



Peri-operative cardiac arrest in children as reported to the 7th National Audit Project of the Royal College of Anaesthetists

Operative cardiac arrest in children as reported to the 7th National Audit Project of the Royal College of Anaesthetists

Oglesby FC, Scholefield BR, Cook TM, Smith JH, Pappachan VJ, Kane AD, Armstrong RA, Kursumovic E, Soar J. Peri-operative cardiac arrest in children as reported to the 7th National Audit Project of the Royal College of Anaesthetists. *Anaesthesia*. 2024 Jun;79(6):583-592. doi: 10.1111/anae.16251. Epub 2024 Feb 18. PMID: 38369586.

The focus for the 7th National Audit Project (NAP7) was perioperative cardiac arrest. This paper by Oglesby and colleagues synthesizes the paediatric data from NAP7, highlighting risk factors and management practices in the United Kingdom. Of note, 62% of cases were assessed to have had 'good' quality of care, suggesting scope for improvement in the remaining cases. Review of the major findings invites reflection on these themes in the Australian and New Zealand context.

Methods

All NHS hospitals undertaking anaesthesia care in the UK were invited to participate. Data collection included a baseline survey of anaesthesia departments, 4-day activity survey (extrapolated to provide denominator data), and a 12-month prospective registry of perioperative cardiac arrests. Critically ill children undergoing anaesthesia before retrieval to tertiary centres were also included. Multidisciplinary peer review allowed qualitative analysis of events surrounding arrests.

Key Findings

- Incidence: Cardiac arrest occurred in 3 per 10, 000 paediatric cases
- Mortality: Immediate mortality rate was 17%
- Setting: 85% of cases occurred in tertiary paediatric hospitals, with 39% occurring postoperatively, primarily in paediatric ICUs.
- Precipitating events: severe hypoxaemia (22%), bradycardia (11%), and major haemorrhage (8%). Tamponade and isolated severe hypotension were important precipitants in cardiac surgery and cardiac interventional procedures.

Major themes:

• Patient factors

Highest incidence occurred in neonates, infants and children with congenital heart disease (CHD). 86% of arrests occurred in children with ASA 3 or higher. Authors noted that ASA status was under-scored in 5.8% of cases, a trend also observed in the adult data.

• Surgical factors

Majority of arrests were associated with non-elective procedures, particularly in cardiac surgery (29%), ENT (13%), interventional cardiology (12%), and lower gastrointestinal surgery (11%).

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- **Anaesthetic factors**

The authors reported several modifiable anaesthetic factors, including inappropriate dose intravenous induction agents in hemodynamically compromised patients and high concentration volatile agents at induction. There were several cases in which bradycardia requiring chest compressions was treated with atropine or glycopyrrolate instead of adrenaline.

Monitoring was also cited as an issue, including lack of basic monitoring at induction, and inadequate monitoring during interventional cardiac procedures in patients with known CHD. In their discussion, the authors recommend early invasive BP (IBP) monitoring, with a second/additional IABP line if prolonged periods without access to an IBP placed by the proceduralist is anticipated. This recommendation is not without controversy. In practice, higher risk patients (neonates and infants with CHD) often present the greatest technical challenge and vulnerability to associated risks of IABP insertion.

- **Airway management**

Airway events were a major cause for postoperative arrests in PICU and NICU, including ETT dislodgement or obstruction, highlighting the importance of focused patient handover, and rescue airway plan.

Authors made comment on gaps in preparedness for paediatric airway emergencies, with 15% of departments lacking access to advanced paediatric airway equipment (e.g. video laryngoscopes) in all anaesthetising locations.

- **Training and Education**

While 94% of cases had a consultant present at induction, only 66% of anaesthetists had up-to-date paediatric advanced life support training, compared to 90% in adult cases. Centralisation of specialist paediatric services and the need for focused education for those not routinely anaesthetising children were noted as challenges.

Conclusion

The NAP7 findings underscore the importance of risk stratification, early appropriate monitoring, and appropriate drug selection and dosing in paediatric anaesthesia. The results are relevant to practitioners in Australia and New Zealand, particularly regarding the management of high-risk groups. The authors raise some contentious points regarding invasive blood pressure monitoring in patients undergoing interventional cardiology procedures.

Reviewed by Dr Heather Patterson

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The relationship between gastric ultrasound findings and endoscopically aspirated volume in infants and determining the antral cutoff value for empty stomach diagnosis

Sever F, Özmert S, Dereci S. The relationship between gastric ultrasound findings and endoscopically aspirated volume in infants and determining the antral cutoff value for empty stomach diagnosis. *Paediatr Anaesth.* 2024 Jun;34(6):532-537. doi: 10.1111/pan.14776. Epub 2023 Oct 10. PMID: 37814933.

This single centre, prospective observational study, performed in a paediatric endoscopy unit between November 2021 and June 2022 examines the relationship between ultrasound measured gastric antrum cross-sectional areas (CSAs), and volumes aspirated by endoscopic suction. It aims to determine a cutoff for antral CSA that correlates with empty stomach diagnosis and assess the utility of a three-point qualitative grading system for identifying the “at risk” stomach.

46 children <2 years, fasted to standard guidelines for age, ASA I or II, undergoing elective gastroscopy were recruited. All children were lightly sedated to tolerate examination whilst maintaining spontaneous ventilation.

A single experienced operator undertook ultrasound of the gastric antrum in supine and right lateral decubitus (RLD). Antral CSA, and gastric contents were assessed. Gastroscopy was then undertaken. All gastric content was aspirated under direct vision and recorded. The 3-point grading system stratified patients as Grade 0 for empty appearances in supine and RLD, Grade 1 for gastric content seen in RLD only, Grade 2 for gastric content seen in both supine and RLD.

- Significant correlation was found between aspirated gastric volume and RLD CSA (p 0.003), but not for supine CSA.
- Mean aspirate was 0.13 ± 0.22 ml/kg, indicating all patients had aspirates below the volume considered at risk for paediatric patients (1.25 ml/kg).
- Optimal CSA cutoff for an empty antrum was determined by Youden’s Index as <2.40 cm², measured in RLD (sens 100% spec 68.6%).
- The grading system classified patients as Grade 0- 76.1%, Grade 1- 23.9%, and Grade 2- 0%. Patients with a Grade 0 antrum had minimal or no gastric aspirate (median 0.0 ml/kg; 0.0-0.09 IQR; sig $p < 0.001$). Those with Grade 1 antrum had significantly higher CSA when measured in RLD compared with supine.

Discussion points:

This was a small study, but findings are in keeping in with similar work. RLD CSA measurement predictably correlates better than supine CSA for aspirated gastric volume. Findings suggest that measurement of supine CSA alone has limited diagnostic value. A CSA of 2.40 cm² measured in RLD is 100% sensitive for diagnosing an empty stomach, allowing the assessing anaesthetist to

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confidently treat as fasted. However, where CSA is greater a more detailed assessment including mathematical formulae is advocated.

The grading system provided additional information on gastric “fullness” and should be used in conjunction with RLD CSA measurement to assist in decision-making.

ASA III and above children were excluded. This limits extrapolation as these groups will be more likely to have conditions or take medications altering gastric motility. Further research is needed in this area and this group may benefit most from gastric ultrasound.

Take home Message:

This study demonstrates that gastric ultrasound can be used to safely identify fasted and “at risk” stomachs and avoid unnecessary cancellation or intubation.

Given that co-operation can be challenging, isolated measurement of antral CSA taken in RLD can be used to confirm fasted state, but additional measurements and grading can add to operator confidence. A note of caution- the operator in this study was highly experienced in imaging techniques, but those of us less experienced with gastric ultrasound may need to upskill prior to committing to anaesthesia based on our ultrasound findings alone, limiting the generalisability of this study.

Reviewed by Dr Aisling Gormley

Development and Validation of a Nomogram for Predicting Heparin Resistance in Neonates and Young Infants Undergoing Cardiac Surgery

A Retrospective Study

Gao P, Zhang Y, Jin Y, Zhang P, Wang W, Liu J. Development and Validation of a Nomogram for Predicting Heparin Resistance in Neonates and Young Infants Undergoing Cardiac Surgery: A Retrospective Study. *Anesth Analg*. 2024 Jun 1;138(6):1233-1241. doi: 10.1213/ANE.0000000000006507. Epub 2023 May 22. PMID: 37216291; PMCID: PMC11081478.

Summary:

This study describes the development of a simple, predictive nomogram using pre-operative variables for heparin resistance in neonates and young infants undergoing cardiac surgery.

Methods:

Heparin resistance was defined as the failure to achieve an ACT of 410 seconds or greater after the administration of 400U/kg heparin. In this single-centre retrospective study of 296 patients,

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patients were divided into a development cohort (70%), and a validation cohort (30%). The development cohort was used to identify predictors of heparin resistance and to establish a nomogram, whilst the validation cohort was used to test the efficacy of the nomogram.

Key Findings:

The predictors of heparin resistance were identified as:

- Antithrombin activity
- Platelet count
- Fibrinogen level

Using these 3 factors, the prediction model achieved an area under the receiver operating characteristic curve of 0.88 and 0.87 in the development and validation cohorts, indicating the clinical utility of the prediction model. The model performed well in both neonatal and infant sub-groups.

Discussion:

The authors present a simple to use clinical tool that can be used pre-operatively to identify young patients at risk of heparin resistance. The authors argue that their nomogram may help to tailor the heparin dose to the patient, thereby avoiding “over-anticoagulation” (which may lead to heparin rebound and post-operative bleeding) as well as “under-anticoagulation” (which may result in repeated dosing and prolonged overall operative time). They did not provide suggestions for tailored anti-coagulation management, or a threshold for the risk score to trigger active management.

Apart from the usual limitations of a small, single centre, retrospective study, there were several other limitations. First, baseline ACT values were not measured, so the heparin sensitivity index (a more robust method of determining heparin responsiveness) could not be calculated. Second, the authors tried to identify as many “potential predictors” of heparin resistance as possible in the initial stage of the study, before the final three (listed above) were selected. This increases the type I error, or likelihood of a false positive error. Finally, heparin resistance is commonly defined as an ACT >480s. In this study, it was defined as ACT >410s due to differences in their assay equipment and technology, thereby reducing the external validity of their result.

Reviewed by Dr Marlene Johnson

Inverse ratio ventilation versus conventional ratio ventilation during one lung ventilation in neonatal open repair of esophageal atresia/tracheoesophageal fistula

A randomized clinical trial

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Youssef AM, El-Ozairy HS, El-Hennawy AM, Amer AM. Inverse ratio ventilation versus conventional ratio ventilation during one lung ventilation in neonatal open repair of esophageal atresia/tracheoesophageal fistula: A randomized clinical trial. Paediatr Anaesth. 2024 Apr;34(4):332-339. doi: 10.1111/pan.14836. Epub 2024 Jan 8. PMID: 38189583.

Rationale

This study is based upon the practice of inverse ratio ventilation (IRV) used in ARDS (acute respiratory distress syndrome) to improve oxygenation and lung function. IRV can be used to prevent alveoli collapse through constant maintenance of lung inflation by increasing inspiratory time, reducing airway pressure and elevating mean airway pressure.

In neonates with oesophageal atresia/tracheoesophageal fistula, it is thought that a ventilation strategy that can maintain oxygenation during one lung ventilation phase of their open thoracotomy surgery can reduce hypoxemia, reduce surgery time and reduce the incidence of surgery being paused due to oxygenation issues. Potential IRV downsides include air entrapment (auto-PEEP), barotrauma, volutrauma, air leaks, decreased venous return and increased pulmonary vascular resistance.

Design

This is a single centre, prospective, blinded study comparing conventional ratio ventilation (CRV) using I:E (inspiratory : expiratory) ratio of 1:2, with inverse ratio ventilation (IRV) using I:E of 2:1 in a sample of 40 term neonates undergoing open right thoracotomy to repair oesophageal atresia / tracheoesophageal fistula in a paediatric hospital in Cairo, Egypt.

The study was approved by their local medical ethics committee and potential participants' parent / guardian was approached for consent. Exclusion criteria were:

- prematurity ≤ 36 weeks
- low weight < 2.5 kg
- age > 28 days
- significant congenital heart disease including cyanotic heart disease
- single ventricle pathology, large intracardiac defect with significant left to right shunt
- severe pulmonary hypertension more than 50 mmHg
- pneumonia or severe chest infection prior to the surgery and parent/guardian refusal

Of the 47 potential participants, 40 were successfully recruited and allocated using a 1:1 ratio randomly using a computer-generated list sealed in opaque envelope. The sample size of 20 per arm of study gives 83% power to detect difference between group proportions of 0.4.

All participants were cared for in a comparable way at a neonatal intensive care unit preoperatively under neonatologist guidance; had standardised anaesthesia monitoring including pre-ductal and post-ductal pulse oximetry; standardised anaesthesia medication and maintenance aims specifically keeping FiO₂ at lower limit to keep preductal saturations $\geq 92\%$ with minimum FiO₂ of 0.3; mechanically ventilated with SIMV-PCV (synchronised intermittent

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mandatory ventilation-pressure controlled ventilation) peak inspiratory pressure (PIP) 10–15 cmH₂O above positive end-expiratory pressure (PEEP) of 5 cmH₂O to achieve expired tidal volume (VTE) from 7 to 10 mL/kg, respiratory rate (RR) ranging from 30 to 50 breath/min to achieve end-tidal CO₂ (EtCO₂) from 30 to 40 mmHg, and pressure support (PS) 12 cmH₂O; and operated on by the same paediatric surgical team.

Results

The IRV group experienced 13 desaturation episodes, needed lower FiO₂ and had shorter operative time of 113 ± 18 min (range of 97–150 min); compared with the CRV group with 38 desaturation episodes and operative time 130 ± 29 min (range of 80–170 min). There were no significant differences in other complications between the two groups, and no major complications were noted. The authors concluded that IRV may have a role in decreasing incidences of hypoxemia for neonates undergoing open repair of oesophageal atresia/tracheoesophageal fistula.

Take Home Message

This small study adds to the paucity of neonatal intraoperative literature surrounding IRV use and is based upon acceptable ventilation strategy in intensive care setting. The authors discussed limitations of the study including potential inaccuracy of estimating PaO₂ from SpO₂ as arterial lines were not used, not confirming exact position of endotracheal tube using bronchoscopy, small sample size and lack of similar neonatal studies to compare results with.

Personally, I ponder whether IRV results would be affected by other variables such as type of ventilator used and surgical techniques (e.g. thoracoscopic rather than open approach), and whether use of cerebral oximetry to further inform on the perfusion state of the patient will be more useful rather than hypoxemia as an outcome measure. Although I would not convert to use IRV as a routine, in the neonate who is difficult to ventilate and oxygenate using CRV, I will be more likely to seek advice and help from my NICU (neonatal intensive care) colleagues to institute IRV/oscillator ventilation as an alternative strategy.

Reviewed by Dr K C Law

Comparison of the efficacy of intranasal atomised dexmedetomidine versus intranasal atomised ketamine as a premedication for sedation and anxiolysis in children undergoing spinal dysraphism surgery

A randomized controlled trial

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Hebbar K C, Reddy A, Luthra A, Chauhan R, Meena SC, Tripathi M. Comparison of the efficacy of intranasal atomised dexmedetomidine versus intranasal atomised ketamine as a premedication for sedation and anxiolysis in children undergoing spinal dysraphism surgery: A randomized controlled trial. *Eur J Anaesthesiol.* 2024 Apr 1;41(4):288-295. doi:10.1097/EJA.0000000000001936. Epub 2023 Dec 14. PMID: 38095481.

Study type:

This is a prospective randomised double-blind trial in a single paediatric tertiary centre.

Methods:

64 children aged 1 to 10 years old referred for elective spinal dysraphism surgery were randomly allocated to the intranasal atomised dexmedetomidine (2.5mcg/kg) or intranasal atomised ketamine (5mg/kg) groups. Premedication was given 30min before surgery. The primary outcome was the level of sedation (using the University of Michigan Sedation Score). Secondary outcomes included ease of parental separation, intravenous cannulation, satisfactory mask acceptance and perioperative vitals.

Findings:

Better sedation was achieved in the dexmedetomidine group (UMSS 1.55 +/- 0.51 vs 1.13 +/- 0.34 at 20min; 2.32 +/- 0.6 vs 1.94 +/- 0.5 at 30min). There was no difference in ease of separation, cannulation and mask acceptance between the 2 groups. Heart rate was lower in the dexmedetomidine group at 10, 20 and 30 min but without clinical significance.

Take home message:

- Relevance of the study
 - a. Perioperative anxiety is a growing issue with some studies reporting up to 60% of patients being anxious in the immediate preoperative period.
 - b. Ketamine and dexmedetomidine are amongst the drugs widely used as premedication.
 - c. Focus on intranasal administration of these 2 drugs using a new device improving drug delivery.
- Recent research, evidence or study on the subject

2 papers per month published over the last 15 months on perioperative anxiety in children and premedication, exploring different drugs, ways of administering them, for different procedures, as well as effects on patient anxiety, clinical side effects (dynamic and respiratory) or organisational impact (staff, length of stay in PACU or before discharge).
- Strengths of the study
 - a. Robust methodology (prospective randomised double-blind trial)
 - b. Investigation of the haemodynamic effects of dexmedetomidine
 - c. Well-designed trial, including power calculation, statistical analysis and recruitment targets were achieved.
 - d. Use of the mucosal atomisation device allowing a more efficient administration of intranasal premedication.

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- Limitations of the study
 - a. Clinical relevance of the difference in UMSS found between the 2 groups. Although dexmedetomidine provides a statistically significant difference in terms of sedation compared to ketamine, there was no difference observed in terms of ease of parental separation, cannulation or mask acceptance.
 - b. Authors didn't use the modified Yale Preoperative Anxiety Scale (usually considered as the gold standard for pre-operative anxiety evaluation).
 - c. Authors' self-declared limitations: single centre study with small sample size, absence of age stratification, baseline anxiety of the patients

- Applicable to our practice?

Yes, these results should be easily transferrable to other procedures and hospitals. Having robust data on the intranasal use of ketamine and dexmedetomidine is useful in children with behavioural issues likely to spit out any drug given orally.

Reviewed by Dr Ben Blaise

Awake caudal anesthesia in ex-premature infants undergoing lower abdominal surgery

A narrative review

Frawley GP, McCann AJ. Awake caudal anesthesia in ex-premature infants undergoing lower abdominal surgery: A narrative review. Paediatr Anaesth. 2024 Apr;34(4):293-303. doi: 10.1111/pan.14830. Epub 2023 Dec 26. PMID: 38146668.

It is well known that ex-premature infants are a high risk patient group, particularly with regard to perioperative apnoea. A question that is front of mind for most paediatric anaesthetists is "how can we use regional anaesthesia safely and effectively to improve outcomes for this vulnerable group of patients?"

We know that spinal anaesthesia for infant hernia repair compared to GA is associated with a lower risk of apnoea, however it does have an appreciable failure rate. Additionally, for success it requires a relatively short surgical time and, although not necessarily borne out in the literature, many clinicians feel that there is a learning curve involved in performing spinals in this group. Awake caudal anaesthesia is proposed as a potential solution to these limitations.

The aim of this narrative review was to determine, from the available literature, whether awake caudal anaesthesia is a feasible and reliable procedure with low complication rates in ex-prem infants having abdominal surgery.

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The authors (both with significant knowledge and experience in awake regional techniques) concluded that there was insufficient evidence to validate or refute the benefits of the use of awake caudal anaesthesia in premature and ex-prem infants.

The overall quality of the data was poor, with 45 reports analysed in total, including 8 RCTs as well as non-randomised prospective and retrospective series. There was significant heterogeneity and incomplete data reporting, overall preventing a systematic review.

The review included 558 (36%) cases of awake caudal, 837 (54.1%) cases of “awake” caudal with sedation and 153 (9.9%) cases of combined spinal caudal epidural (CSEA) without sedation.

Main findings:

- 1) Marked variability in approaches to “awake” caudal anaesthesia. Original description of awake was using no sedation, but more recently the technique seems to involve sedation for initiation and/or throughout (for example with sevoflurane, propofol or dexmedetomidine)
- 2) Slow onset of surgical anaesthesia (although only 35% of papers reported onset times)
- 3) Overall failure rates and perioperative apnoea rates were considered high:
 - Failure rates were highest for CSEA (13.7%), intermediate for awake caudal (6.6%) and lowest for “awake” caudal with sedation (5.85%). Non-significant differences.
 - The incidence of perioperative apnoea was highest for “awake” caudal with sedation (8.16%), intermediate for awake caudal (7.62%) and lowest for CSEA (5.53%). These differences were not significant.
- 4) It was noted that large doses (often more than the maximum recommended) of local anaesthetic was common and there was a significantly higher rate of high spinal blocks in the larger series.

Reviewed by Dr John Burnett

Edited by Dr Su May Koh

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