33 Cardiac arrest in critically ill children receiving anaesthetic care in non-specialist centres





Barney Scholefield
Fiona Oglesby
Jonathan Smith
John Pappachan
Tim Cook

Key findings

- Cardiac arrest in critically ill infants and children requiring resuscitation, stabilisation and intubation by district general hospital staff before transfer to a regional paediatric intensive care unit was an uncommon event, occurring every 1 in 160 cases.
- More than half of cases (7/13) were in children 6–15 years, compared with cardiac arrest in paediatric perioperative patients who were predominantly neonates and infants.
- The key contributory factors to cardiac arrest were the clinical condition or pre-existing co-morbidity of the patient in 75% and anaesthesia in 25%.
- There was a high mortality following cardiac arrest (5/13).
- Hypoxaemia and airway complications were the most frequent causes of cardiac arrest. Airway problems occurred in six cases and often involved composite failures.
- Senior anaesthetic staff were present for all cases, but more than half did not have regular paediatric anaesthetic sessions.
- Stabilisation and anaesthesia were delivered in multiple different locations within hospital.
- Examples of good communication and collaboration with regional paediatric critical care transport services were identified.
- Most cardiac arrests occurred out of hours.
- Long-term physical and mental health impacts on staff involved in cardiac arrest management were reported

What we already know

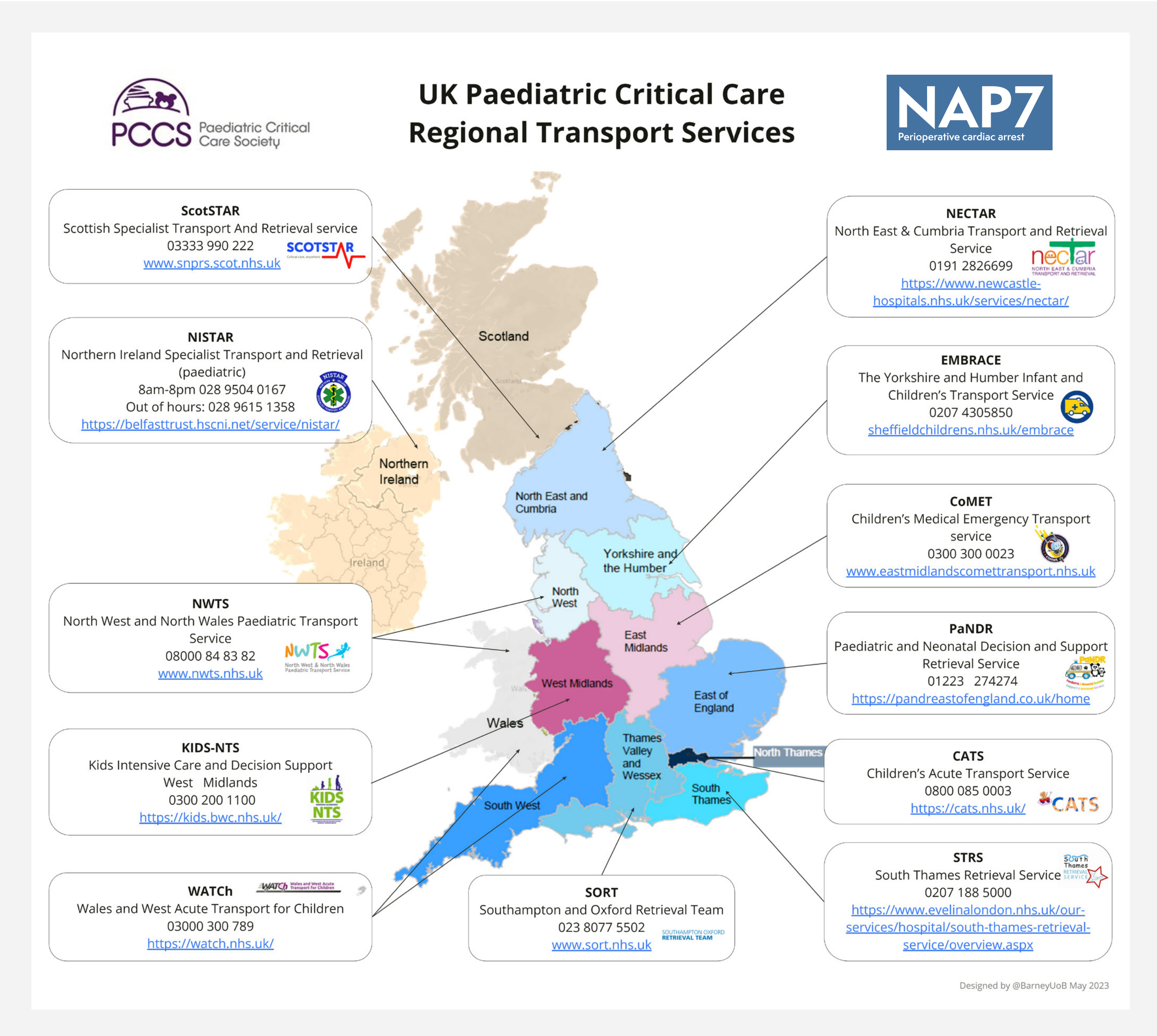
Annually, around 4,000–4,500 critically ill or injured infants and children require stabilisation and transfer to regional paediatric intensive care units (PICUs) in the UK (PICANet 2023). Initial resuscitation and stabilisation requires collaborative management by paediatricians, emergency physicians, anaesthetists, adult intensive care specialists, neonatologists and regional paediatric critical care transport teams. Medical advice, transfer and intensive care bed allocation is coordinated via 12 regional paediatric transport services in the UK (Figure 33.1).

The Royal College of Anaesthetists (RCoA), Association of Paediatric Anaesthetists of Great Britain and Ireland (APAGBI) and Paediatric Critical Care Society (PCCS) provide standards for provision and training of anaesthetic support for critically ill children in DGHs without on-site paediatric critical care services (RCoA 2023; PCCS 2021). More than 60% of these patients require airway interventions (eg tracheal intubation) performed by anaesthetists, neonatologists and adult intensivists before transport team arrival (PICANet 2023). However, following regionalised commissioning and provision of paediatric critical care services and specialist transport teams there have been concerns raised about continuing training and retention of paediatric skills and frequency of exposure to these high-risk patients by anaesthetists with infrequent paediatric practice in DGHs (Gilpin 2016, Morris 2022).

The Paediatric Intensive Care Audit Network (PICANet) collects data on patients requiring transport and PICU admission. In 2021, 4,396 non-elective patients were transported to a regional PICU. Of note, 25 patients deteriorated and were not transported, 11 died before the transport team arrival, 25 died while the transport team was present and 1 died during transport. In the same year, 7 (0.2%) patients were successfully resuscitated following a cardiac arrest after the arrival of the paediatric transport team (PICANet 2023). However, cardiac arrests occurring before the arrival of the paediatric transport team are not captured in this dataset.

Although the frequency of cardiac arrest and death during stabilisation of the sick child is low, the impact on individual patients and the teams providing care can be profound. Stakeholders and the NAP7 steering panel highlighted management of the critically ill child as a specific area of concern for anaesthetists working in nonspecialist hospitals, defined as those that admit children but do not have a paediatric intensive care unit. Cardiac arrest in the critically ill infant or child

Figure 33.1 Locations, names and contact details of 12 regional paediatric transport services in the UK



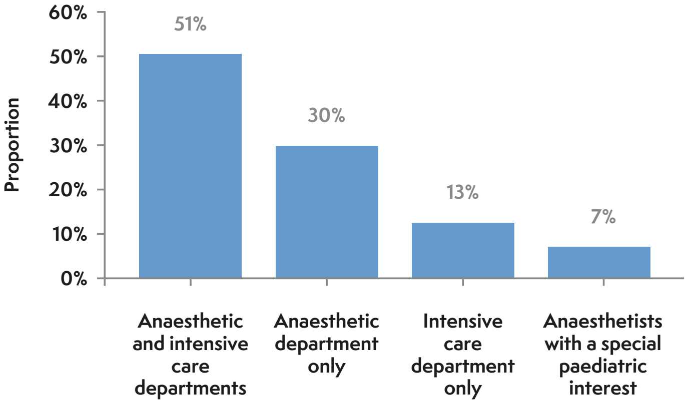
requiring anaesthetic or intensive care support before arrival of the retrieval team in a non-specialist hospital was therefore incorporated as a special inclusion criterion in NAP7 (Chapter 6 Methods).

What we found

As outlined in detail in the baseline organisational survey (Chapter 9 Organisational survey), 165 (84%) of 197 hospitals reporting to NAP7 admitted children and provided paediatric anaesthesia, of which 156 combined both paediatric and adult services and 9 paediatric anaesthesia care only. Only 21 (13%) of the 165 hospitals that admit children had a PICU, 78 (40%) hospitals had an on-site paediatric high-dependency unit and 101 (52%) hospitals a neonatal intensive care unit (NICU). Therefore 144 (87%) hospitals were defined as 'nonspecialist' and may need to transfer critically ill children to a tertiary centre for paediatric intensive care.

The stabilisation of critically ill children (in operating theatres, the emergency department or ward) before retrieval to a specialist tertiary children's hospital is managed by both the anaesthetic and intensive care team in 73 (51%) of 144 hospitals without a PICU, only the anaesthetic team in 43 (30%) hospitals, only the intensive care team in 18 (13%) hospitals and only by specialist anaesthetists with paediatric interest in 10 (7%) hospitals (Figure 33.2). However, specialist anaesthetists with a paediatric interest were available in 33 (23%) of 144 responding hospitals without a PICU.

Figure 33.2 Proportion of anaesthesia staff who provide stabilisation of children in hospitals without a PICU (n = 144) before retrieval to a specialist children's hospital



Anaesthetic involvement as part of stabilisation of the critically ill infant and child was not captured within the NAP7 Activity Survey but was a special inclusion criterion for reports to NAP7. Baseline denominator data are therefore estimated via the nationally reported data from PICANet for paediatric retrievals of critically ill children. However, definition and case inclusion differ slightly (eg some cases managed in a DGH may have died before a referral to a paediatric transport service occurred and are not captured by PICANet data; the PICANet definition of cardiac arrest only includes patients achieving return of spontaneous circulation (ROSC) and the period of PICANet data collection was January 2021 to December 2021).

Overall, NAP7 received reports of 13 cases of cardiac arrest in children receiving an anaesthetic during stabilisation for critical illness. This is approximately 0.3% (1 in 300) of the 4396 children referred to regional paediatric transport services in UK in 2021. Including only patients anaesthetised before arrival of a regional paediatric transport team as the denominator (n = 2056), the rate increases to 0.6% (1:160) cardiac arrests.

Of the 13 cases, eight were female, two were infants (28 days to 1), three were 1–5 years old and seven were 6–15 years. Three patients had COVID-19 and three had bronchiolitis with hypoxia; difficult ventilation was common. Capnography was used to confirm tracheal intubation and lung ventilation in 11 cases, a capnometer in 1 (infant) case and the question was not answered for 1 case. The time of cardiac arrest was recorded in 13 cases and all occurred before 09.00 or after 15:00 (00.00 to 09.00, n = 7; 15.00 to 24.00, n = 6): 11 of 13 cardiac arrests occurred 'out of hours'. Four patients were managed in the emergency department, four in theatre, two in recovery, two on the ward (one in a 'stabilisation room') and one each in the anaesthetic room.

An anaesthetic or intensive care consultant was present for all cases. The primary anaesthetist had regular paediatric anaesthetic commitments in five cases and did not in eight cases. Of 11 anaesthetists replying, 7 had undertaken advanced training in paediatrics and 4 had additional training such as a specific anaesthesia fellowship, although the latter did not always correlate with regular paediatric anaesthetic sessions. In 10 of 13 cases, at least two consultants were present at the time of arrest and in four cases three or more. In addition, a median of 2 (range 0 to 7) non-consultant-grade anaesthetic team members were present during the cardiac arrest. In most cases, additional consultant support from paediatrics, neonatology (if appropriate) and paediatric transport team personnel was also reported.

Induction of anaesthesia or tracheal intubation was required in 12 cases (1 was already intubated). A retrieval PICU paediatric drug sheet was used to guide drug dosing in 10 cases. In eight cases, the induction agent was ketamine, in two no induction agent was used in a patient who had already arrested, and in one case each midazolam and propofol were used. In the case in which propofol was used, the patient had a seizure and was not cardiovascularly unstable.

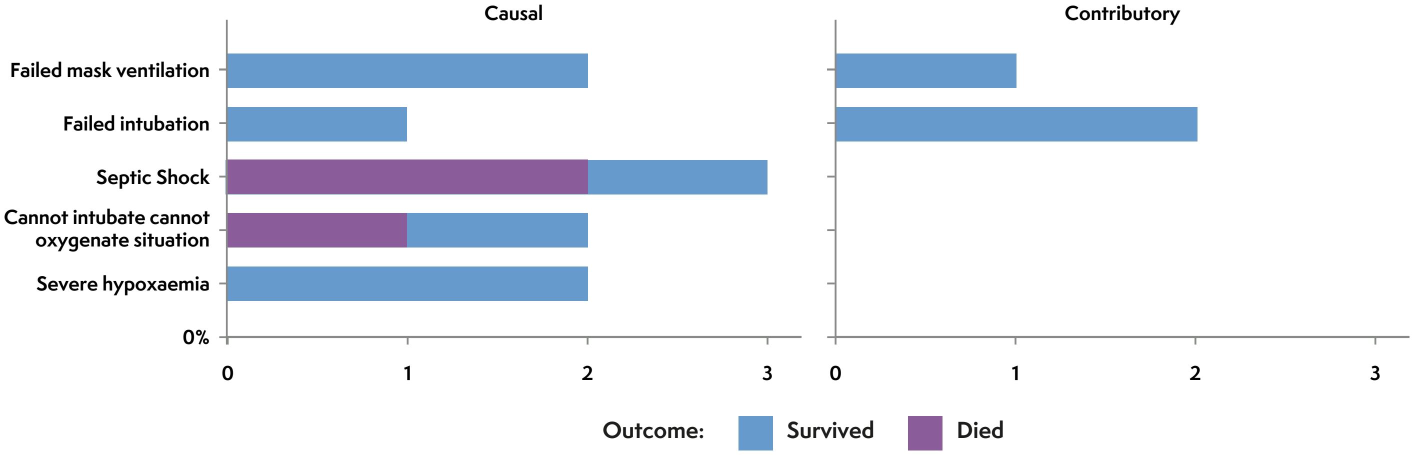
Unexpected events were notable for the number of airway events, including three cases of failed mask ventilation, three failed tracheal intubations, two cases of severe hypoxaemia and two cases of cannot intubate cannot oxygenate (Figure 33.3).

The initial rhythm during cardiac arrest was pulseless electrical activity in seven patients, bradycardia in four cases, asystole in one and unknown in one. No patients were in a shockable rhythm. All received cardiopulmonary resuscitation (CPR) and none defibrillation.

Adrenaline was given to 12 of 13 patients. In one case, glycopyrrolate was given for hypoxia associated bradycardia in a brief cardiac arrest. Calcium was given to six patients and bicarbonate was also given to five of these patients; all were more prolonged cardiac arrests. However, only one case had a clear indication (hyperkalaemia).

The most common reported causes (more than one might be attributed) of cardiac arrest were hypoxaemia, bradycardia and septic shock. Airway and respiratory causes included

Figure 33.3 Unexpected events in 13 cases reported to NAP7 of cardiac arrest in critically ill children before arrival of retrieval teams. More than one event may be attributed to a single case.



hypoxaemia, laryngospasm, tension pneumothorax, unrecognised oesophageal intubation and 'cannot intubate cannot oxygenate' (CICO). Metabolic causes included severe hyperkalaemia and severe acidaemia.

Duration of resuscitation was less than 10 minutes in six cases but prolonged (more than 20 minutes) in seven cases (Table 33.1).

Five patients died; four immediately following the cardiac arrest event and one within 24 hours.

The panel judged quality of care in 10 cases. Care before cardiac arrest was rated good in six cases and poor in one: this was as a result of failure to use waveform capnography leading to an unrecognised oesophageal intubation. Care during and after cardiac arrest was rated as good in all 10 cases reviewed and overall care as good in 6 and poor in 1.

Among the five deaths one was considered the result of an inexorable process, three partially and one not.

Debriefs were frequently performed or planned (in all five deaths and in five of seven survivors) and the practice appeared positively received.

There were reports of significant psychological impact on anaesthetic teams in some instances, including resulting in significant periods of time off work (see also Chapter 17 Aftermath and learning).

Table 33.1 Duration of resuscitation and survival at 24 hours

Duration (minutes)	Patients (*n*)	Survived (*n*)
< 10	6	6
10–19	0	–
20–29	2	1
30–39	1	0
40–49	0	–
50–59	2	0
60–120	1	0
> 120	1	0

An infant developed worsening respiratory distress secondary to viral bronchiolitis. Two anaesthetic consultants took the patient to the operating theatres to intubate. The patient desaturated after an initial unsuccessful intubation with size 4.0 mm cuffed tracheal tube and had a bradycardic cardiac arrest. CPR was required and intubation was successful with size 3.5 mm cuffed tracheal tube. Return of a spontaneous circulation was achieved within a few minutes and the patient transferred to the regional PICU.

Airway difficulties occurred in six patients with multiple problems in four cases. All led to hypoxaemia. 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 emergency front of neck airway. 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 ear, nose and throat (ENT) or other surgical team was involved, but a rather brief report was submitted so we cannot be certain. In a younger child, unpredicted difficulty in intubation was followed by failed rescue technique until successful intubation with a videolaryngoscope at the third attempt at intubation. Videolaryngoscopy was mentioned in two cases (both to rescue failed intubation) but its use was not a specific question in NAP7 documentation.

There were seven cases of cardiac arrest soon after induction. Some of these were airway and hypoxia related but several occurred in association with intravenous induction followed by cardiovascular collapse. The causation was complex but may have included some intubations at the point of cardiac arrest or after delay during which clinical deterioration occurred, and two included drug doses (but not drug choices) that may have contributed to cardiovascular arrest (eg higher dose of opioids, co-induction drugs, volatile anaesthetic drugs).

In 12 of 13 cases, the regional transport service was contacted before cardiac arrest. This occurred a median duration of 72 minutes (IQR 30–158 minutes) before the cardiac arrest event and in half of cases the transport service was contacted before the arrival of the anaesthetic/intensive care team at the bedside. The median duration between anaesthetic team attending the patients and cardiac arrest was 40 minutes (IQR 25–170 minutes). In 12 of 13 cases where induction of anaesthesia preceded cardiac arrest, the cardiac arrest occurred at a median 3.5 minutes (IQR 1–18 minutes) after the start of induction and in 10 cases this was within 2.5 minutes of induction. The time of arrival of the transport team was known in 12 of 13 cases. In two cases, the transport team attended more than one hour before cardiac arrest and worked collaboratively with the local anaesthetic/intensive care team. In these two cases, the cardiac arrest occurred three to four hours following induction of anaesthesia. In the remaining 10 of 12 cases, where the transport team arrived after cardiac arrest, the median time of arrival was 135 minutes (IQR 22–189 minutes) following the cardiac arrest event and a median 160 minutes (IQR 93–236 minutes) following initial first contact with the transport service.

The low frequency of cases prevented the identification of patterns relating to intra- or post-arrest care. However, the panel identified the following learning points across cases:

- The need for earlier recognition of the deteriorating child.
- The value of proactive teamwork and communication between paediatricians and anaesthetists, and local teams with regional paediatric transport services.
- Failure to use or correctly use assistive computer/telephone-based drug calculators resulting in miscalculation of drug doses.
- Selection of incorrectly sized equipment and inappropriate choice of location for delivery of anaesthesia (eg in paediatric ward side room rather than an ICU or theatre environment).

A child presented to a DGH in septic shock late at night. The resuscitation team consisted of consultants in emergency medicine, paediatrics and anaesthesia. Despite appropriate treatment of sepsis and pneumonia, the child deteriorated. By phone, the regional transport service advised intubation and ventilation using ketamine and rocuronium with a peripheral adrenaline infusion running. Five minutes following intubation the child had a cardiac arrest. Cardiopulmonary resuscitation was prolonged and was stopped following the arrival of the retrieval team. Return of a spontaneous circulation was never achieved and the child died. The whole team (including transport team) was supported via both hot and cold debriefs.

An older child with complex medical problems presented with sepsis and hypotension and rapidly deteriorated despite administration of intravenous fluid and inotropes. There was disagreement between teams about timing of intubation, with some wishing to delay for stabilisation. Tracheal intubation was not undertaken and the child deteriorated further and had a cardiac arrest, was intubated and had prolonged resuscitation but died.

Discussion

The call to assist in the management of a sick and deteriorating infant or child may be the most daunting and challenging one for the anaesthetic and intensive care team in a DGH but often involves advanced resuscitation, airway, vascular access and drug management that they hold the most expertise in. The RCoA, PCCS and Royal College of Paediatrics and Child Health acknowledge that the most experienced clinician available should be present to manage these cases, necessitating the involvement of anaesthetists and intensivists who may not routinely care for infants and children in their elective work but who possess the appropriate technical and non-technical skills (RCoA 2023; PCCS 2021). Care also relies on considerable high-pressure teamwork between senior clinicians who often do not work together and indeed may not have even met each other before.

It is a significant logistical challenge for DGHs to manage rotas to provide senior expert paediatric anaesthesia care for these high-risk cases. In the cases reported to NAP7, despite almost all occurring out of hours, almost all had had multiple senior anaesthetists, although far from all were regular paediatric anaesthetists. Efforts were generally made to move patients to safe or familiar areas for anaesthesia, but for some patients this was not possible because of the speed or extent of deterioration. Drug choices for anaesthetic induction were generally good, with ketamine used for the vast majority. An important lesson from NAP7 is that most cardiac arrests in critically ill children were not due to excessive drug dosing or post-induction hypotension but, rather, airway and respiratory causes were extremely prominent.

NAP7 is the first study to focus on the resuscitation and outcome of critically ill children in cardiac arrest managed by DGH anaesthetic staff. Thirteen children had a cardiac arrest with almost half not surviving. Although the numbers are low, when assessed within the context of delivery of anaesthetics to critically ill children, this occurred at a rate of approximately 1 in 160 anaesthetics; an event therefore common enough to require institutional and national awareness, preparation and training to prevent and manage.

Our reported rate is lower than previously reported and may represent an underestimation. In 2019, a North Thames and East Anglia-based observational study reported over a two-year period that 17 of 1,051 (1.6%; 1 in 62) patients intubated by DGH staff (89% anaesthetists) had a peri-intubation cardiac arrest (Matettore 2019). The PICANet national transport registry recorded variation and reduction in the annual number of cardiac arrests, when the transport teams were present, over the past three years (2019 *n* = 25, 2020 *n* = 12, 2021 *n* = 7; PICANet 2023). However, at the time the NAP7 study commenced, overall rates of hospital admission for severe childhood respiratory and invasive infections had significantly reduced, by up to 94% (Kadambari 2022), and admissions to paediatric intensive care remained 10% lower than pre-COVID-19 pandemic levels (PICANet 2023). The indirect and direct impact of public health measures during the COVID-19 pandemic are likely to have changed the population studied during NAP7 and future effects are uncertain. As cardiac arrest in this population was a 'special inclusion' for NAP7, it is also possible that a substantial number of cases have not been reported, but we have no way of determining this possibility.

The panel identified good practice, teamwork and collaboration between paediatric transport services, the local team managing the patient and within the local organisation. Only one case identified delay in referral to or arrival of a paediatric critical care transport team. The majority of cases were referred and had paediatric critical care specialist advice more than one hour before cardiac arrest, although in half of cases this was before arrival of the anaesthetic/intensive care team at the bedside and earlier referral to these teams may have been possible.
Two cases demonstrated good practice of combined, prolonged resuscitation by both the anaesthetic and mobile transport team before induction of anaesthesia. However, in the majority of cases, the transport team only attended the bedside two hours or later following the cardiac arrest (although an important exclusion criterion for NAP7 was that cardiac arrest cases that occurred after care was handed over to the transport team or the child had left the DGH were not included). These timings are similar to the national PICANet data, where 64% of transport teams are mobilised within 30 minutes, although the actual time to bedside within 60 minutes was achieved in only 27% and within one to two hours in 47% of retrievals (PICANet 2023). This highlights the importance of local teams remaining proficient in paediatric resuscitation and stabilisation in the critical stages of paediatric illness or injury.

Disagreement between management plans (eg in relation to timing of induction of anaesthesia) between paediatric transport services, paediatricians and anaesthetic/intensive care teams was uncommon. However, in the setting of rapidly deteriorating, unintubated, critically ill children, anaesthetists can be faced with a near-impossible 'catch-22' situation where anaesthesia and intubation is required for continued resuscitation to avoid cardiac arrest, but which may also precipitate cardiac arrest. Good teamwork, communication and debriefing between anaesthetists and specialist transport services are essential to try and manage these situations. These relationships are also essential to maintaining skills, training and feedback. Good examples of collaboratively run courses in stabilisation of the sick child, including simulation, or bespoke feedback training days exist and should be supported within training and CPD activities (eg RAPT: Regional Acute Paediatric Training Course; https://kids.bwc.nhs.uk/rapt-2). It is also important to note that the vast majority of children who are critically ill and managed in DGHs before transfer to regional centres do not experience the cardiac arrest that is the focus of NAP7 and this is an important and reassuring finding. Box 33.1 provides a brief list of key principles that might usefully be applied to resuscitation and stabilisation of the critically ill child or infant.

Team management and leadership during a paediatric cardiac arrest in a DGH is an infrequent and unfamiliar task with a high risk of cognitive overload. In addition to resuscitation training, cognitive aides can help to reduce error and improve performance. Intubation checklists, equipment-size calculators, drug calculators and resuscitation algorithms are all useful cognitive aides. One case identified deviation from recommended drug dosing and equipment selection, which may have been preventable if cognitive aides had been used. Institutions should ensure access to and training on internet or paper-based resources (often provided by regional transport services and accessed via websites; Figure 33.1) for rapid support during emergency events. Such aids to drug dosing were used in 11 of 13 cases reported to NAP7. However, research is urgently needed to identify best practice, ideal format of cognitive aides, and how the transport services can best support teams remotely.

A strong theme of moral injury and professional impact of these cases was apparent through the anonymous reporting system and panel discussions. Psychological support, debriefing, peer support and continual education and input between paediatric critical care specialists and DGH staff are likely to represent best practice. We report elsewhere that cardiac arrests involving children, emergencies or with a fatal outcome are all associated with psychological impact on care providers and the critically ill child is likely to be a high-risk case for such second victim impacts (Chapter 17 Aftermath and learning).

Box 33.1 Key points for resuscitation of sick infants and children

1. Use a drug/equipment calculator (eg local retrieval team drug calculator) and two-person check to reduce cognitive load.
2. Two consultants should ideally be involved in the anaesthesia and intubation of the critically ill child.
3. Use the most experienced local resource whether from adult intensive care, anaesthesia, neonatology or paediatrics.
4. Where possible, induce anaesthesia in a safe and familiar environment.
5. Use full monitoring including waveform capnography.
6. Anaesthesia induction with IV ketamine and rocuronium is recommended.
7. Avoid the use of propofol and volatile anaesthetic drugs in sick children.
8. If the patient is unstable, have weight-specific dilute adrenaline and volume preprepared (use local retrieval team drug calculator).
9. If the patient is unstable, have peripheral adrenaline infusion preprepared (use local retrieval team drug calculator).
10. Use a (downsized) cuffed tracheal tube.
11. Anticipate hypoxaemia and airway difficulty, manage early and actively and be prepared to call other specialties for assistance.
12. Consider non-accidental injury and metabolic diagnoses (eg measure plasma ammonia).

Particularly for the neonate and child with potential or actual congenital heart disease:

13. Follow the ABCD and prostaglandin E2 (eg Prostin®) infusion approach (ABCDP).
14. Do not deny a child oxygen unless the circulation is unresponsive to ABCDP (patient circulations in which high concentrations of oxygen unbalance the circulation by increasing pulmonary blood flow at the expense of systemic blood flow are rare).
15. Measure before (right arm) and after (left foot) oxygen saturations in neonates.
16. Consider differential diagnosis of a collapsed neonate (eg Use SCAMS: sepsis, cardiac, abuse, metabolic, seizures or another suitable acronym).

Recommendations

National

- There should be provision of training programmes in care of the critically ill or injured child suitable for teams in DGHs.
- There should be a standardised approach within NHS retrieval service networks for emergency drug dosing calculators and guidance for appropriate equipment size for critically ill or injured infants and children.

Institutional

- Institutions should ensure adequate staffing, training and resources to provide 24/7 consultant anaesthetic availability for emergency anaesthesia of critically ill or injured infants and children.
- Institutions should support rotas and collaborative working to enable the most experienced local team members to support infant and child resuscitation, which may involve general intensivists, anaesthetists, neonatologists and paediatricians.
- Institutions should provide regular training for multidisciplinary teams in the care of the critically ill infant or child, including allied health professional, nursing and physician input from paediatrics, neonatology, transport medicine, anaesthesia and intensive care.
- Institutions should provide access to and resources for psychological support for all staff involved in care of the critically ill infants and children.

Individual

- Airway managers who are or maybe 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.
- Resuscitation of the critically ill infant or child requires use of the most experienced local resource whether adult intensivist, anaesthetist, neonatologist or paediatrician.
- Individual consultants should insist on holding a debrief and morbidity and mortality review in the event of a cardiac arrest, whatever the outcome.

Research

- There is a need for research on the best cognitive aids, calculators, aide memoires, or remote support (eg telephone or video link) for paediatric cardiac arrest resuscitation by teams in DGHs.

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