23 Perioperative cardiac arrest associated with major haemorrhage

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Key findings

- Major haemorrhage was the primary cause or major contributory cause of 167 (19%) of 881 cardiac arrests reported to the Seventh National Audit Project (NAP7).
- Of these, 153 (92%) were adults (age ≥ 18 years) and 14 (8.4%) were children.
- Major haemorrhage occurred in 1% (95% confidence interval, CI, 0.9–1.2%) of all cases in the NAP7 UK hospital Activity Survey and was therefore notably overrepresented in the NAP7 cardiac arrest data set.
- The incidence of cardiac arrest from major haemorrhage is 0.62 per 10,000 (95% CI 0.5–0.7) patients undergoing anaesthesia care.
- More than half (55%) of these patients had died at the time of panel review. In 52% of these cases this was judged the result of an inexorable process. A further 23 (14%) patients sustained severe harm.
- The often emergent nature of this pathology is represented by 57% of patients requiring immediate surgery (compared with 19% in the whole cardiac arrest dataset).
- Twenty-eight (17%) cardiac arrests related to major haemorrhage occurred during elective procedures.
- The majority of cardiac arrests occurred in the operating theatre (71%) and half (52%) during the surgical procedure. Cardiac arrest occurred in the emergency department in eight cases (4.8%).
- Of the major haemorrhage cases, 14 (8.4%) were associated with major trauma, accounting for 1.6% of 881 cases of cardiac arrest in the full data set.
- The specialties most represented in adult cases were vascular surgery (27% of cases) and gastroenterology combined with upper and lower gastrointestinal surgery (22%).
- Major haemorrhage was a major cause in 10% of cardiac arrests in elective cases and 22% in non-elective cases.
- Eleven cases of cardiac arrest from major haemorrhage occurred during minor surgery or procedures, of which six were endoscopy cases (five upper and one lower gastrointestinal endoscopy).
- The rhythm was pulseless electrical activity (PEA), bradycardia or asystole in 85%.
- Patient factors were deemed to be a key cause in 84% of cases, followed by surgery in 48% of cases and anaesthesia in 16%.
- Mortality was relatively high: in 57 cases (35%) initial resuscitation was not successful (vs 21% in cardiac arrests from other causes) and 56% died before report to NAP7 (vs 36% in other causes of cardiac arrest).
- While care was judged to be good in 84% of cases during and after cardiac arrest, care before cardiac arrest was good in just 53%.

What we already know

There are a variety of definitions of major haemorrhage but a recent pragmatic definition is bleeding, which (in an adult) leads to a systolic blood pressure of less than 90 mmHg or a heart rate higher than 110 beats/minute (Shah 2023). Previous investigators have documented severe haemorrhage as a common cause of intraoperative cardiac arrest. In a series of 223 perioperative cardiac arrests from the Mayo Clinic during 1990 to 2000, 35% were judged to be related to bleeding, with 44% were attributed to cardiac causes (Sprung 2003). Among a series of 50 intraoperative cardiac arrests reported from Korea, haemorrhagic shock was the cause in 46% (Hur 2017). An analysis of the American College of Surgeons National Surgical Quality Improvement Program database documented an incidence of intraoperative cardiac arrest of 7.22 per 10,000 operations and 46% of these cases were associated with intraoperative red blood cell transfusion of four or more units (Goswami 2012). Major haemorrhage protocols are now a standard of care in all acute hospitals (Stanworth 2022) and initial resuscitation with blood products will follow standard algorithms. Continuing blood

product management is now guided increasingly by point of care viscoelastic haemostatic assays (eg thromboelastography or rotational thromboelastometry (Shah 2023).

What we found

Baseline Survey

Major haemorrhage was the top cause of the most recently attended cardiac arrest by anaesthetists in the Baseline Survey and accounted for 20% of cases (Chapter 10 Anaesthetists Survey).

Activity Survey

There were 248 (1%) cases of major haemorrhage in the Activity Survey (n = 24,172); 135 cases occurred during 16,739 general anaesthetics, 7 during 2,279 cases with sedation and 106 during 4,355 awake procedures, including obstetric care.

Case review

Cases of cardiac arrest due to major haemorrhage compared with the Activity Survey

These data refer to adult non-obstetric patients only (153), with paediatric and obstetric cases in separate chapters (Chapter 27 Paediatrics and Chapter 34 Obstetrics).

There was a preponderance of male patients in the major haemorrhage group (67%) compared with the Activity Survey (46%). Some 30% of these patients were over 75 years, compared with 17% in the Activity Survey (Figure 23.1). The distribution of body mass index (BMI) values was similar to those in the Activity Survey as was ethnicity (84% white). There was a striking increase in ASA grades in the major haemorrhage group compared with the Activity Survey (ASA 4 in 35% vs 4.5% and ASA 5 20% vs 0.3%; Figure 23.2).

Figure 23.1 Age distribution in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

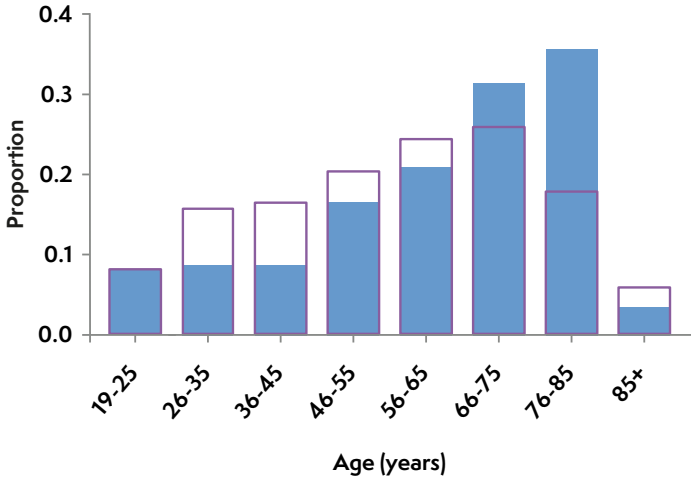
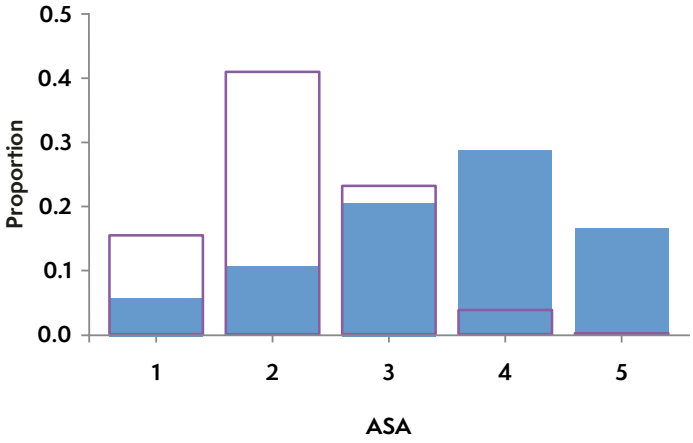


Figure 23.2 ASA distribution in cardiac arrest cases due to major haemorrhage and in NAP7. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.



Vascular surgery accounted for the greatest proportion of cardiac arrests associated with major haemorrhage (see also Chapter 35 Vascular surgery) with the other highest ranked specialties listed in Table 23.1.

More of these cases occurred at weekends, 20% compared with just 8.5% of Activity Survey cases (Figure 23.3). There was also increased activity in the evening (17% vs 3.9%) and at night (22% vs 1.7%; Figure 23.4).

Table 23.1 Main subspecialties accounting for cardiac arrest due to major haemorrhage compared with the proportion of caseload in the NAP7 Activity Survey

Specialty	Cardiac arrest due to major haemorrhage		Activity Survey case load (%)	Ratio
	(n)	(%)		
Vascular	39	23.4	2.3	10
Gastroenterology	14	8.4	0.9	9.3
Lower gastrointestinal	10	6.0	5.9	10
Upper gastrointestinal	7	4.2	2.7	1.6
Cardiac surgery	8	4.8	1	5
Thoracic surgery	6	3.6	1.1	3
Urology	7	4.2	10	0.4
Obstetrics	7	4.2	13	0.3
Neurosurgery	5	3.0	2.3	1.3
Other (including 10 unknown)	50	30	62.6	0.5
Paediatric (all)	14	8.2	14.3	0.6

Figure 23.3 Day of procedure of cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

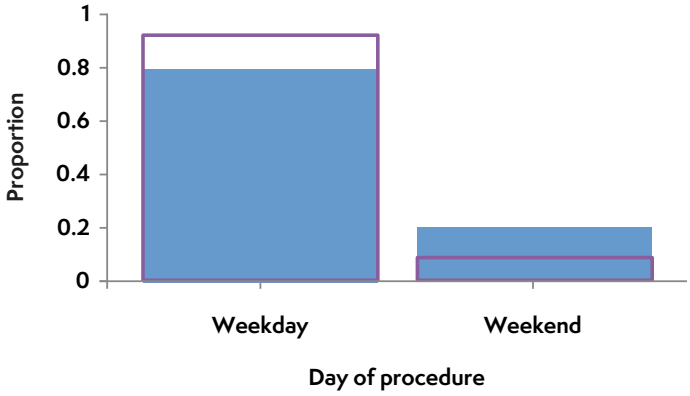


Figure 23.4 Time of day of surgery in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

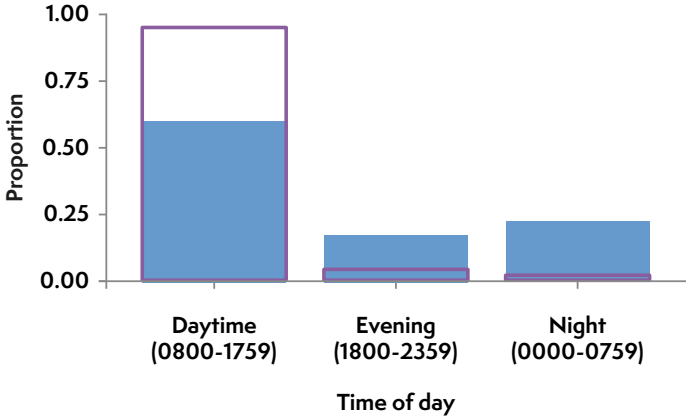


Figure 23.5 Urgency of surgery in cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.

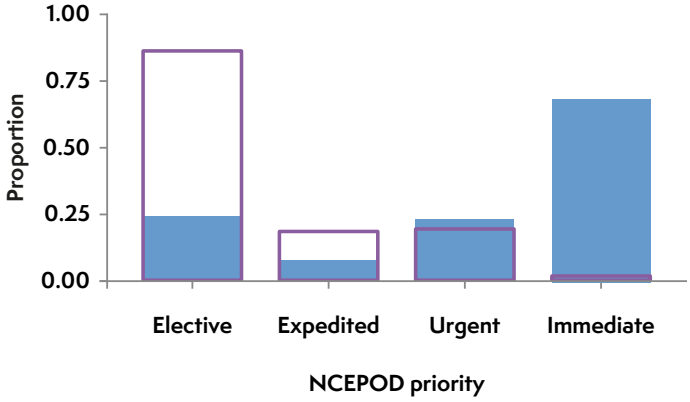
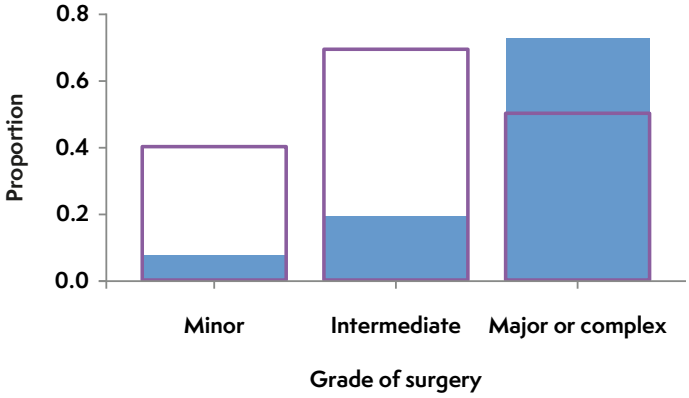


Figure 23.6 Grade of surgery of cardiac arrest cases due to major haemorrhage and in NAP7 Activity Survey cases. The blue bars represent cases and the purple line Activity Survey caseload. A blue bar substantially above the line indicates overrepresentation of that feature and below the line underrepresentation.



Urgency of surgery was 'immediate' in 55% (vs 1.3% of Activity Survey data) and 'urgent' in 19% (vs 15%). Of cardiac arrests associated with major haemorrhage, 20% (n = 27) occurred in adult elective cases compared with 68% of Activity Survey cases (Figure 23.5). Surgery was graded major or complex in 73%: more than twice the Activity Survey frequency (31%; Figure 23.6). Minor surgery accounted for 7.7% of cases, a significant proportion of which were endoscopies for gastrointestinal bleeding. The mode of anaesthesia was general anaesthesia in 79%, slightly more than the 68% in the Activity Survey.

Cases of cardiac arrest due to major haemorrhage compared with other cases of cardiac arrest

The data in this section include adults and children. Major haemorrhage accounted for 167 (19%) of all the cardiac arrests reported to NAP7 as either the primary cause (149; 89%) or a contributary cause (18; 11%).

Males were overrepresented in the major haemorrhage cardiac arrests (68% vs 54% in all other cardiac arrests). Only 6.6% of major haemorrhage cases had a BMI over 35 kg m^{-2} compared with 12.4% in all other cardiac arrests, although some data were missing. In the major haemorrhage group, there was an overrepresentation of ASA 4 (33% vs 28%) and especially of ASA 5 (20% vs 4.6%). There was no difference in frailty scores or modified Rankin Scale. The proportion with a do not attempt cardiopulmonary resuscitation (DNACPR) recommendation was similar to other cardiac arrest cases, with 95% having no recommendation.

Urgency of surgery was immediate priority in 49% compared with 12% in all other cardiac arrests. In major haemorrhage cardiac arrest occurred during the actual surgery more commonly than cardiac arrest from other causes (50% vs 30%).

Most (118, 71%) cases occurred in main theatres with eight (4.8%) cases in the emergency department. Initial rhythms are detailed in Table 23.2, with PEA accounting for the majority. Defibrillation was used in 31 (19%) cases, similar to non-haemorrhage cases (17%). CPR perhaps lasted longer than in non-haemorrhage cases, lasting less than 10 minutes in 90 (54%) cases compared with 70% in cardiac arrests from other causes, and the longest lasting over two hours.

There were more deaths as the initial outcome in this group, 35% compared with 21% among other causes, and more deaths as the hospital outcome (56% vs 36%).

Table 23.2 Initial cardiac arrest rhythms in those cases caused by major haemorrhage compared with other causes. AED, automated external defibrillator.

Rhythm	Major haemorrhage (*n* = 167)		Other causes of cardiac arrest (*n* = 714)	
	(*n*)	(%)	(*n*)	(%)
Asystole	11	6.6	125	18
Bradycardia	10	6.0	119	17
Pulseless electrical activity	121	72	335	47
Pulseless ventricular tachycardia	10	6	39	5.5
Unknown	8	4.8	44	6.1
Ventricular fibrillation	7	4.2	50	7.0
AED used (non-shockable)	0	0	2	0.2

A debrief was performed in 45% of cardiac arrests caused by major haemorrhage (in 36% of those who survived the initial event and 63% of those who died); it was not done and not planned in 34%, planned in 8%, and unknown in 13%.

Hospital outcome was available for 81% of those who survived the initial event; 44% were alive at hospital discharge, 37% had died and 19% were still in hospital.

Panel review

Information on drugs given before and during cardiac arrest was incomplete in many of the case forms. From what was recorded in adult patients only, tranexamic acid, calcium and vasopressors were given as shown in Table 23.3. While blood products were given during each case, the amount, ratios of different blood products and the timing of such are not available.

Table 23.3 Use of tranexamic acid, calcium and vasopressors before and during cardiac arrest in major haemorrhage patients. Note that data are incomplete, meaning that we report cases where drugs were known to be used but it is likely these drugs were used in other cases but their use not captured (*n* = 167).

Drug	Given before cardiac arrest	Given during cardiac arrest
Tranexamic acid	37	1 (0 given before)
Calcium	33	27 (of which 4 also before)
Metaraminol	63	1 (also before)
Noradrenaline	38	11 (4 also before)
Ephedrine	13	2 (1 also before)
Vasopressin	4	–
Phenylephrine	10	1 (0 given before)

Information on the use of point of care coagulation testing (eg thromboelastogram, rotational thromboelastometry, activated clotting time) is also limited; it was definitely used in 26 of the 153 (17%) cases before cardiac arrest, but we lack information for during cardiac arrest.

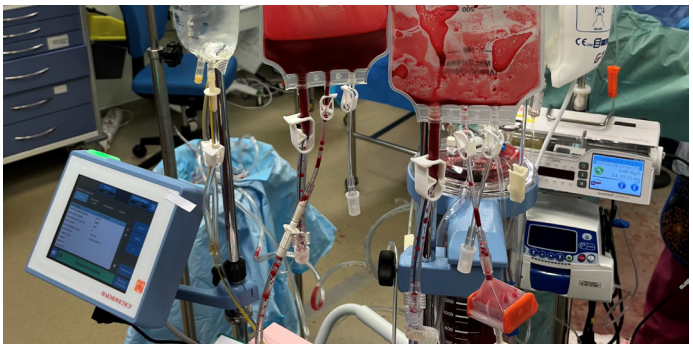
Major trauma

Major trauma accounted for 14 (8.4%) of 167 cases within the major haemorrhage cohort, with blunt and penetrating trauma both represented. Some 8 patients were 25 years or younger (including three aged < 18 years), a similar proportion in this age range as for all other cardiac arrests (4.8% vs 4.1%). Twelve patients were male. Four had a cardiac arrest in the emergency department. Six patients died without successful initial resuscitation and at the time of review nine patients had died, with six of these deaths judged the result of an inexorable process. Care was considered good in 71% before cardiac arrest, in 79% during and in 86% after cardiac arrest. A debrief was performed in nine cases, although the NAP7 panel considered that a debrief should also have been conducted in the remainder, especially owing to the nature of the cases.

Vascular

There were 39 (27%) cases of cardiac arrest caused by major haemorrhage related to vascular surgery or pathology. For further details relating to these cases, see Chapter 35 Vascular surgery.

A patient for repair of a ruptured abdominal aortic aneurysm had blood product resuscitation and invasive line insertion in the operating room. Induction with propofol, fentanyl and rocuronium was followed by PEA cardiac arrest; return of spontaneous circulation (ROSC) was achieved after three cycles of CPR.



Gastroenterology

Fourteen (8.4%) cases of cardiac arrest caused by major haemorrhage occurred in patients undergoing a gastroenterology procedure. The procedure performed was an oesophagogastroduodenoscopy (OGD) in 13 cases and endoscopic retrograde cholangiopancreatography (ERCP) in one. All patients except one were ASA 3–5, predominantly ASA 4. Eleven patients were aged 55 years or more. Twelve arrests occurred in main theatres, with one OGD and the ERCP in the endoscopy suite. Three patients were induced in an anaesthetic room, despite the potentially unstable nature of these cases. Propofol was used for induction of anaesthesia in eight and ketamine in six, with one patient receiving both. Six patients died at the time of the event, four in the following few days and one after 30 days, with only three patients who survived. The NAP7 panel concluded that death was the result of an inexorable process in five and partially so in three.

Elective cases

Of the 167 major haemorrhage-related cardiac arrests, 28 (17%) occurred in patients undergoing elective procedures with haemorrhage the primary cause of cardiac arrest. In a further eight cases, major haemorrhage was a major contributory factor. These 36 cases accounted for 4.1% of all 881 cardiac arrests in the full NAP7 dataset and 9.7% of 371 cardiac arrests in elective adult patients in NAP7. This contrasts with major haemorrhage contributing to 99 (22%) of 441 non-elective adult cardiac arrests.

Most of the 28 patients with haemorrhage as a primary cause of cardiac arrest during elective surgery were ASA 3–5 (63%) and were undergoing major or complex surgery (82%) with general anaesthesia (83%), with or without neuraxial block, on a weekday (93%) during working hours (75%). A variety of surgical specialties were involved, including cardiac, vascular and urology. Only one patient had a DNACPR recommendation or treatment limitation in place.

Seventeen (61%) cardiac arrests were during surgery. In several cases, the major haemorrhage was caused by direct vascular injury, including during laparoscopic surgery. Two-thirds of cardiac arrests occurred in a main theatre suite, but one-third occurred postoperatively: one en-route to recovery, one in recovery and seven after leaving recovery. Two cases occurred in radiology.

The predominant initial rhythm was PEA (22; 79%) compared with 51% in all other cardiac arrests (including non-elective haemorrhage) and 25 (89%). Eighteen (67%) cardiac arrests lasted 10 minutes or longer (similar to other cardiac arrest causes).

Five patients (18%) died at the time of the event and eight (29%) patients at the time of reporting to NAP7: in only one patient was this deemed the result of a partially inexorable process. Six patients experienced severe harm.

A debrief was performed or planned in only 50% of cases. This is surprising for a group of patients undergoing elective surgery, in whom a cardiac arrest was presumably not expected, and where deaths were not part of an inexorable process.

Care was considered good in 50% of these cases before cardiac arrest, 82% during and 93% after cardiac arrest.

Discussion

Major haemorrhage was the primary cause of cardiac arrest in 149 (17%) of the 881 NAP7 cases and was cited as a secondary cause in a further 18 cases; thus, major haemorrhage contributed to cardiac arrest in 167 (19%) of all cases. Although we have identified major haemorrhage as the leading cause of perioperative cardiac arrest, in comparison with previous studies (Sprung 2003; Hur 2017; Goswami 2012) this is a smaller proportion. Previous studies have been retrospective analyses of routinely collected data and it is likely that the prospective design of the NAP7 project will have captured far more perioperative cardiac arrests that may have been missed by other studies.

In several cases, the local reports and/or panel members opined that the extent of hypovolaemia had been grossly underestimated.

> A young adult required anaesthesia for post-tonsillectomy bleeding. Their blood pressure was maintained but they were markedly tachycardiac (heart rate ≥ 140 beats/minute) before induction. Anaesthesia was induced in the anaesthetic room with standard doses of propofol, fentanyl and rocuronium. This was followed immediately by a PEA cardiac arrest. ROSC was achieved after a brief period of CPR.

The priority in major haemorrhage is to stop the bleeding and in many of the NAP7 cases anaesthesia was being undertaken primarily to enable surgical intervention to control haemorrhage (eg ruptured abdominal aortic aneurysm). In other cases, bleeding occurred as a complication of the surgical procedure. Regardless of whether major bleeding is the primary problem or secondary to the surgical procedure, some cardiac output must be maintained until bleeding can be controlled and intravascular volume restored. The challenge is that inducing and/or maintaining anaesthesia in the presence of hypovolaemia

is likely to cause severe hypotension, yet attempts to restore circulating volume and a normal blood pressure before bleeding is controlled may be harmful because it will exacerbate blood loss. The anaesthetist may have to balance tolerance of some hypovolaemia and hypotension with sufficient volume replacement to prevent profound hypotension and cardiac arrest. In these circumstances, vasopressors, particularly metaraminol, are often infused to maintain blood pressure. However, infusing high doses of vasopressors in the presence of severe hypovolaemia can cause a substantial reduction in cardiac output and can worsen tissue ischaemia and lactic acidosis. Recent European guidelines on the management of major bleeding following trauma recommend that, until bleeding is controlled, if a restricted volume replacement strategy does not achieve a blood pressure of 80 mmHg systolic or greater, an infusion of noradrenaline should be used to maintain tissue perfusion (Rossaint 2023). Increasing adoption of protocols for the use of peripheral intravenous noradrenaline will enable a noradrenaline infusion to be started before central venous access has been achieved (Clark 2020). In some NAP7 cases, panel members were concerned that high doses of vasopressors had been used at the expense of adequate volume resuscitation.

A moderately comorbid and frail patient underwent orthopaedic surgery with spinal anaesthesia. A metaraminol infusion was in place to support blood pressure. Later, significant intraoperative bleeding caused haemodynamic instability and the dose of metaraminol was increased. PEA cardiac arrest followed and required prolonged CPR before ROSC was achieved. On-table echocardiography showed an underfilled left ventricle.

The use of ketamine instead of propofol for induction of anaesthesia is generally considered to cause less hypotension but there is little proof for this theory from prospective trials. A retrospective study comparing ketamine with propofol for inducing anaesthesia in trauma patients documented a greater reduction in systolic blood pressure with propofol, but this was not statistically different (Breindahl 2021). In several NAP7 cases, the panel was critical of the use of propofol in patients with major haemorrhage, instead suggesting that ketamine would have been more appropriate. It was noted that hindsight bias and outcome bias might influence these views, but panel review emphasised the potential value of avoidance of propofol, particularly in standard or rapidly administered doses in hypovolaemic patients.

Recommendations

National

- All institutions should have protocols and facilities for managing predictable perioperative complications occurring during anaesthesia both in the main operating theatres and remote locations, including protocols for:
  - haemorrhage
  - cardiac arrest
  - all clinical staff who deliver anaesthesia autonomously should be trained, skilled and practiced in the management of these emergencies.
- The establishment of a national standard for formal debriefing in the event of perioperative cardiac arrests should be developed to encourage the use of this tool when deemed appropriate.

Institutional

- Institutions that might manage patients with major haemorrhage either as presentation or complication of procedures should have a standardised major haemorrhage protocol in place.
- Institutions managing major haemorrhage from whatever cause should provide training in major haemorrhage protocols and the recognition and management of major haemorrhage in the perioperative setting. This training should include major haemorrhage drills and debriefs that emphasise the importance of communication and processes for activation of major haemorrhage protocols and rapid access to blood products.
- Institutions managing patients with major haemorrhage from whatever cause should have point of care viscoelastic haemostatic assays (eg thromboelastography) available for clinical use and should provide training in its application and interpretation.
- Institutions should provide guidance documents on the use of appropriate anaesthetic drugs for the induction of general anaesthesia in major haemorrhage patients.
- Institutions managing patients with major gastrointestinal bleeding should provide guidance on the appropriate choice of location within the hospital for managing emergency endoscopy (eg main theatres vs an endoscopy unit).

Individual

- Anaesthetists should be competent in the choice of appropriate induction drugs and techniques for general anaesthesia in the face of hypovolaemia secondary to major haemorrhage.
- Anaesthetists should be competent in the recognition and adequate resuscitation of major haemorrhage, and major haemorrhage should be included in hospital mandatory training programmes.
- Anaesthetists should remain up to date with current recommendations in the management of major haemorrhage.

Research

- Further research should be performed in the use of anaesthetic induction drugs for patients who have had major haemorrhage.

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