25 Advanced life support for perioperative cardiac arrest: triggers for chest compressions, adrenaline dosing and timing in adults

Jasmeet Soar

Jerry Nolan

Key findings

- In the Baseline Survey, most (54%) anaesthetists stated they would start chest compressions in a 75-year-old patient graded ASA 3 with hypertension, when there was profound hypotension (non-invasive systolic blood pressure less than 50 mmHg) when refractory to initial treatment.
- Despite this, delay in starting chest compressions when blood pressure was very low or even unrecordable was common.
- In 585 (65%) of 881 reports submitted to the Seventh National Audit Programme (NAP7), the initial rhythm was pulseless electrical activity (PEA) or severe bradycardia and most of these cases (67%) received an initial 1 mg dose of adrenaline.
- Several complications of high-dose adrenaline were seen when a smaller dose might have been effective.
- Underdosing of adrenaline was seen only rarely.
- There were several cases of significant delay in administration of adrenaline.

What we already know

Chest compressions

Unless there is asystole or ventricular fibrillation in a closely monitored deteriorating patient, it can be challenging to know when to start chest compressions and whether to wait or not until cardiac arrest is absolutely certain. Current resuscitation guidelines include the recommendation for experienced advanced life support providers to start chest compressions in an unresponsive patient who has an absent central pulse – this already means that chest compressions are probably started in some patients with PEA and a low cardiac output (PEA low flow state, sometimes called 'pseudo-PEA'), rather than a complete absence of cardiac output (PEA cardiac arrest).

When a patient is monitored continuously, as is the case intraoperatively, it may be appropriate to start chest compressions even if a blood pressure is detectable by non-invasive or invasive means and before actual cardiac arrest occurs. Resuscitation guidelines err on starting chest compressions early: 'Delivering chest compressions to a patient with a beating heart is unlikely to cause harm. However, delays in diagnosing cardiac arrest and starting cardiopulmonary resuscitation (CPR) will adversely affect survival and must be avoided' (Soar 2015).

Recently, it has been suggested that chest compressions should be started if the systolic blood pressure decreases and remains below 50 mmHg despite interventions (Harper 2020) in adults during general anaesthesia. There are no data to indicate whether anaesthetists use this threshold for profound hypotension in clinical practice.

Chest compressions are probably less effective in hypovolaemia, cardiac tamponade or tension pneumothorax, and early efforts should be made to correct these conditions. A study using an animal model of traumatic haemorrhagic cardiac arrest suggested that there was an improved outcome when initial resuscitation focused on controlling haemorrhage and restoring circulating blood volume with blood transfusion either with or without chest compressions compared with chest compressions alone (Watts 2019).

The triggers that anaesthetists use to make the call to start chest compressions have not been studied.

Adrenaline dose

If the initial cardiac arrest rhythm is shockable, a shock from a defibrillator should be administered as soon as possible but chest compressions should be started while awaiting the defibrillator. The standard advanced life support algorithm recommends the injection of adrenaline 1 mg every 3–5 minutes, starting immediately for non-shockable rhythms and after delivery of the third shock for ventricular fibrillation or pulseless ventricular tachycardia.

This dose has been advocated for decades, although in one of the earliest descriptions of modern advanced life support, in 1964, Peter Safar recommended an initial dose of 0.5 mg increased to 1–2 mg during prolonged resuscitation (Safar 1964).

The optimal dose of adrenaline during cardiac arrest remains uncertain, but it is possible that smaller doses are appropriate when there is a very short time between the onset of cardiac arrest and injection of adrenaline. Anaesthetised patients are monitored closely, and a very low blood pressure may be measurable even if peripheral pulses are absent, particularly in those with arterial lines.

When cardiac arrest may be rapidly reversed a large dose of adrenaline may lead to severe hypertension and tachyarrhythmias. For this reason, in special circumstances current guidance is that a lower dose may be appropriate:

- The current Resuscitation Council UK advanced life support course manual states that for perioperative cardiac arrest 'If adrenaline is required according to the ALS algorithm, give the initial dose in increments (eg 50–100 mcg IV), rather than a 1 mg bolus (Soar 2021). If 1 mg in total has been given with no response, consider further adrenaline doses of 1 mg IV'.
- UK guidelines for the management of cardiac arrest in the cardiac catheter laboratory recommend that adrenaline is given after three cycles of chest compressions (ie about six minutes) of cardiopulmonary resuscitation (CPR; Dunning 2022). Specifically, they state: 'We recommend that intravenous epinephrine [adrenaline] (1 mg) is given after the third cycle. It may be acceptable to administer smaller doses of epinephrine if a senior clinician feels that there may be reactive hypertension on ROSC [return of spontaneous circulation]'.
- Guidelines for cardiac resuscitation in the cardiac surgery setting state 'Cardiac arrests in patients after cardiac surgery are often quickly reversible and circulating standard advanced life support doses of epinephrine/adrenaline (ie, 1 mg intravenous) can therefore cause excessive hypertension and arrhythmias when achieving ROSC. Therefore, only small doses of adrenaline (eg 50–100 µg intravenous) should be given' (Karcher 2022).

What we found

Chest compressions

Baseline Survey

The NAP7 Baseline Survey included hypothetical questions on when anaesthetists would consider starting compressions (Tables 25.1 and 25.2, Figure 25.1; see also Chapter 10 Anaesthetists survey). In terms of blood pressure triggers, among anaesthetists who chose a blood pressure cut-off (around 80% of respondents) – for the ASA 2 50-year-old patient, more than 50% would start CPR when systolic blood pressure fell below 40 mmHg, and for the ASA 3 hypertensive 75-year-old patient more than 50% would start CPR when systolic blood pressure fell below 50 mmHg.

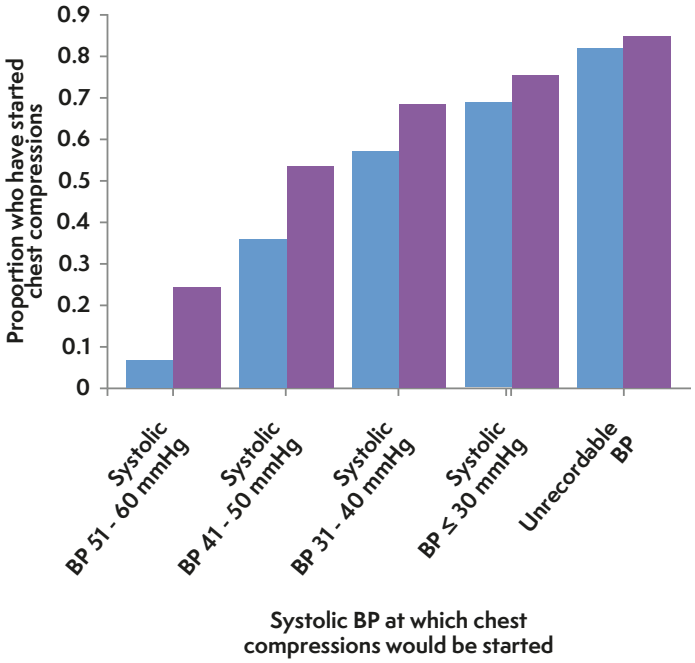
Table 25.1 Responses to the question: 'In an anaesthetised 50-year old ASA 2 patient, without an arterial line, who developed hypotension, whilst treating causes of profound hypotension, what would you use as an indication to start chest compressions?' Multiple responses were allowed.

Indication (*n*=10740)	Responses	
	(*n*)	(%)
Systolic blood pressure		
51–60 mmHg	707	6.6
41–50 mmHg	3148	29.3
3–40 mmHg	2264	21.1
≤ 30 mmHg	1270	11.8
Unrecordable	1410	13.1
No palpable peripheral pulse	2328	21.7
No palpable central pulse	9574	89.1
Very low end-tidal CO_2	6864	63.9
None of these	39	0.4
I'm not sure	197	1.8
Severe bradycardia	198	1.8
Loss of plethysmography (oxygen saturations) trace	82	0.8
Not applicable (paediatrics only)	25	0.2
Other	53	0.5

Table 25.2 Responses to the question: 'In an anaesthetised 75-year old hypertensive ASA 3 patient, without an arterial line, who developed hypotension, whilst treating causes of profound hypotension, what would you use as an indication to start chest compressions?' Multiple responses were allowed.

Indication (*n*=10737)	Responses	
	(*n*)	(%)
Systolic blood pressure		
51–60 mmHg	2604	24.3
41–50 mmHg	3146	29.3
3–40 mmHg	1580	14.7
≤ 30 mmHg	778	7.2
Unrecordable	990	9.2
No palpable peripheral pulse	2784	25.9
No palpable central pulse	9414	87.7
Very low end-tidal CO_2	7066	65.8
None of these	51	0.5
I'm not sure	272	2.5
Severe bradycardia	153	1.4
Loss of plethysmography (oxygen saturations) trace	61	0.6
Not applicable (paediatrics only)	24	0.2
Other	45	0.4

Figure 25.1 Comparison of systolic blood pressure (BP) triggers for starting chest compressions in a 50-year-old ASA 2 compared with a 75-year-old hypertensive ASA 3 patient. Graph shows cumulative proportions. ASA 2 ■, ASA 3 ■.



Case reports of perioperative cardiac arrest

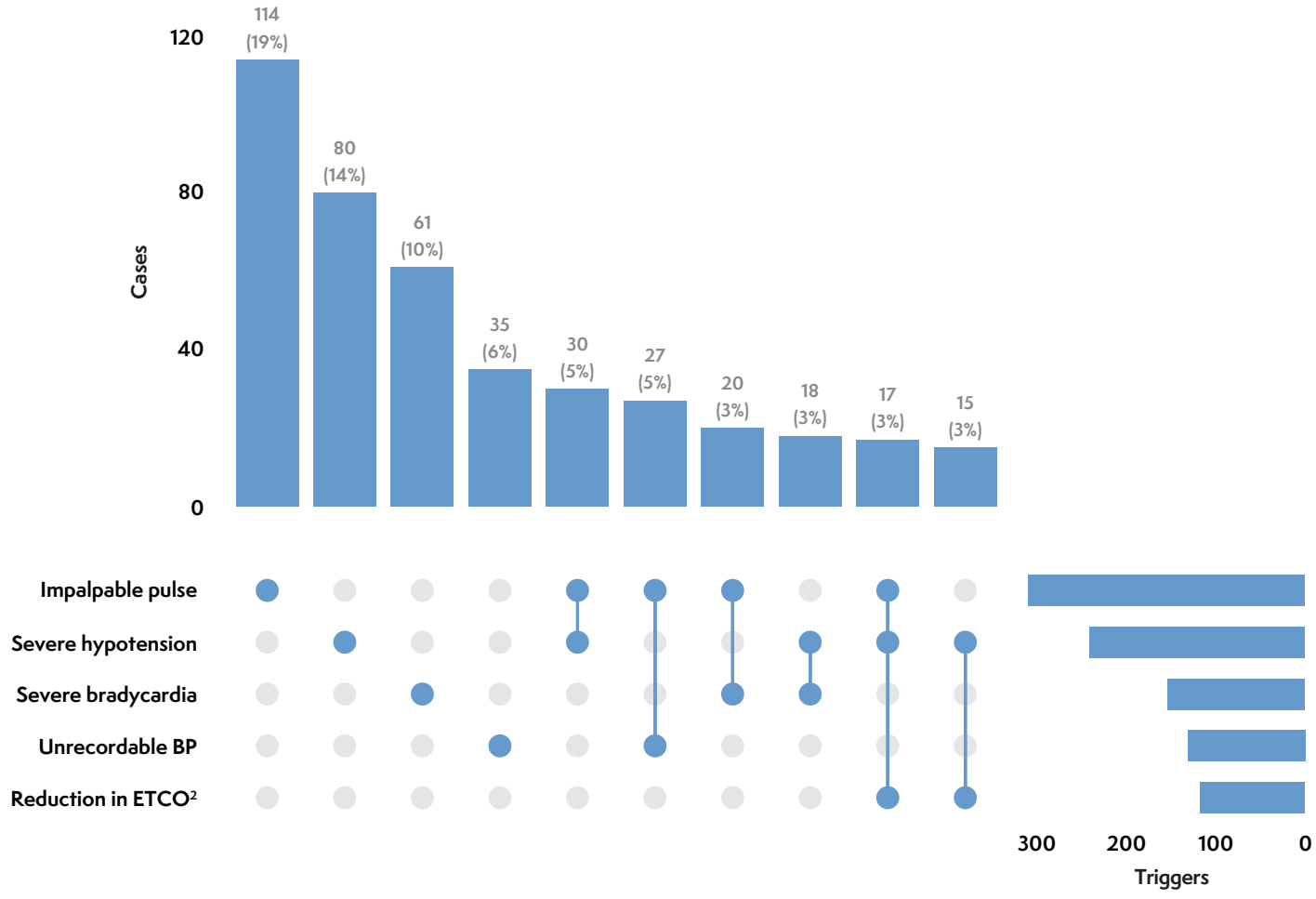
Of the 881 NAP7 cases, 723 (82%) had an initial non-shockable rhythm, 106 (12%) were in a shockable rhythm, and in 52 (5.9%) cases the initial rhythm was unknown (Table 25.3).

Among the 585 patients with an initial rhythm of PEA or bradycardia, the three most common triggers for starting CPR were an impalpable pulse (39%), severe hypotension (31%) and severe bradycardia (19%) (Figure 25.2).

Table 25.3 Initial cardiac arrest rhythm for all 881 NAP7 cases. AED, automated external defibrillator.

Initial cardiac arrest rhythm	Cases	
	(*n*)	(%)
Pulseless electrical activity	456	52
Asystole	136	16
Bradycardia	129	15
Ventricular fibrillation	57	6.5
Pulseless ventricular tachycardia	49	5.6
AED used (non-shockable)	2	0.2
Unknown	45	5.1

Figure 25.2 Indications for starting chest compressions in 585 patients reported to NAP7 with perioperative cardiac arrest and an initial rhythm of pulseless electrical activity or bradycardia. BP, blood pressure; $ETCO^2$, end-tidal carbon dioxide.



Adrenaline dosing

Case reports

In the 585 cases with PEA/bradycardia, adrenaline was given as a 1 mg bolus in 392 (67%) cases, by titrated aliquots in 120 (21%), as an infusion in 47 (8.0%) cases and no adrenaline was administered in 82 (14%) cases (Table 25.4).

Table 25.4 The method of adrenaline administration in 585 NAP7 cases with an initial rhythm of pulseless electrical activity/bradycardia

	Cases	
	(*n*)	(%)
Initial 1 mg bolus	392	67
Initial titrated aliquots	120	21
Adrenaline infusion	47	8.0
No adrenaline	82	14
Unknown	9	1.5

In some cases, the injection of 1 mg of adrenaline was considered by the panel to be unnecessarily high, while in other cases it was the opinion of the panel that the dosing was insufficient or that injection of adrenaline was delayed. Comments from the panel included:

- 0.4 mg adrenaline too high a (initial) dose for a severe bradycardia.
- Adrenaline dose generous.
- Adrenaline likely underdosed. Only 1 mg used during the whole arrest. Use of metaraminol not considered appropriate in cardiac arrest by panel.
- Only 100 µg adrenaline given – this agrees with advice to use 50–100 µg increments in guidelines.
- Metaraminol administrated instead of adrenaline.
- Delay to adrenaline of six minutes.
- Small dose of adrenaline used with good effect.
- Very small amount adrenaline administered (20 µg).

Immediately after induction of anaesthesia, an older patient with moderate frailty became asystolic. Chest compressions were started and adrenaline 1 mg was injected. Return of spontaneous circulation was achieved after one cycle of CPR, which was followed immediately by a broad complex tachycardia. The panel judged that that the high dose of adrenaline was responsible for the broad complex tachycardia.

An older patient with severe frailty developed severe bradycardia and hypotension five minutes after injection of a spinal anaesthetic. Chest compressions were started because the systolic pressure was less than 50 mmHg. Atropine and adrenaline 1 mg were injected, followed immediately by stopping chest compressions. The blood pressure immediately after ROSC was not documented. The panel judged that 1 mg adrenaline was too high an initial dose in a patient with a low flow state.

A healthy patient undergoing general anaesthesia for a laparoscopic procedure became bradycardic as the pneumoperitoneum was being established. Glycopyrrolate 200 µg was injected when the heart rate decreased to below 40 [beats] per minute and atropine and chest compressions were started after the heart rate decreased below 20 [beats] per minute. Adrenaline 1 mg was injected and severe tachycardia and severe hypertension developed. The patient then developed pulmonary oedema and hypoxaemia. The surgery was abandoned, and the patient spent several days in a critical care unit. The panel judged that 1 mg of adrenaline was an inappropriate initial dose in a low-flow state caused by severe bradycardia and caused the tachycardia and severe hypertension that followed.

An otherwise healthy overweight patient was in the recovery room following general anaesthesia for minor surgery. He became very hypotensive and hypoxaemic – chest compressions were started but the first dose adrenaline 1 mg was not given until almost 10 minutes after the onset of cardiac arrest. The resuscitation attempt was terminated after 20–30 minutes of CPR and a total of over 5 mg of adrenaline.

Discussion

Pulseless electrical activity was the initial rhythm in just over half of all perioperative cardiac arrests reported to NAP7. Our Baseline Survey showed that most anaesthetists would start chest compressions when the systolic blood pressure was less than 50 mmHg and when interventions were failing in an ASA 3 hypertensive adult patient during general anaesthesia. In practice, anaesthetists use a combination of clinical signs together with information from monitoring to decide when to start chest compressions. Resuscitation guidelines err on starting chest compressions early and in many cases there will be a low-flow circulation when chest compressions are started. Chest

compressions in a patient with a beating heart are unlikely to cause harm and delays in diagnosing cardiac arrest and starting CPR should be avoided (Soar 2015).

Our case review data showed that anaesthetists use a range of doses of adrenaline including adrenaline infusion. It appears that few anaesthetists are aware of the guidance for smaller intravenous doses of adrenaline when used very early in a PEA perioperative cardiac arrest, as most adult patients were given a 1 mg dose.

The optimal dose of adrenaline during cardiac arrest remains uncertain; smaller doses are appropriate when:

- adrenaline is first given for profound hypotension
- there is a high probability of a low flow state during PEA or severe bradycardia
- there is a very short time between the onset of cardiac arrest and injection of adrenaline.

In parallel, the underlying cause of deterioration or cardiac arrest must also be addressed.

Anaesthetised patients are monitored closely; a very low blood pressure may be measurable even if peripheral pulses are absent, particularly in those with an arterial line. The current adult advanced life support guidance for perioperative cardiac arrest, and guidelines for cardiac arrest following cardiac surgery recommend an initial dose of adrenaline 50–100 µg when given very early in cardiac arrest but this is based only on expert opinion. Giving a dose of 1 mg adrenaline immediately after the onset of cardiac arrest may result in marked hypertension and tachycardia if return of spontaneous circulation is achieved rapidly and may cause increased bleeding (Karcher 2022).

The main challenge is knowing how to titrate adrenaline during cardiac arrest. Options include:

- Combining high-quality chest compressions and adrenaline to increase the end-tidal CO_2.
- When an arterial line is in place, titrating adrenaline aiming to increase the diastolic blood pressure during chest compressions (Morgan 2023). This increases the coronary perfusion pressure and expert opinion is to aim for a diastolic blood pressure greater than 25 mmHg (Meaney 2013).
- If it can be set up quickly, using a continuous infusion of adrenaline. Increasing adoption of peripheral infusions of vasopressors in anaesthetic practice (Pancaro 2020) may increase familiarity with this option.

Recommendations

National

- There should be greater clarity in guidelines for starting chest compressions and the use of adrenaline in closely monitored settings (eg during anaesthesia care).

Individual

- In a monitored perioperative adult patient who is deteriorating (e.g. following anaphylaxis) despite initial treatment of the underlying cause, start chest compressions if the systolic blood pressure remains below 50 mmHg.
- In a perioperative adult patient who is deteriorating with profound hypotension initially use small doses of intravenous adrenaline (eg 50 µg in adults, 1 µg/kg in children) or an infusion of adrenaline.
- In early perioperative cardiac arrest, use small doses of intravenous adrenaline (eg 50 µg in adults, 1 µg/kg in children) or an infusion of adrenaline – when initial small doses of adrenaline fail and ROSC is not achieved within the first four minutes (about two 2-minute cycles of CPR) of cardiac arrest, give further adrenaline using the standard adrenaline dose for cardiac arrest (1 mg in adults, 10 µg/kg in children).
- Avoid using a standard cardiac arrest bolus dose of adrenaline (1 mg in adults, 10 µg/kg in children) when there is a low flow circulation or when a circulation has already been restored.

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