21 Airway and respiratory complications associated with perioperative cardiac arrest

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Key findings

- In the Activity Survey, airway complications were the second most common complication, with an incidence of 1.7% and accounting for 21.9% of all complications. The most common airway complications were laryngospasm (38% of airway complications), airway failure (30%) and aspiration (6.4%). The incidence of cannot intubate and cannot oxygenate (CICO) situation or the need for an emergency front of neck airway (eFONA) was 1 in 8370 (95% confidence interval, CI, 1 in 2,296 to 1 in 30,519).
- Breathing complications were the fourth most common complications with an incidence of 1.1% and accounting for 13.7% of all complications. The most common breathing complications were severe ventilation difficulty (37% of all breathing complications), hyper- or hypocapnia (24%) and hypoxaemia (23%).
- Airway and respiratory complications were a leading cause of perioperative cardiac arrest in NAP7, accounting for 12.8% of all cardiac arrests and 9.2% of deaths.
- Hypoxaemia was the primary cause of these perioperative cardiac arrests.
- While survival after cardiac arrest due to airway and respiratory events was higher than for other events, a disproportionate number of survivors experienced a severe outcome, indicating permanent harm or prolonged critical care stay.
- Patients with obesity were overrepresented, with extubation and recovery representing a particularly high risk period for this group of patients.
- Infants (age range 28 days to less than 1 year) were overrepresented, with cases occurring in theatres, in paediatric critical care and during preparation for retrieval.
- Airway issues in cases of cardiac arrest of the critically ill child were prominent.
- Out-of-hours cases were overrepresented in airway and respiratory related cardiac arrests.
- While supervision of anaesthetists in training was generally good, there were examples of patients with a predictably higher-risk airway being inappropriately managed by inexperienced anaesthetists.
- Lack of monitoring during transfer to recovery areas contributed to unrecognised hypoxaemia and cardiac arrest in several cases.
- eFONA was very rare and was performed exclusively in patients with a predicted difficult airway.
- Cases of pulmonary aspiration leading to cardiac arrest were very rare. Most cases occurred during rapid sequence induction (RSI) for acute abdominal surgery.
- There was a single case of aspiration associated with supraglottic airway (SGA) use; this is in contrast to NAP4. This and the marked increase in use of second generation SGAs since NAP4 are notable.
- There were at least three cases of unrecognised oesophageal intubation resulting in hypoxaemia and cardiac arrest. Failure to correctly interpret capnography was a recurrent theme in these events.
- A lack of familiarity with or misuse of airway and breathing equipment contributed to cardiac arrest in some cases.
- Fatal airway events were more likely to be followed up by a debrief while only 50% of cases in which the patient survived were followed by a debrief.
- Overall, the data, while distinct from NAP4, suggest that airway management is likely to have become safer in the last decade, despite the surgical population having become more anaesthetically challenging.

What we already know

National Audit Project 4 (NAP4) is the largest prospective study of airway management to date (Cook 2011). Its findings underpin much of our understanding of the complications of airway management and have shaped current airway management guidance. The project looked at high severity complications, including death, over a year in the UK. Key themes included

failure to assess patient risk and respond to findings, failure to create and communicate an airway strategy, poor judgement, use of SGAs in inappropriate settings and failure to use capnography, particularly in locations outside operating rooms. Patients with obesity were identified as a high-risk group and extubation was noted to be a particularly a high-risk time for adverse airway events.

Since the publication of NAP4 in 2011, surgical patient demographics have changed markedly, with a higher prevalence and degree of obesity, increased age and increased comorbidity, all of which are likely to make airway management more challenging than a decade ago (Kane 2023, Chapter 11 Activity Survey). Several recent studies, such as the AeroComp study into aerosol precautions and airway complications, support this premise (Potter 2022). As well as being at higher risk for airway compromise, these populations may also be more predisposed to poorer outcomes should cardiac arrest occur.

A national survey of the impact of NAP4 on airway management in UK hospitals was published in 2016 (Cook 2016a). Notable positive changes included designated departmental airway leads, increased training in eFONA and more widespread capnography use. Poorly adopted recommendations included preassessment of patients with morbid obesity, airway strategy documentation and capnography availability in all recovery areas. If NAP4 recommendations, as intended, are considered recommendations for best safe practice, the survey showed significant 'closing of the safety gap' in the three years after NAP4: 56% in ICU, 48% in emergency departments and 39% in anaesthesia. However, this survey focused on process, not outcomes, and NAP7 provides a partial opportunity to explore the frequency and nature of airway events since then.

The findings of NAP4 have been followed by a series of epidemiological studies of airway complications from the UK and other countries (which might be called mini-NAPs), which offer additional insights into the frequency of major airway events, including cardiac arrest (Table 21.1). Obesity was a recurrent risk factor across all but one of these (Huitink 2017, Endlich 2020, Potter 2022, Shaw 2021). Other high-risk groups included younger children and older adults (Huitink 2017), emergency cases (Endlich 2020), ASA 3–4 patients (Endlich 2020) and those with predicted difficult airways (Cumberworth 2022). Additional factors included head and neck surgery (Endlich 2020), inexperienced airway managers (Potter 2022), the use of (particularly reusable) FFP3 masks (Potter 2022) and the periods at and immediately following induction (Huitink 2017, Endlich 2020).

Further insights into complications of airway management, minor and severe, are provided by a recent analysis of litigation data from claims made against the NHS between 2008 and 2018 (Oglesby 2022). Airway events were infrequent but outcomes in these cases tended to be severe, accounting for 31% of all deaths leading to litigation. One in six claims relating to cardiac arrest was associated with airway events, of which 36% were unanticipated difficult airway, 18% extubation related and 18% postoperative airway compromise. This proportion of deaths gives an indication of the frequency of airway-related mortality, albeit with a number of these cases representing delayed deaths not associated with cardiac arrest at the time of the airway event.

What we found

Activity Survey

Among 16,906 cases of general anaesthesia in the Activity Survey a tracheal tube was used in 51.6% (*n* = 8,721 cases) and an SGA in 44.9% (*n* = 7,585). Of the SGAs used, 65% (*n* = 2,632) were second generation and 35% (*n* = 4,953) first generation.

Considering only those patients managed with a tracheal tube or SGA, as body mass index (BMI) rose the rates of tracheal tube use rose, most notably when BMI was above 40 kg m^{-2} (Figure 21.1 and Table 21.2). Conversely as BMI rose, when an SGA was used, the proportion of first- to second-generation SGAs changed very little (Figure 21.2). For cases with an airway device left in place for transfer to recovery, end-tidal CO_2 monitoring was used in only 25.9% of cases.

Table 21.1 Epidemiological studies of airway complications since NAP4

Study	Country	Setting (number of sites)	Cases (*n*)	Cardiac arrest (*n*)	Deaths (*n*)	eFONA (*n*)
Huitink (2017)	Netherlands	Tertiary (1)	2803	1	1	2
Endlich (2020)	Australia/ New Zealand	Tertiary (12)	131,233	n/r	1	3
Pedersen (2021)	Switzerland	Tertiary (1)	7454	n/r	0	0
Cumberworth (2022)	UK	Mixed (tertiary: 1, DGH: 3)	74,400	n/r	1*	4
Potter (2022)	UK	National (70)	5905	n/r	0	0
Shaw (2021)	UK	Regional (39)	1874	0	0	0

DGH, district general hospital; eFONA, emergency front of neck airway; n/r, not reported.
*One death occurred during the study but was not reported in the formal results.

Figure 21.1 Type of airway used by body mass index (BMI). SGA, supraglottic airway; TT, tracheal tube. 1st generation SGA ■, 2nd generation SGA ■, TT ■.

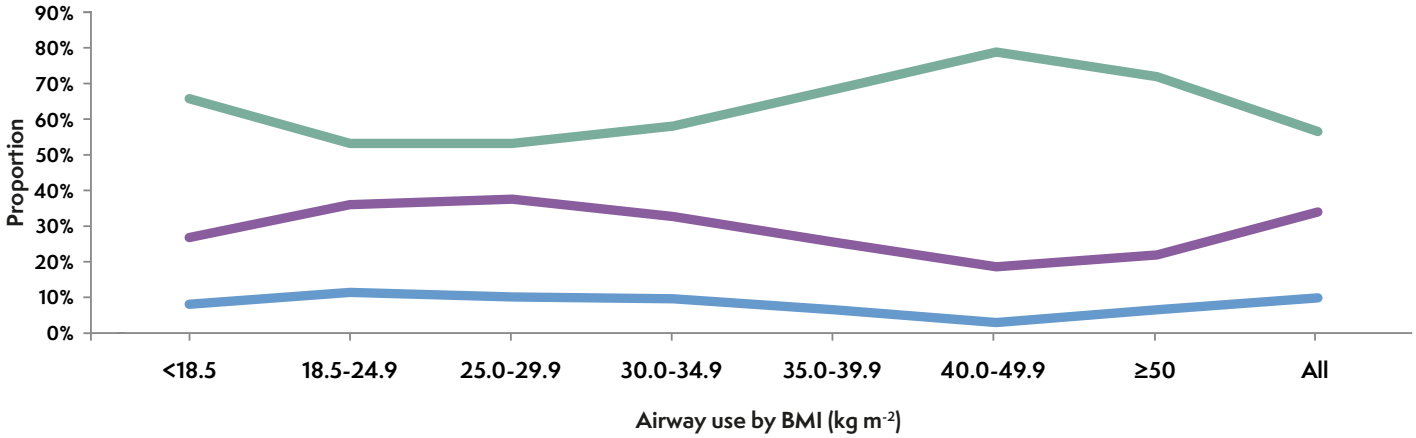
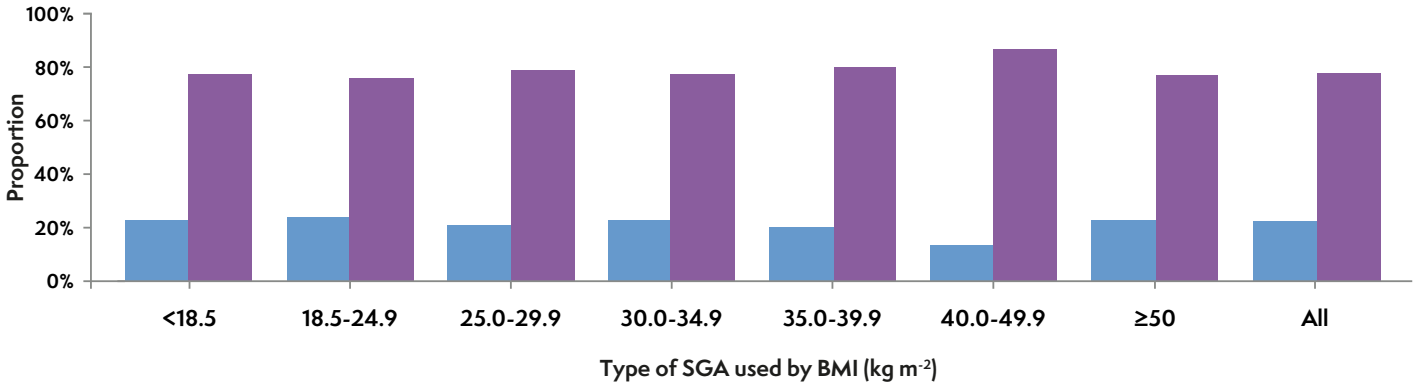


Table 21.2 Airway device by body mass index (kg m^{-2})

Airway	Body mass index, *n* (%)						
	< 18.5	18.5–24.9	25.0–29.9	30.0–34.9	35.0–39.9	40.0–49.9	≥ 50
SGA:							
1st generation	21 (7.8)	571 (11.3)	368 (9.9)	226 (9.5)	68 (6.4)	14 (2.8)	8 (6.5)
2nd generation	72 (26.7)	1812 (35.8)	1392 (37.3)	774 (32.6)	270 (25.4)	91 (18.5)	27 (21.8)
TT	177 (65.6)	2684 (53)	1976 (52.9)	1373 (57.9)	724 (68.2)	387 (78.7)	89 (71.8)

SGA, supraglottic airway; TT, tracheal tube.

Figure 21.2 Type of supraglottic airway (SGA) used and body mass index (BMI). 1st generation SGA ■, 2nd generation SGA ■.



In the Activity Survey, airway complications were the second most common complications: there were 421 airway complications in 24,721 cases, an incidence of 1.7% accounting for 21.9% of all complications. The most common airway complications reported in the Activity Survey were laryngospasm, accounting for 38% of reported events, airway failure (mask ventilation, SGA insertion or tracheal intubation), accounting for 30% of reports and aspiration accounting for 6.4%. Laryngospasm and airway failure had an incidence of 1 in 109 (95% CI 1 in 93 to 1 in 127) and 1 in 143 (95% CI 1 in 119 to 1 in 171), respectively. Aspiration had an incidence of 1 in 670 (95% CI 1 in 454 to 1 in 988) and a CICO or eFONA situations 1 in 8370 (95% CI 1 in 2,296 to 1 in 30,519).

Airway complications rose from BMI 35 kg m^{-2} and were two-fold higher than 'healthy' BMI with BMI greater than 60 kg m^{-2} (Chapter 12 Activity Survey – complications).

In the Activity Survey there were 264 breathing complications accounting for 13.7% of all complications. The most common breathing complications reported in the Activity Survey were severe ventilation difficulty, accounting for 37% of all breathing complications, hyper- or hypo-capnia accounting for 24% and hypoxaemia accounting for 23%. Severe ventilation difficulty had an incidence of 1 in 178 (95% CI 1 in 146 to 1 in 218), hypercarbia 1 in 289 (1 in 223 to 1 in 373) and severe hypoxaemia 1 in 310 (1 in 238 to 1 in 404).

Complications are discussed in greater detail in Chapter 12 Activity Survey – complications.

Case reports

Of the 881 reported cardiac arrest cases, 113 (12.8%) were attributed to airway management or respiratory problems. Of these, airway management accounted for 71 (63%) and respiratory problems for 42 (37%). The nature of these events was diverse and included:

- failed mask ventilation
- failed ventilation with an SGA
- failed tracheal intubation
- CICO
- eFONA
- displaced tracheostomy
- unrecognised oesophageal intubation
- extubation complications
- laryngospasm
- airway haemorrhage
- aspiration
- bronchospasm
- pneumothorax
- equipment misuse
- failure to monitor.

The cause of cardiac arrest was hypoxaemia in almost all instances and the outcome was death or severe disability in 32 (28%) and 16 (14%) cases, respectively. Of the 32 cases in which the outcome was death, 13 (41%) were associated with an airway event and 19 (59%) a respiratory event. Of the 16 cases where the outcome was severe disability, 10 (62%) related to an airway event and 6 (38%) to a respiratory event. The death rate for airway and respiratory events was comparatively low compared with the entire NAP7 dataset (40%). However, of those patients who survived an airway or respiratory related cardiac arrest, a greater proportion had severe outcomes compared with the other reported causes of cardiac arrest (12%).

Compared with other cardiac arrests in the NAP7 cohort, airway and breathing cases were more likely to occur at induction (26% vs 14%) and less likely to occur during surgery (22% vs 35%). One quarter (27%) of cases occurred after surgery either at emergence, in recovery or on the wards. Airway and breathing events were more likely than other NAP7 cases to have occurred in the anaesthetic room (16% vs 11%); 8 (7%) events took place in remote locations and 22 (19%) on wards or in critical care.

Of 99 cardiac arrests with a rhythm reported, most were pulseless electrical activity (PEA) (57%), bradycardia (30%) or asystole (8%). Duration of cardiac arrest was most commonly less than 10 minutes (79%) but with 13% lasting beyond 20 minutes; 96 (85%) patients survived the initial event and 17 (15% died during resuscitation. However, in 13 (26%) and 30 (61%) of 49 patients with a reported hospital outcome, respectively, this included harm and delayed discharge.

Twenty-nine percent of airway and breathing reports to NAP7 occurred in patients undergoing ear, nose and throat (ENT) (26.5%) and maxillofacial (2.7%) surgery. This is a greater proportion than in the Activity Survey, where all head and neck surgery represented 8% of the workload.

There were many examples of well managed events with care rated as 'good' throughout in 48 (43%) cases. Conversely, 52 (46%) cases had elements of care rated as 'poor' by the panel. In these cases, the period of concern was predominantly before cardiac arrest, with care rated poor in 50 (96%) of these 52 cases.

Of the 32 deaths in the airway and breathing cohort, 22 (69%) were judged by the panel to be in patients with an underlying inexorably fatal clinical condition. In 10 cases, the panel concluded that improvements in care could have prevented cardiac arrest and death.

Case report demographics

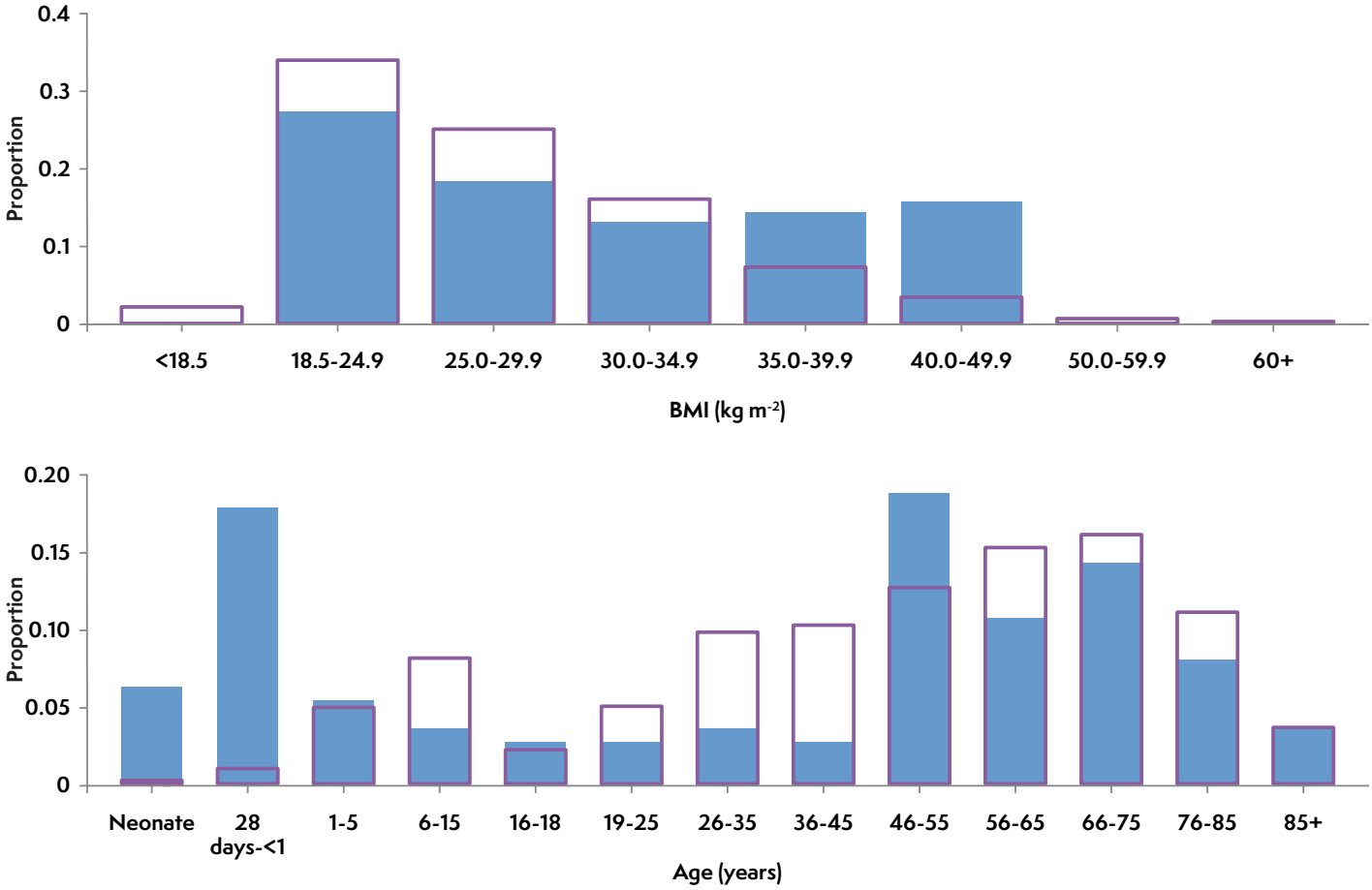
Patients with obesity (specifically BMI 35.0–49.9 kg m^{-2}) were overrepresented in airway and breathing reports (Figure 21.3). While 11.7% of patients in the Activity Survey had a BMI 35.0–49.9 kg m^{-2}, this population accounted for 20% of airway and respiratory related cardiac arrest.

For patients with a BMI greater than 30 kg m^{-2}, 18% of cardiac arrests with airway or respiratory precipitants occurred at emergence or during transfer to recovery. This is a greater proportion than for lower BMI groups (5.7%), suggesting that this time phase is higher risk for this patient group. Airway obstruction was a common aetiology either following extubation or in the immediate postoperative period.

> A patient with a high BMI having a minor general surgical procedure was managed by an inexperienced anaesthetist in training. General anaesthesia and tracheal intubation were chosen over spinal anaesthesia. Airway obstruction occurred at extubation. Hypoxia progressed to cardiac arrest. Resuscitation attempts were challenging due to body habitus and, despite reintubation, return of spontaneous circulation (ROSC) was never achieved and the patient died.

Neonates and infants were also overrepresented, accounting for 27 (24%) airway and respiratory cases and 1.1% of surgical activity (see also Chapter 27 Paediatrics). Nine events (33%) occurred at induction or soon after induction. The nature of events was diverse and included failed intubation, tracheal tube displacement and CICO situations. Among these cases, all survived with moderate harm, except in one case where the outcome was severe harm. Six (22%) events occurred postoperatively, with several examples of cardiac arrest due to a misplaced tracheal tube on the paediatric intensive care unit, including endobronchial migration and accidental extubation. Capnography was in place for all these cases.

Figure 21.3 BMI and age of cases (blue shaded bar) compared with Activity Survey denominator data (purple lines). A blue bar substantially above the line indicates over representation of that feature and below the line underrepresentation.



Among patients with airway and respiratory related cardiac arrests 16% of cases reported to NAP7 were in patients of Asian ethnicity compared to 7% of the Activity Survey population, and 24% were of Non-white ethnicity compared to 12% of the Activity Survey population.

Case reports and organisational factors

Airway incidents leading to cardiac arrest occurred disproportionately out of hours, with 36% of events taking place out of hours compared with 10% of anaesthetic activity in the Activity Survey.

Where patients died as a result of airway or respiratory related cardiac arrest, a debrief was held in 88% of cases. However, debrief was notably less common (50%) when patients survived.

Supervision of anaesthetists in training and the involvement of senior clinicians in resuscitation attempts was generally good, with a consultant present at induction of anaesthesia in 87% of cases. Of eight cases where no consultant was present, the panel judged that only two were inappropriate cases for solo management by an anaesthetist in training. However, there were several examples of junior clinician management of high-risk airways for training purposes.

An inexperienced anaesthetist in training was designated as the first intubator for RSI in an unwell, hypoxaemic adult undergoing emergency surgery. Following induction of anaesthesia, there was rapid oxygen desaturation. Bag–mask ventilation failed. Airway management was taken over by the consultant anaesthetist. Intubation was difficult and hypoxaemia led to cardiac arrest. ROSC was achieved following correction of hypoxaemia.

An adult with a known difficult airway presented for emergency surgery. Awake tracheal intubation (ATI) was planned with ENT surgeons standing by. Both sedation and ATI were managed by the only anaesthetist present. Desaturation occurred during the procedure as a result of respiratory depression caused by excessive sedation. Mask ventilation and intubation with videolaryngoscopy failed. A hypoxic cardiac arrest followed and an emergency tracheostomy was undertaken by the surgeons. ROSC was achieved following airway rescue and correction of hypoxaemia.

The panel judged the assistance of a second anaesthetist could have prevented deterioration and cardiac arrest in several cases. These situations included where airway management itself is likely to require two anaesthetists due to anatomical abnormalities or body habitus; a separate operator for sedation management in awake tracheal intubation; a second 'pair of hands' for emergency airway management, particularly in unfamiliar settings; and in physiologically high-risk patients where focus on cardiovascular integrity may detract from airway management.

Case reports and perioperative care

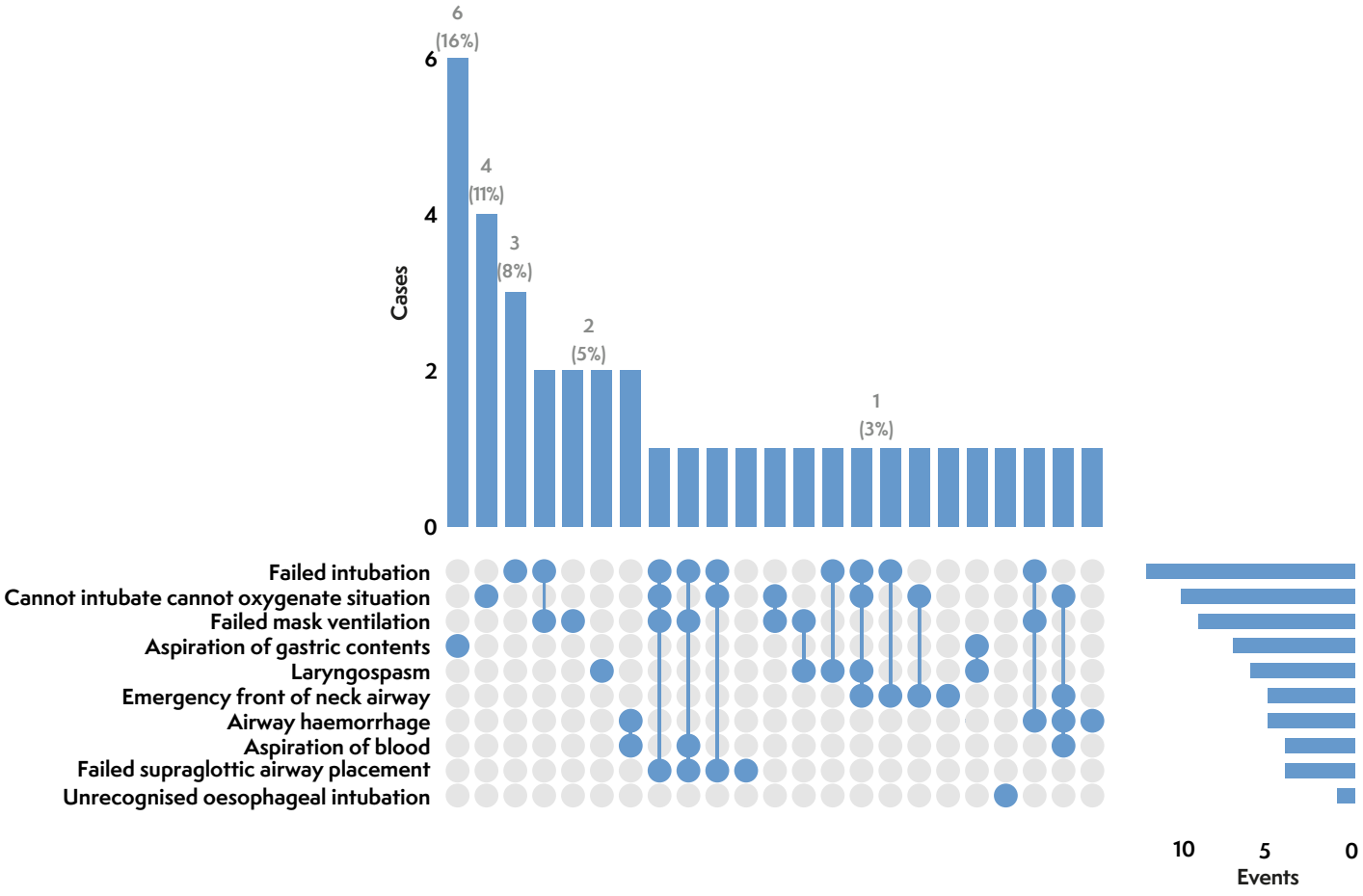
There were 27 cases (3% of all reports) where respondents reported an unanticipated airway event. These events included failed face mask ventilation, failed SGA placement, failed tracheal intubation, CICO or eFONA situations, and unrecognised oesophageal intubation (Table 21.3). Of these 27 cases, 18 (66.6%) did not have a predicted difficult airway. In many instances, multiple unexpected events occurred (Figure 21.4)

Four (14.8%) patients did not have a documented airway assessment; all were critically ill children requiring emergency intubation and specialist retrieval. They were all managed by consultants who covered paediatric services only when on-call and reported not having advanced paediatric training (Chapter 33 Critically ill children).

Table 21.3 Unanticipated airway events. The number of events exceeds the number of cases as there were multiple events in some cases.

Event	(*n*)
Failed tracheal intubation	12
Cannot intubate cannot oxygenate	10
Failed mask ventilation	9
Aspiration of gastric contents	8
Laryngospasm	6
Airway haemorrhage	6
Aspiration of blood	5
Emergency front of neck airway	6
Failed supraglottic airway placement or ventilation	4
Unrecognised oesophageal intubation	3

Figure 21.4 Combinations of unanticipated airway events for each case



Monitoring

In six (5.3%) cases, failures of monitoring contributed to unrecognised hypoxaemia and cardiac arrest. These cases occurred either on transfer from an anaesthetic room to theatre, transfer from operating table to bed or from theatre to recovery (see also Chapter 31 Monitoring and transfer).

Airway management at the time of cardiac arrest

The airway in place at the time of cardiac arrest was reported in 872 cases and is listed in Table 21.4. Although Activity Survey data do not allow a full comparison of airway devices, in broad terms, comparing airway device use in cases of cardiac arrest with the Activity Survey, SGAs were underrepresented (11% vs 46%) and both tracheal tubes (86% vs 53%) and tracheostomy (2.7% vs 0.4%) were overrepresented.

> A patient with obesity was extubated in theatre following urgent surgery. The patient was alert and tidal volumes were adequate. Monitoring was removed. During transfer to recovery the patient had a respiratory arrest. Recognition of deterioration was delayed and there was progression to cardiac arrest. Monitoring was resumed in recovery and ROSC was achieved following airway management and correction of hypoxaemia.

The method by which airway positioning was confirmed was reported in 723 cases, of which 604 had a tracheal tube or SGA in place. Confirmation with capnography (waveform or capnometry) was the most common mode of confirmation, used in 595 (98.5%) cases.

Table 21.4 Airway in place at the time of cardiac arrest in 872 cases in which these data were provided

Airway	Patients	
	(*n*)	(%)
Tracheal tube (oral or nasal)	537	62
Oxygen mask or nasal specs	93	11
Face mask (± Guedel)	86	10
SGA (2nd generation)	64	7
None	57	7
Tracheostomy	17	2
SGA (1st generation)	7	1
eFONA	4	0.5
Double lumen tube	3	0.3
High-flow nasal oxygen	3	0.3
Rigid bronchoscope	1	0.1

eFONA, emergency front of neck airway; SGA, supraglottic airway.

Pulmonary aspiration

Eleven aspiration events, 9.7% of airway and breathing cases, leading to hypoxaemia and cardiac arrest, were reported. Most of these cases involved aspiration of gastric content in patients with an acute abdomen. It is unknown whether these patients had nasogastric tubes in place and, if present, whether they were aspirated prior to induction of anaesthesia. Rapid Sequence Induction (RSI) appears to have been performed in the most instances, but some deviations from usual practice, such as administration of midazolam before induction, were noted.

There was one case relating to aspiration while the airway was managed with a second-generation SGA for elective surgery in a healthy patient who was moderately obese. The remaining aspirations were secondary to airway or upper gastrointestinal haemorrhage.

Five of this group of patients died immediately following the cardiac arrest event. Half of the remaining patients survived to hospital discharge and half were still admitted at the time of reporting.

Emergency front of neck airway

There were six cases of eFONA reported to NAP7. All six had a predicted difficult airway. Two cases occurred at extubation.

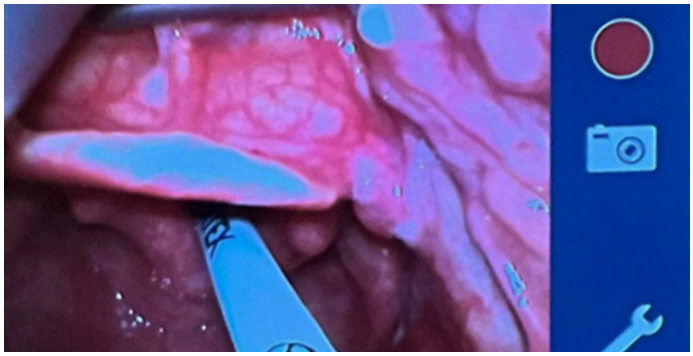
Three cases were reported in patients undergoing head and neck surgery. eFONA was successfully performed by an ENT surgeon and the patients survived the initial event. Final outcomes were one death, one survival to discharge and one not reported.

In three reports of patients not undergoing head and neck surgery, there was no ENT involvement. In these instances, eFONA was probably performed by the anaesthetist present. Two of these patients died during eFONA attempts and one survived the initial event but died several days later. The details of airway management attempts and eFONA methods were not reported.

Two events, in both of which the patient survived the initial cardiac arrest and eFONA, were not followed up with a debrief.

Unrecognised oesophageal intubation

There were three cases judged to be delayed or unrecognised oesophageal intubation and one in which this was a possible diagnosis. In two cases, the diagnosis was not offered by the



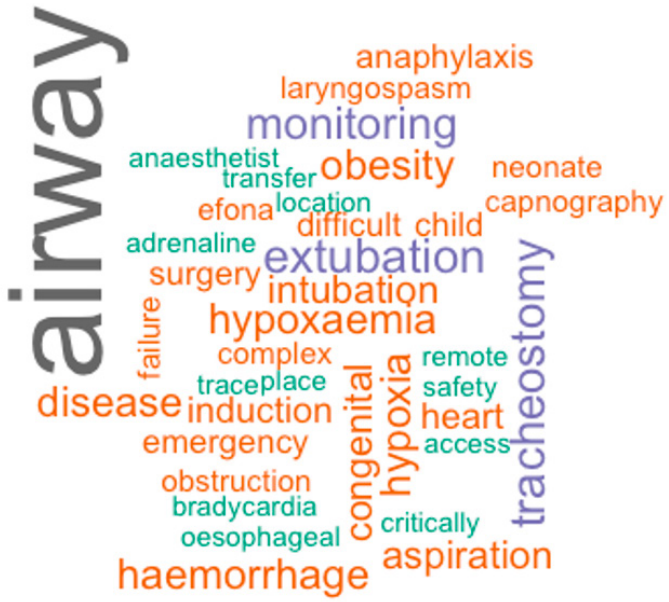
A patient with airway pathology underwent elective head and neck surgery. Intubation was carried out awake. Before extubation, neuromuscular blockade was reversed and an adequate level of consciousness was confirmed. ENT surgeons were present and scrubbed. Following removal of the tracheal tube, the patient showed signs of respiratory distress. Anaesthesia was induced again and an attempt at reintubation was made but failed and was followed by oxygen desaturation and cardiac arrest. eFONA was performed by the surgical team during resuscitation. Ventilation was established and ROSC was achieved. The patient survived the initial event but final outcome was not reported.

reporting team but was the view of the panel. In one case, intubation of a critically ill patient led to difficult ventilation, hypoxaemia and cardiac arrest. Capnography was not in use. After a short delay, reintubation led to resolution of ventilation and hypoxaemia and ROSC. Underlying themes with these events included failure to use or correctly interpret waveform capnography. In one case, a flat capnograph was attributed to presumed severe bronchospasm. Reintubation during cardiac arrest (which included administration of adrenaline) led to resolution of the critical event. Although all patients survived the initial event, two were left with moderate disability and ongoing hospital admission.

A further two cases of unrecognised oesophageal intubation were reported in the Activity Survey.

Equipment

Figure 21.5 Word cloud based on the airway and respiratory cardiac arrest case reviews



There were two cases where errors in the use of equipment resulted in hypoxaemia and cardiac arrest. In one case, connection of the wrong part of the anaesthetic circuit to the anaesthetic machine common gas outlet resulted in failure to ventilate. In another case, a patient with a tracheostomy underwent anaesthesia but it was found that the tracheostomy was not compatible with the anaesthetic circuit in use.

Discussion

Activity Survey

Compared with NAP4 data (Woodall 2011), rates of tracheal tube use were higher in NAP7 (NAP7 51.6% vs NAP4 37.8%) and SGA use lower (NAP7 44.9% vs NAP4 56.4%). This may in part be explained by an increase in patients with higher BMI (Chapter 11 Activity Survey). Conservative practice surrounding aerosol-generating procedures (AGPs) during the COVID-19 pandemic may also have contributed, although research undertaken since then indicates that this is an unnecessary precaution (Brown 2021 and Shrimpton 2021).

Guidance, from the Society for Obesity and Bariatric Anaesthesia, suggests that a tracheal tube should be the technique of choice in patients with obesity (Nightingale 2015) but that guidance is rather non-specific and generalised suggesting 'in the obese patient, tracheal intubation with controlled ventilation is the airway management technique of choice'. We found that SGA devices were used in almost one quarter of patients with a BMI greater than 40 kg m^{-2}.

Perhaps more notable, we found no clear evidence of an increase in use of second-generation SGAs as BMI rose. This perhaps suggests that first-generation SGA users use their normal SGA irrespective of BMI. As second-generation devices generally have a higher pharyngeal seal than first-generation devices, and design features to reduce the risk of aspiration, this approach has little to recommend it.

Airway complications (n = 421) were approximately 60% more common than respiratory complications (n = 264) in the Activity Survey. Conversely the outcomes from respiratory events were worse than those from airway events.

Case reports

Overall airway and respiratory cases account for a significant proportion of cardiac arrests, deaths and severe outcomes reported to NAP7. It is not possible to make direct comparisons with NAP4 as case mix and practices have changed. The population is older, more comorbid and complex than a decade ago (Chapter 11 Activity Survey), all of which likely results in greater risk of both airway and respiratory events and poorer outcomes. Further, the inclusion criteria for NAP7 (cardiac arrest) are not the same as for NAP4 (an airway complication leading to death, brain damage, eFONA or ICU admission/prolongation of stay). Specific aspects are discussed below.

Although survival rates were higher in this data subset compared with other causes of cardiac arrest, the outcomes for surviving patients were relatively more severe. This finding is supported by previous work showing serious airway incidents to be low in frequency but high in outcome severity due to patients surviving with the sequalae of hypoxic brain injury (Oglesby 2022).

In 10 cases of fatality, the cardiac arrest was judged to be potentially preventable. Although in the context of several million anaesthetics this is a small number of cases, it serves as a reminder that avoidable airway complications may lead to death. The aetiology of these events was diverse but human factors, levels of supervision and organisational issues were recurring themes.

Preoperative assessment

One of the key findings of NAP4 was that poor preoperative airway assessment was associated with poor airway outcomes. In NAP7, care before cardiac arrest was rated as poor in 44% of cases; however, few of these instances related to a lack of adequate airway assessment. In 85% of cases involving an unanticipated airway event, an airway assessment was documented. This likely represents an improvement in preoperative attention to airway assessment and planning since the publication of NAP4.

The small number of cases where no airway assessment was documented were all critically ill paediatric patients awaiting specialist retrieval. This issue is discussed in Chapter 33 Critically ill children.

Obesity

In common with multiple previous studies, we found patients with obesity to be overrepresented in cases reported to NAP7 (Huitink 2020). Management of these events was frequently described as challenging due to difficulties with airway rescue techniques and associated procedures, such as establishing intravenous access. Obesity increases the risk of failure of many airway procedures and the short safe apnoea time compounds difficulty (Huitink 2020). It is also well recognised that when one airway technique fails, the likelihood of rescue techniques succeeding is lower than would otherwise be expected: a phenomenon termed *composite airway failure* (Cook 2012) and observed in many airway cases reported to NAP7. This underlines, as described in NAP4, the need for an airway management strategy (ie a series of plans each contingent on the failure of the previous technique and communicated within the airway team) rather than one plan (Cook 2011).

There were instances where airway management could have been avoided if regional techniques had been employed in patients with obesity. This was also noted in NAP4 (Cook 2011). NAP7 reports lower rates of regional anaesthesia in patients with obesity (see Chapter 25 Obesity). While central and peripheral nerve blockade may also be more challenging in this population, where practical, such techniques may be considered to avoid

complications associated with airway management. In these circumstances, as regional anaesthesia is also more likely to fail, an airway strategy should be in place to prevent unplanned urgent airway management (Cook 2011).

In contrast to NAP4, we have not observed reports of misuse of SGAs in the obese population leading to harm (see below). The NAP7 Activity Survey (Chapter 11 Activity Survey) showed that, over the past decade, the average BMI of patients has increased significantly. Importantly, not only do more patients have obesity but the degree of obesity is increasing. These trends are even more notable in the obstetric population. Age and comorbidity have also increased, and both trends are likely to make airway management more challenging. It is therefore likely that unless these trends are reversed the cohort of patients now undergoing surgery are likely to be more at risk of airway complications and harm than is historically the case.

Small and critically ill children

The results of NAP7 clearly highlight, not for the first time, the high-risk nature of airway management in infants and neonates (Disma 2021, Engelhardt 2018, Fiadjoe 2016, Graciano 2014, Morray 1993). Importantly, there were numerous reports from theatres, paediatric critical care and when critically ill infants and neonates being prepared for transfer. This issue is discussed further in Chapter 27 Paediatrics and Chapter 33 Critically-ill children.

Among 13 cardiac arrests reported to NAP7 relating to care of critically ill children before transfer to a regional centre, airway problems were prominent, occurring in half of cases and often involving composite failures. All led to severe hypoxaemia and this was the most common cause of cardiac arrest in this group. Primary airway problems were failed mask ventilation, difficult or failed intubation and laryngospasm. There were two cases of failure of all rescue techniques resulting in CICO and in one case an attempt at eFONA. In one out-of-hours case in an older child with a highly predictable difficult airway an experienced paediatric anaesthesia team could not secure the airway by any means and the child died. The report did not state that any ENT or other surgical team was involved. In a younger child, unpredicted difficulty in intubation was followed by failed rescue technique until successful intubation with a videolaryngoscope,

the third attempt at intubation. Videolaryngoscopy was mentioned in only two cases (both to rescue failed intubation) but its use was not a specific question. This issue is discussed further in Chapter 33 Critically-ill children.

Head and neck surgery

As in NAP4 a disproportionate number of cases were reported from ENT and maxillofacial surgery (Figure 21.6), highlighting the high-risk nature of this group of patients, although the proportion of cases reported to NAP7 (29%) is substantially lower than reported to NAP4 (40%; Cook 2011).

Aspiration

Pulmonary aspiration was the single most common type of primary airway event leading to death or death and brain damage in NAP4, with many events leading to cardiac arrest (Cook 2011). Such cases frequently related to suboptimal use of SGAs and use of first-generation SGAs in patients with significantly obesity.

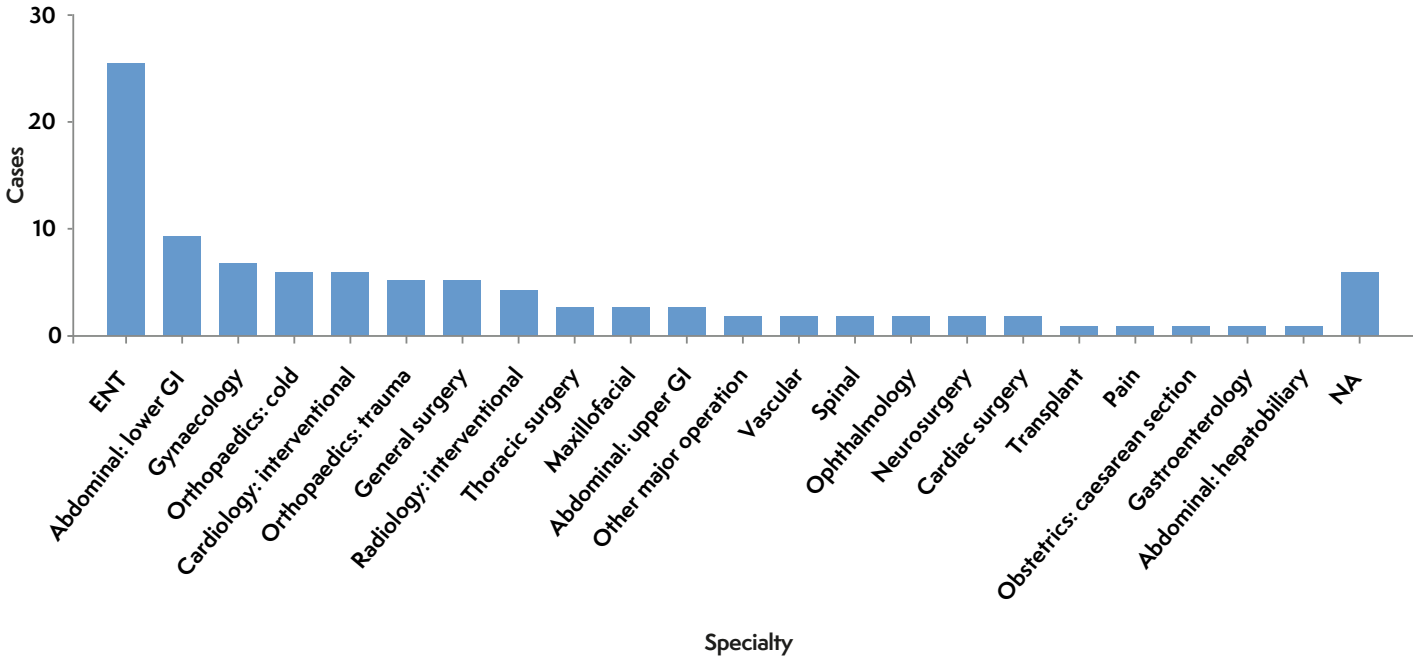
In NAP7, most cases relating to pulmonary aspiration occurred during RSI for acute abdominal pathology. The debate over the use of RSI and in particular cricoid force has raged over many years and there is a lack of definitive evidence to support one particular viewpoint (Priebe 2009, Birenbaum 2019, Cook 2016b). The current data act as a reminder that, particularly in the setting of the acute abdomen, harm from pulmonary aspiration remains a significant risk and all the elements of an RSI that might mitigate the risk of aspiration are worthy of consideration. It has been argued that cricoid force, when taught and applied correctly, is a low-risk procedure, unlikely to cause harm and which can simply be removed if it is deemed to be interfering with intubation (Cook 2016b). Consideration should be given to passing a nasogastric tube and if one is present, it should routinely be suctioned before induction. Videolaryngoscopy enables the assistant to see what the intubator sees, can enable airway manipulation to optimise laryngeal view and cricoid force and improve first pass success.

In contrast to NAP4, there was only one case of aspiration associated with SGA use. This occurred in a patient with obesity undergoing elective general surgery with a second-generation SGA. The rate of SGA use in patients of BMI 30–34.9 kg m^{-2} was 42% and little different from patients with lower BMIs. Since NAP4, the use of second-generation SGAs has significantly risen: 10% of SGA uses in NAP4, rising to 65% in NAP7. Although the inclusion criteria for NAP4 and NAP7 differ, these results suggest a decrease in SGA-related major aspiration events. This may reflect an improvement in patient selection for SGA use and/or the increased use of second-generation SGAs. Taken together, these data also tentatively suggest that the use of a second-generation SGA in patients with obesity undergoing elective surgery is likely to be relatively safe.

Emergency front of neck airway

It is notable that there were only six eFONA cases reported to NAP7. Two patients died during resuscitation attempts, two died days later and two survived. Of the surviving patients, one was still admitted at the time of reporting, and one was discharged with slight disability. This contrasts with 58 cases reported to NAP4. While there was no requirement for cardiac arrest for a case to be reported to NAP4, this was a relatively common occurrence and the report included 11 deaths and 7 reports of permanent harm in survivors. This 14-fold reduction in reports suggests that there has been a substantial reduction in the number of such procedures. Conversely, the early mortality rate in cases reported to NAP7 (33.3%) is higher than in NAP4 (13.8%), which is consistent with NAP7 only capturing a subset of cases.

Figure 21.6 Airway and breathing cardiac arrest cases by specialty. ENT, ear nose and throat; GI, gastrointesitinal; NA, not applicable.



All reports of eFONA had a predicted difficult airway. We have not collected data on the technique used, the time taken or the number of attempts. While, as in NAP4, it would be easy to conclude that there is a stark difference in patient outcome when an ENT surgeon is present, this probably hides multiple confounding factors. In NAP4, all cases undertaken by surgeons (all involving a scalpel and large tube-based technique) were 'successful' but in many cases the anaesthetist maintained the airway and oxygenation during the procedure, the procedure took up to an hour in some instances and outcome was not necessarily favourable. Conversely, when anaesthetists undertook eFONA (most often with a narrow bore cannula) the technique failed, but the setting was often one of impending death in which the anaesthetist had to abandon upper airway management to undertake eFONA. As such, the two groups are not comparable. A similar picture emerges in NAP7. In the next year, the Royal College of Anaesthetists' eFONA database is expected to launch and will explore this topic in more detail.

Following NAP4, a joint statement was published regarding eFONA in the setting of CICO. This explored the relative merits of securing the airway through the cricothyroid membrane for anaesthetists and non-head and neck surgeons, while accepting that, for surgeons experienced in tracheostomy, this might be expedient (Pracy 2016). A recent study suggested eFONA by suitably trained anaesthetists may be at least as prompt and effective at establishing an airway as surgeons who do not have a head and neck background (Groom 2019). In cases of anticipated difficult airway, where available, a surgeon experienced in tracheostomy is likely to be the optimal person to establish eFONA. Anaesthetists should be trained in eFONA and, despite its rarity, should be willing and able to undertake eFONA when a surgeon with specific expert skills is not available.

Unrecognised oesophageal intubation

NAP7 likely received six reports of unrecognised oesophageal intubation, two during the Activity Survey, three certain reports in the registry and a further probable one. Although all three definite cases of oesophageal intubation leading to cardiac arrest (unrecognised or delayed according to definition) survived the event, all experienced severe hypoxaemia and two came to significant harm. All were judged to be major and avoidable events.

These incidents were notable for failure to recognise a flat capnograph trace as an indication of failure of alveolar ventilation and the need to immediately remove the tube or to exclude oesophageal intubation. All cases progressed to hypoxaemic cardiac arrest. It is pertinent to remind readers that cardiac arrest is an insufficient explanation for a lack of sustained exhaled carbon dioxide (Chrimes 2022) both during CPR and for a prolonged period after it has ceased. Such an occurrence should lead to an assumption of oesophageal intubation and removal of the tube followed by mask or SGA ventilation, unless there is a clear reason not to do so (Chrimes 2022). Reasonably prompt tube removal in the cases reported to NAP7 probably prevented death, but earlier default removal might have prevented both cardiac arrest and the harms that did occur.

Although the harm occasioned by unrecognised oesophageal intubation is less than reported in NAP4 (2 deaths related to anaesthesia), the number of cases is not (three cases in NAP4). The problem remains a cause of avoidable patient harm.

Equipment

Although only two cases of cardiac arrest relating to airway equipment problems were reported, they were both avoidable. One would have been detected by a circuit check (Magee 2012) and the other by simple confirmation that the anaesthetic circuit and the airway to which it was to attach were compatible. Both would be considered basic standards of care. Circuit checks before anaesthesia for each case are essential and should be routine practice (Magee 2012). Similarly, confirmation of the ability to connect an in situ airway to the anaesthetic circuit should be sought before induction of anaesthesia. Tracheostomy sets should contain the appropriate connectors to facilitate ventilation with standard 15-mm anaesthetic circuits.

Debriefing and impact on staff

In NAP4, it was recommended that debriefing should be embedded in practice (Cook 2011). Failure to review cases is likely to mean that individuals and organisations will fail to identify key lessons and opportunities to improve patient safety. However, debriefs were infrequent (50%) after events that patients survived and common (88%) after death at the time of cardiac arrest. Several eFONAs were undertaken without subsequent debrief. Failure to debrief after such events misses opportunities to identify key lessons, share concerns and reinforce positive aspects of care (Cook 2011). Major airway events are potentially highly traumatic experiences for the anaesthetist and team involved and debriefing has much to recommend it (see Chapter 17 Aftermath and learning). Debriefing all such cases represents best practice regardless of outcome.

Has airway management become safer since NAP4?

NAP7 cannot answer the question whether airway management has become safer since NAP4 because of major differences in inclusion criteria, and also the passage of time, meaning that case mix and anaesthetic practices have changed. There are some themes evident in the cases reported to NAP7 which echo those from NAP4. These include the need for airway assessment, the need for an airway strategy and the high prevalence of head and neck surgery and patients with obesity in reports, but in all these regards the number of cases implicated is notably lower in NAP7 than in NAP4. Further, the decrease in cases of fatal aspiration, major problems with (particularly first-generation) SGAs and the low number of reports of eFONA are reassuring. In the context that the surgical population has become higher risk during this time (higher BMI, older and with more comorbidity), the findings can be considered reassuring. Finally, that among airway cases reported to NAP7 (in which cardiac arrest was an inclusion criterion), mortality was 18%, which is very similar to the 14% in all anaesthesia cases in NAP4 (in which multiple other criteria were included) is also reassuring.

Recommendations

National

- Airway managers should be aware of recently published guidance on unrecognised oesophageal intubation as a core component of safe airway management and adhere to it.

Institutional

- Infants and neonates should be recognised as a group at high risk of airway difficulty, during and after surgery and when critically ill. Departments should make provision for senior and expert airway care for such patients at all times of day and night.
- Institutions should ensure that the training facilities and time exist for anaesthetists to establish and maintain skills in eFONA.
- Regardless of outcome, all instances where airway management leads to cardiac arrest should be followed by debrief and departmental review.

Personal

- All anaesthetists should recognise that airway and respiratory management remains a major cause of perioperative cardiac arrest and engage in education and training that maintains and develops their airway skills, throughout their career.
- The airway of patients with obesity should be managed as high risk. This may involve avoidance of general anaesthesia but requires a strategy and consideration of the risks of composite airway failure and short safe apnoea time.
- Anaesthetists should treat cases of acute abdomen as high risk for aspiration, assess the extent of that risk and plan airway management accordingly. Each airway manager should decide which elements of RSI they wish to use and be prepared to justify their use or omission.
- Despite its rarity, anaesthetists need to establish and maintain the lifesaving skills of eFONA and be willing to use them promptly when needed, if a more specifically skilled surgical operator is not immediately available.
- Airway managers who are or may be involved in resuscitation of the critically ill child should maintain paediatric airway skills and knowledge of methods to prevent and manage hypoxaemia and airway difficulty in the critically ill child.
- Anaesthetists should be familiar with all the equipment they use and ensure both that anaesthetic circuits are working before use and that all elements of the circuit including the patient interface are compatible.

References

Birenbaum 2019: Birenbaum A, Hajage D, Roche S *et al* Effect of cricoid pressure compared with a sham procedure in the rapid sequence induction of anaesthesia. *JAMA Surg* 2019; 154: 9–17.

Brown 2021: Brown J, Gregson FKA, Shrimpton A *et al* A quantitative evaluation of aerosol generation during tracheal intubation and extubation. *Anaesthesia* 2021; 76: 174–81.

Chrimes 2022: Chrimes N, Higgs A, Hagberg CA *et al* Preventing unrecognised oesophageal intubation: a consensus guideline from the Project for Universal Management of Airways and international airway societies. *Anaesthesia* 2022; 77: 1395–415.

Cook 2016a: Cook TM. The cricoid debate: balancing risks and benefits. *Anaesthesia* 2016; 71: 721–2.

Cook 2016b: Cook TM, Woodall N, Frerk C. A national survey of the impact of NAP4 on airway management practice in United Kingdom hospitals: closing the safety gap in anaesthesia, intensive care and the emergency department. *Br J Anaesth* 2016; 117: 182–90.

Cook 2011: Cook TM, Woodall N, Frerk C. Major complications of airway management in the UK: results of the 4th National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1 Anaesthesia. *Br J Anaesth* 2011; 106: 617–31.

Cook 2012: Cook TM, MacDougall-Davis SR. Complications and failure of airway management. *Br J Anaesth* 2012; 109(Suppl 1): i68–85.

Cumberworth 2022: Cumberworth A, Lewith A, Sud H *et al* Major complications of airway management: a prospective multicentre observational study. *Anaesthesia* 2022; 77: 640–8.

Disma 2021: Disma N, Virag K, Riva T *et al* Difficult tracheal intubation in neonates and infants. NEonate and Children audiT of anaesthesia pRactice IN Europe (NECTARINE): a prospective European multicentre observational study. *Br J Anaesth* 2021; 126: 1173–81.

Endlich 2020: Endlich Y, Beckmann LA, Choi SW *et al* A prospective six-month audit of airway incidents during anaesthesia in twelve tertiary level hospitals across Australia and New Zealand. *Anaesth Intensive Care* 2020; 48: 389–98.

Engelhardt 2018: Engelhardt T, Virag K, Veyckemans F. Airway management in paediatric anaesthesia in Europe insights from APRICOT (Anaesthesia Practice In Children Observational Trial): a prospective multicentre observational study in 261 hospitals in Europe. *Br J Anaesth* 2018; 121: 66–75.

Fiadjoe 2016: Fiadjoe JE, Nishisaki A, Jagannathan N, *et al* Airway management complications in children with difficult tracheal intubation from the Pediatric Difficult Intubation (PeDI) registry: a prospective cohort analysis. *Lancet Respir Med* 2016; 4: 37–48.

Graciano 2014: Graciano AL, Tamburro R, Thompson AE *et al* Incidence and associated factors of difficult tracheal intubations in pediatric ICUs: A report from National Emergency Airway Registry for Children: NEAR4KIDS. *Intensive Care Med* 2014; 40: 1659–69.

Groom 2019: Groom P, Schofield L, Hettiarachchi N *et al* Performance of emergency surgical front of neck airway access by head and neck surgeons, general surgeons, or anaesthetists: an in situ simulation study. *Br J Anaesth* 2019; 123: 696–703.

Huitink 2020: Huitink JM, Cook TM. The epidemiology of airway management complications. In: Cook TM, Kristensen MS, eds. *Core Topics in Airway Management*, 3rd edn. Cambridge: Cambridge University Press; 2020. pp. 22–37.

Huitink 2017: Huitink JM, Lie PP, Heideman I *et al* A prospective, cohort evaluation of major and minor airway management complications during routine anaesthetic care at an academic medical centre. *Anaesthesia* 2017; 72: 42–8.

Kane 2023: Kane AD, Soar J, Armstrong A *et al* Changing patient characteristics, anaesthetic workload, and techniques in the UK: an analysis from the 7th National Audit Project (NAP7) Activity Survey. *Anaesthesia* 2023; 78; 7011–11.

Magee 2012: Magee P. Guidelines for Checking Anaesthetic Equipment: AAGBI 2012 guidelines. *Anaesthesia* 2012; 67: 571–4.

Morray 1993: Morray JP, Geiduschek JM, Caplan RA *et al* A comparison of pediatric and adult anaesthesia closed malpractice claims. *Anaesthesiology* 1993; 78: 461–7.

Nightingale 2015: Nightingale CE, Margarson MP, Shearer E *et al* Perioperative management of the obese surgical patient 2015: Association of Anaesthetists of Great Britain and Ireland Society for Obesity and Bariatric Anaesthesia. *Anaesthesia* 2015; 70: 859–76.

Oglesby 2022: Oglesby FC, Ray AG, Shurlock T *et al* Litigation related to anaesthesia: analysis of claims against the NHS in England 2008–2018 and comparison against previous claim patterns. *Anaesthesia* 2022; 77: 507–9.

Pedersen 2021: Pedersen TH, Ueltschi F, Hornshaw T *et al* Optimisation of airway management strategies: a prospective before-and-after study on events related to airway management. *Br J Anaesth* 2021; 127: 708–806.

Potter 2022: Potter T, Cronin N, Kua J *et al* Aerosol precautions and airway complications: a national prospective multicentre cohort study. *Anaesthesia* 2022; 78: 23–35.

Pracy 2016: Pracy JP, Brennan L, Cook TM *et al* Surgical intervention during a Can't Intubate Can't Oxygenate (CICO) Event: Emergency Front-of-Neck Airway (FONA)? *Br J Anaesth* 2016; 117: 426–8.

Priebe 2009: Priebe HJ. Cricoid pressure: an expert's opinion. *Minerva Anesthesiol* 2009; 75: 710–14.

Shaw 2021: Shaw M, Waiting L, Barraclough K *et al* Airway events in obese vs. non-obese elective surgical patients: a cross-sectional observational study. *Anaesthesia* 2021; 76: 1585–92.

Shrimpton 2021: Shrimpton AJ, Gregson FKA, Brown JM *et al* A quantitative evaluation of aerosol generation during supraglottic airway insertion and removal. *Anaesthesia* 2021; 76: 1577–84.

Woodall 2011: Woodall NM, Cook TM. National census of airway management techniques used for anaesthesia in the UK: first phase of the Fourth National Audit Project at the Royal College of Anaesthetists. *Br J Anaesth* 2011; 106: 266–71.