organisation with a memory* (OWAM), which highlighted the consistent and repeated failure of the NHS to learn from mistakes. The following recommendations were made.

Figure 1 An error chain



- Unified mechanisms for reporting and analysis when things go wrong.
- A more open culture, in which errors or service failures can be reported and discussed.
- Mechanisms for ensuring that, where lessons are identified, the necessary changes are put into practice.
- A much wider appreciation of the value of the system approach in analysing and learning from errors.

It was clear from the report that human error could not sensibly be considered in isolation from the wider processes and systems of the NHS and a subsequent publication 'Building a safer NHS for patients'⁶ described how the recommendations should be implemented. Despite all the good intentions detailed in these reports, the Chief Medical Officer felt the need to commission a further investigation. 'Safety first: a report for patients, clinicians and healthcare managers'⁷ was published in December 2006 and showed that:

- awareness of error had been increased but the pace of change had been much too slow
- boards and managers do not give safety the same priority as achieving financial and access targets
- more effective methods of learning from error are required for the future.

Understanding Errors in the Workplace

An 'Error Chain' can represent a simplistic view of adverse incident causation. Latent Failures (also known as 'system errors' or 'accidents waiting to happen') combine with Active Failures (also known as 'human errors' or 'operator errors') to set up an unsafe situation. Sometimes these unsafe situations can be energised by Catalyst Events ('coincidental factors' or 'happenstance'), which confound the clinical picture (Figure 1). A hypothetical example might be in a hospital where anaesthetists and theatre teams are not regularly trained in emergency airway management (*latent failure*), and the emergency airway trolley is missing a cricothyroidotomy device (*latent failure*). The anaesthetist fails to perform a thorough examination of the airway (*active failure*) and the patient reports that he has starved since midnight when questioned, despite having eaten a pizza two hours earlier (*catalyst event*). The team's situation awareness is poor as they are not in possession of all the facts they need in order to make a fully informed decision about how to proceed. Should a CICV event arise, there is now an increased risk of complication by aspiration of gastric contents, poor management due to poorly honed skills, lack of requisite equipment and the likelihood of failure to rescue the situation despite many previous years of apparently 'safe' anaesthesia.

The error chain is not predictive of when or how an adverse event is likely to occur, and the relative importance of the different components may only become clear following a thorough investigation. Unsafe situations may be present for



long periods of time, possibly even for years and a number of 'near-miss' events may occur before the adverse event ultimately happens. The final error is usually accompanied by a lack of situation awareness on the part of one or more team members who are totally oblivious to the fact that an error is about to occur. The time frame is then often very short to the ensuing adverse event. Poor quality investigations focus only on the final event, rather than the chain.

A more dynamic attempt to model adverse events is demonstrated by James Reason's 'Swiss Cheese Model' (Figure 2). The bullet represents the passage of a potential adverse event through the system, and the slices of cheese represent barriers for prevention of errors. The holes represent a combination of latent and active failures which allow the bullet to pass through when the holes line up. This model works well in industries where a major focus has been placed on developing safe systems, which then reduce the size of the holes in the cheese. Unfortunately, the more common situation in healthcare is that less time and effort has perhaps been invested in system development and the barriers are often incomplete or sometimes absent altogether (Figure 3). Traditionally, too much reliance has been placed on individual practitioners to perform consistently to an excellent standard and too little attention has been paid to assessing and managing risk. The performance of individual practitioners, who form this last line of defence when an (airway) catastrophe occurs, may be subjected to intense scrutiny. This may occur in a court of law, as in the Fatal Accident Inquiry into the death of Gordon Ewing.⁸ In contrast, the system faults, which made the incident ultimately inevitable, may not be examined and studied in such depth.

Figure 2 The Swiss cheese model of risk. The adverse event has occurred because all the holes in the barriers to the event have happened to line up. More frequently these holes do not line up and the event is prevented (a near miss). A high-risk industry strives to increase the number of barriers and reduce the size of the holes



Figure 3 In this model, perhaps depicting a poorly performing healthcare system, the barriers are ineffective as the holes are large. A near miss is highly likely at some point to progress through all the barriers to become a critical event



Case review

The NAP₄ data collection process, being a web-based reporting system, was well suited to collecting data on the mechanistic aspects of events (e.g. timelines, equipment and procedures used, complications identified). It was less well suited to identifying issues of training, interpersonal interactions and human factors. While efforts were made to identify this information at the review stage it is likely that relevant data will have been missed either by the process of reporting or review: numbers reported in this chapter are therefore an approximation.

Aspects of human factors could be seen throughout the NAP₄ report and there are inevitable overlaps with other chapters. HF issues which emerged during panel review of the cases included:

System design and management

- Equipment shortages
- Inadequate maintenance of equipment
- Incompatible goals (e.g. conflict between financial and clinical need)
- Reluctance to undertake a formal analysis of adverse events/learn from errors
- Loss of documentation (e.g. previous patient records not available)
- Inadequate systems of communication
- Highly mobile working arrangements leading to difficulties in communication
- Inexperienced personnel working unsupervised
- No scheduled training sessions for updating staff in the use of new techniques/equipment
- Incomplete training/inadequate knowledge or experience
- Heavy personal workloads/lack of time to undertake thorough assessments

- Organisational and professional cultures which induce or tolerate unsafe practices
- No requirement at organisational level to undertake formalised checking procedures

Individual and team NTS

- Casual attitude to risk/overconfidence
- Peer tolerance of poor standards
- Lack of clarity in team structures (e.g. in a multidisciplinary team, who is in charge?)
- Incomplete or inadequate briefing and handovers/poor or non-existent debriefing
- Poor or dysfunctional communication – especially between specialities
- Failure to follow advice from a senior colleague
- Inadequate checking procedures
- Failure to request previous patient records
- Failure to take and document a comprehensive history
- Failure to undertake appropriate preoperative investigations
- Wrong interpretation of clinical findings/test results
- Failure to use available equipment (e.g. capnography)
- Attempts to use unfamiliar equipment in an emergency situation
- Failure to cope with stressful environment/interruptive workplace
- Failure to formulate back-up plans and discuss with the team members
- Fixation errors, resulting in a failure to recognise and abort a plan which is not working, and move to another potential solution
- Frequent/last-minute changes of plan

The case studies highlighted in this chapter give examples of some of the individual and team behaviours that were observed by the review panel. These would normally not be considered in isolation from system factors following an adverse event but this is the only chapter where a detailed analysis of individual NTS will be discussed. The system failures are discussed in detail in Chapter 23.

Case 1

A middle-aged, overweight adult patient developed laryngospasm on emergence from an uncomplicated anaesthetic for incision and drainage of an abscess with a laryngeal mask in situ. At this point, control of the airway became difficult. Once problems began to occur the anaesthetic assistant was felt to be underperforming, and was deemed to be less able than the circumstances required, so extra help was summoned at an early stage. An anaesthetic consultant colleague arrived to help but difficulty was experienced in re-siting the laryngeal mask. Consultant 1 commented that the efforts required to maintain oxygenation did not allow time to attempt any unfamiliar techniques. Two attempts at intubation failed but were followed by a successful re-siting of a laryngeal mask by which time the stomach had become distended from attempts to mask ventilate. A plan was made to pass a fibrescope through the laryngeal mask but before this could be done, a third anaesthetic consultant arrived to give assistance and decided to try and pass a nasogastric tube which dislodged the laryngeal mask. Consultant 1 made further attempts to provide leadership and delegated responsibility to the two colleagues to perform a cricothyroidotomy whilst summoning help from an ENT consultant in case an emergency tracheostomy should become necessary. The cricothyroidotomy did not provide successful ventilation as the cannula was positioned pointing cephalad. It did however provide a useful aiming point for a further attempt at intubation, which was then successful. The incident lasted for an hour with prolonged and sometimes profound hypoxia. The patient made a full recovery.

This first case demonstrates what can happen when a group of peers, who are not used to working together, try and assist each other. As is common in medicine, there was no obvious natural hierarchy and although one individual was attempting to stand back and distribute the task load, other colleagues did not recognise this, leading to unco-ordinated activity and further problems. A useful comparison can be made between this case and that of Elaine Bromiley⁹ (which will be familiar to most anaesthetists) to help pick out some of the behaviours that may be relevant to the outcome. More than one consultant anaesthetist also attended Elaine Bromiley once difficulties had been identified.

The consultants in Case 1 did not become fixated in the same way as Elaine's team. The level of situation awareness was much better maintained in this case as demonstrated by the rapid recognition of the limited ability of the anaesthetic assistant, early recognition of the need for extra help and summoning an appropriate person. Consultant 1 took a step back from the rest of the group once there were enough people to carry out the necessary tasks, and then summoned specialist help from an ENT consultant in case a surgical airway was required. Attempts were made to provide leadership for the team by Consultant 1. Tasks



were prioritised and delegated to others so workload was distributed appropriately. The plan evolved as the clinical situation changed and information was communicated, with varying degrees of success, to the rest of the team. A number of different options were generated for consideration and this case shows some good decision-making skills. However leadership and situation awareness failed in some respects. An appropriate level of assertiveness was not achieved in the interaction with one consultant colleague and a common understanding of the plan was not achieved with all members of the team. Overall, the teamwork was good and it produced a positive outcome on this occasion.

We do not know if there was a team debrief following this event. Teams who are required to perform to a very high level often report that the single most useful team activity they undertake is a thorough debriefing following every event, whether things went smoothly or not. The debriefing provides an opportunity to share concerns and to reinforce the things that went well. In stressful situations individuals often believe they are acting appropriately, whereas other individuals within the team may have a different opinion. Without an opportunity to discuss how the rest of the team felt about what happened, improvement in performance is unlikely. The NPSA website provides information, tools and support to develop safety techniques within healthcare.¹⁰

This case also makes a strong argument for team-based simulated practice. A simulated episode provides an excellent opportunity for individuals to practise both technical and non-technical skills within their normal teams. This is important, especially for situations which are rarely encountered in clinical practice. The reporting consultant commented that he was reluctant to attempt unfamiliar techniques in this stressful situation. Simulated practice also offers an ideal opportunity for individuals who may only work together occasionally (as occurred in this case) to develop some familiarity with this unusual situation in a safe environment and to obtain feedback on their performance.

Case 2

A middle-aged adult who was known to have a supraglottic tumour was scheduled for insertion of a PEG. The patient had been intubated four weeks previously using direct laryngoscopy and a bougie. An inhalational induction was used and manual ventilation was confirmed prior to administration of a muscle relaxant. Two anaesthetists were present – one consultant and one year 3 specialist trainee. Two attempts were made to visualise the larynx using direct laryngoscopy. Only tumour was visible and an attempt to pass a bougie resulted in significant bleeding. Initially mask ventilation was possible, but impaired, and eventually a CICV situation ensued. A surgical tracheostomy was performed without delay by a consultant ENT surgeon, who was already present. The patient returned to the ward with a tracheostomy in place.

Case 3

An elderly patient with a suspected laryngeal tumour, with minimal symptoms from upper airway obstruction, was scheduled for an urgent panendoscopy. The patient was pre-oxygenated prior to an intravenous induction performed by a consultant anaesthetist. An opioid and a muscle relaxant were administered as part of the technique. On laryngoscopy the opening to the larynx was completely obscured by an extensive laryngeal tumour. Two attempts at intubation using first, a Macintosh laryngoscope, and then a fiberoptic scope failed. The airway became totally obstructed and ventilation using a mask or a laryngeal mask became impossible. An ENT consultant rapidly performed a surgical tracheostomy, but the patient suffered a cardiac arrest during the course of the procedure. Resuscitation was successful with no apparent neurological deficit. The anaesthetist involved commented that, with hindsight, the patient was only suitable for tracheostomy under local anaesthesia.

A number of cases were reported where problems could have been avoided if the patients had been more carefully assessed, overconfidence avoided and if further investigations had been undertaken, e.g. appropriate scans and/or nasendoscopy. Despite the fact that some cases were designated as urgent, the clinical condition of the patient indicated that there would have been enough time to perform preoperative scans. In some cases it is likely that the anaesthetists were lulled into a false sense of security by the fact that the patient had undergone interventions quite recently. In these cases, no further consideration appeared to be given during the decision-making process as to whether the clinical condition of the patient may have changed. Back-up plans were often absent or not thought out carefully enough.

The organisational culture in healthcare is frequently much more tolerant of 'cutting corners' than the culture found in other safety-critical industries. There are a number of reasons for this.

- The principles of safety training and HF theory have traditionally not been promulgated throughout healthcare.
- The skill and ability of many practitioners is such that many potential problems are avoided in real time as events unfold. Individuals are used to 'getting away with it'.
- Pressure of work and time constraints are a recurring daily problem and people may cut corners in order to save time.
- Practitioners in healthcare often have to deal with a greater degree of uncertainty than that which is found in other industries. Individuals who cope well with uncertainty are less likely to follow guidelines and protocols.

- The professional culture embedded within healthcare, especially amongst medical staff, is to ensure the patient receives treatment no matter what obstacles are placed in the way of delivering that treatment.
- The flat hierarchy, which exists when two or more anaesthetists of the same grade try to work together, can lead to a reluctance, either to take command of the situation, or to offer constructive criticism of a colleague's plan/technique.
- The steep hierarchy which exists, either between senior and junior practitioners in the same profession, or between team members from different professions or specialities, can lead to a situation where individuals feel unable or afraid to speak up.

Many of these tenets are deeply embedded within the various organisational and professional cultures found in healthcare. The aim should be to encourage practitioners to be more thorough in their assessment of risk in any given situation, and to embrace a more structured approach to decision-making, without losing the ability to cope with the uncertainty of the clinical arena.

While many cases showed evidence of excellent teamwork and good communication within multi-disciplinary teams, there were some cases that showed considerable evidence of poor teamwork, absent communication and even open criticism and hostility between colleagues of the same or different specialties. Such cases hint at a 'broken team' in which effective collaboration is likely to be impossible. It is unlikely that a critical airway incident will be managed well in these circumstances. Strenuous efforts should be made to empower people to speak up if they feel something is wrong, but the language used and the tone of the message should be constructive, objective and helpful. We should strive to foster a culture where individuals feel comfortable to voice their concerns. Senior staff should show good leadership skills by encouraging input from all members of the team. No one should be made to feel under threat from negative comments and dysfunctional behaviour.

Case 4

A middle-aged patient with a known laryngeal tumour was scheduled for a palliative tracheostomy. The patient had mild stridor preoperatively but no respiratory distress. Neither the anaesthetist nor the surgeon considered that this might be a high-risk airway. The CT scan appeared unchanged for two months. The plan was to use a TIVA induction and then a Storz C-Mac videolaryngoscope to aid visualisation of a potentially distorted larynx. An awake tracheostomy was not discussed. A prophylactic needle cricothyroidotomy was considered but rejected in case of a subglottic extension of the tumour but, despite this, cricothyroidotomy was the chosen back-up plan in case of failed intubation. In total, four attempts at intubation were made and the anaesthetists concerned later felt they may have developed a fixation error during attempts to use the C-Mac laryngoscope, so there was a delay in moving to an alternative strategy. The patient's oxygen saturation was below 85% for 45 minutes and below 70% for almost half an hour. Bag and mask ventilation was initially difficult and then became impossible. Cricothyroidotomy was attempted unsuccessfully and the surgeon was summoned for help, but took several minutes to arrive. The surgeon used a rigid laryngoscope to intubate the patient but ventilation remained inadequate and the patient suffered a PEA arrest and could not be resuscitated. The surgeon felt that the root cause of the problem was poor anaesthesia and made strongly adverse comments about anaesthetic performance.

Fixation errors were noted in some the reported cases. When a team becomes fixated, the passage of time often appears distorted and events can seem to either speed up or slow down. Whenever time is of the essence, a team member should be specifically delegated to note the timing of events and keep the rest of the team apprised.

Numerical analysis

In industries where significant levels of protection and redundancy have been built into the system (unlike healthcare) the human contribution to error (active sharp-end failures) can be as high as 80%. Where this level of attention is not given to developing and maintaining robust and safe systems within an organisation, errors from system problems are seen more frequently and 'human error' becomes responsible for a smaller proportion of events.

Human factors issues (in terms of the individual or the team) were deemed by the review panel to have contributed to the adverse outcome in just over 40% (75/184) of cases reported to NAP4. This indicates that system errors (latent failures) played a bigger part in error causation than would be anticipated in many other safety-critical industries. In a quarter of these cases HF was considered by the reviewers to be a major factor in the poor outcome. Poor judgement was considered to have contributed to the adverse event in 46% of cases and to be



causal in a further 10%. Notably, as can be seen with many aspects of human factors, good judgement was assessed as having mitigated against a worse outcome in 13% of the reviewed cases. Team and social behaviours were considered contributory in 18% of cases but made a positive contribution in 12%. The importance of communication was clearly demonstrated with an almost equal number of cases suffering from poor communication (22%) and benefiting from good communication (21%).

The reporters were asked to comment on whether they felt outcomes had been affected by defective judgement or poor team behaviour. The results itemised for the individual departments and are shown in the Table below:

	Defective judgement	Poor teamwork
Anaesthesia	56% (74/133)	14% (18/133)
Intensive Care	17% (6/36)	5.5% (2/36)
Emergency Department	47% (7/15)	20% (3/15)

Discussion

Building a safety-conscious culture is a massive undertaking. Cultural norms are very important to all individuals. They are often the values which give meaning to people's daily working lives, and provide a framework which gives a purpose and a sense of comfort around delivery of care. Consequently, cultural change is the hardest change to bring about in any organisation or profession. It requires

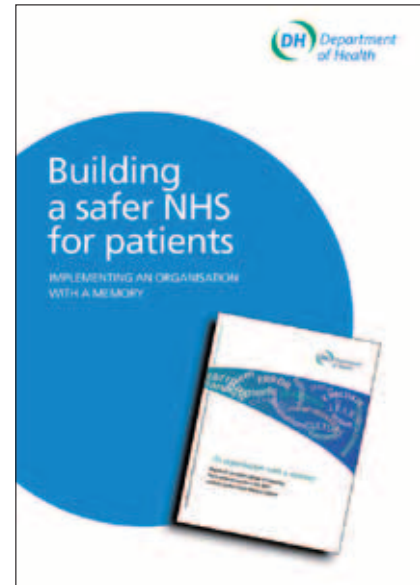
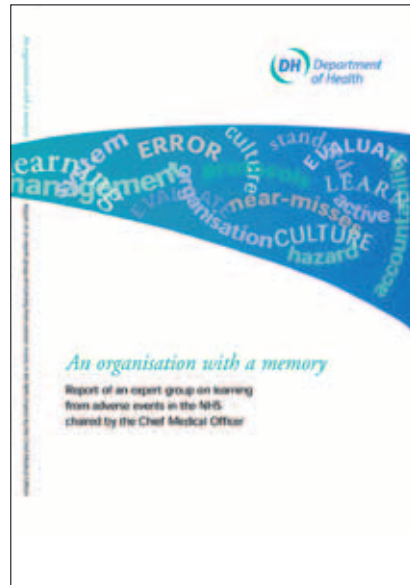
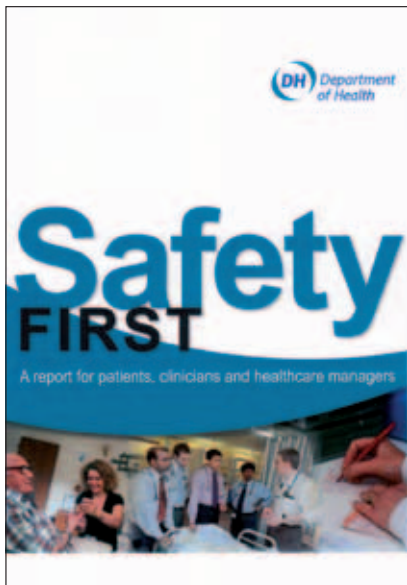
education and training to be delivered at the earliest possible time in any individual's career span. Some practitioners will never embrace the modern safety agenda, or the change in personal approach, which is required to make it work. It may require a whole new generation of safety-conscious individuals who have grown up with these principles before a really effective change can be demonstrated (see Foreword by Martin Bromiley).

In the meantime, organisations must focus on learning from error in a more effective way. The introduction of NTS training for teams and individuals is certainly desirable and often appeals to anaesthetists who enjoy the 'hands-on' aspects of such activity. Implementation into any organisation requires proper and systematic integration, and training the facilitators for such a programme is lengthy and labour-intensive. NTS training can only be maximally effective alongside organisational learning and improvement. This begins with encouraging incident and near-miss reporting which will never hold the same fascination and appeal for individual practitioners as NTS and simulation training. Organisational learning can only succeed if adverse incidents are reported and used as tools for learning.

A reporting culture can only blossom if individuals feel confident that they will be treated fairly.¹⁰ These are the tenets that drive the safety engine in all safety-critical industries. In order to achieve this, best-practice guidelines should be issued to all healthcare organisations



Fixation error is a barrier to safe resolution of critical events



for investigation of adverse events. Investigations must be seen to be fair and objective, with more focus on organisational learning and less focus on individual blame and culpability. The investigating team should have the requisite professional knowledge as well as specific training to undertake an objective investigation. The NPSA provides a toolkit for undertaking a systematic Root Cause Analysis.¹¹ Individuals with managerial responsibility for a given area or department under investigation should never be included within the investigation team. This constitutes poor practice because their ability to take a fair and objective approach will be questionable. Such practice is, however, commonly seen within healthcare organisations, especially for high-level investigations.

Learning points and recommendations

These are intentionally broad.

Education

Knowledge of Human Factors theory would benefit all healthcare practitioners at all levels. Team training would be beneficial for certain groups of staff who may face unexpected or uncommon emergency situations.

Recommendations

- Introduction of safety training into all anaesthetic, intensive care and emergency department curricula at the earliest possible stage.²²
- Provision of HF training as part of corporate mandatory training for all members of staff who work with patients with difficult airways.
- Opportunity for multidisciplinary teams working with the difficult airway to train together within simulated scenarios to practice technical and non-technical skills.

Guidelines and protocols

Evidence from NAP₄ shows that guidelines and protocols are not always followed.

Recommendations

- Guidelines and emergency algorithms should be immediately available in all clinical areas where airway emergencies may arise.
- Team training scenarios should reinforce the use of guidelines within the clinical arena.

Building an organisational safety culture

All healthcare organisations have a long way to go in order to achieve the standards recommended by the Department of Health.

Recommendations

- Airway incidents, including near misses, should be routinely reported and regularly audited.
- Investigations into adverse events should be performed according to best practice to determine if changes need to be made that will make the systems safer for future patients.

Communication

Communication failures were a common feature in reports to this project both within and between teams from different disciplines. The routine use of systematic briefing and debriefing helps to foster good communication practice within the organisation and promotes individual development of skills.



Recommendations

- Organisations should encourage the use of routine briefing and debriefing as recommended by the NPSA.¹³ In particular this should occur before management of an anticipated difficult airway and after such management of a critical airway incident.
- Consultants and senior staff should lead by example and use briefing and debriefing techniques in these clinical situations.

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