Anesthetic management of common pediatric emergencies

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Purpose of review
To keep pediatric anesthesiologists up-to-date in their management of pediatric emergencies by identifying the key publications from 2012 that are relevant to the anesthetic management of common pediatric emergencies.

Recent findings
Little has been published about specific pediatric emergencies. A large multi-institutional audit of tracheo-esophageal fistula demonstrated a wide range of anesthesia practice and a difficulty with ventilation on induction in 7% of cases. Large audits of bronchoscopy for foreign body have also demonstrated a variety of effective practices with a low complication rate. More generally, studies have increasingly demonstrated that postoperative pain may be substantial after many common procedures including some emergency surgery. The management of the full stomach remains controversial and the use of ultrasound to assess gastric volume is promising but unproven. Recent guidelines for resuscitation have been published. It is increasingly recognized that meticulous management of pediatric brain injury is vital, and although the evidence base is very weak, a more coherent anesthetic approach is emerging.

Summary
Many areas of the management of pediatric emergencies remain controversial and based on little good evidence. In spite of this, the complication rate is low. Postoperative pain is an emerging problem while the optimal management of the full stomach is still unresolved.

Keywords
bronchoscopy, emergency surgery, pediatric anesthesia, pediatric resuscitation, pediatric trauma, postoperative pain, tracheo-esophageal fistula

INTRODUCTION
There are a variety of pediatric emergencies that require anesthesia. Recent publications cover a range of topics and conditions. This is not an exhaustive review of all aspects of anesthesia management for all pediatric emergencies. In keeping with the aim of the journal, this review will only highlight and discuss the articles published in 2012 and early 2013 that are informative and relevant to a variety of aspects of the anesthesia management of pediatric emergencies.

An excellent and broad review of pediatric emergencies has been recently published by Rob McDougall in Anesthesia [1]. The review is aimed at the anesthesiologist working at a district general hospital that may be called to assist with or manage a pediatric emergency. It covers airway and respiratory emergencies, status epilepticus, the acute abdomen in the newborn, intussusception, the bleeding tonsil, trauma and burns.

PAIN AFTER EMERGENCY SURGERY
An emerging theme in the pediatric anesthesia literature is a greater interest in the management of postoperative pain, especially for ambulatory or what is usually regarded as less invasive surgery. This issue is not new [2]. In older children, one of the commonest emergency procedures is laparoscopic appendectomy. Several studies have compared pain in open versus closed appendectomy and it is usually accepted that laparoscopic surgery leads to faster recovery; however, a single centre retrospective...
cohort study by Tomecka et al. [3*] found that children having laparoscopic appendectomy still had significant postoperative pain. In their hospital, one-third of the children had substantial postoperative pain on the day of surgery, and a fifth on the day after surgery. Substantial pain was defined as a score of at least 4 out of 10, for more than 60% of the time on that day. Most children were prescribed pro re nata acetaminophen or a NSAID and an opioid, with only 11% having patient-controlled analgesia.

In the same issue of Pediatric Anesthesia, Stewart et al. [4] investigated pain after tonsillectomy, orchidopexy and hernia repair. Although not usually regarded as emergencies, the article once again found that we need to improve our management for pain after some surgeries. Inguinal hernia repair was associated with minimal pain, and most children having orchidopexy had minimal pain except for a few on the first postoperative day. In contrast, tonsillectomy was associated with substantial pain in the majority of children for up to 7 days.

Several techniques have been proposed to reduce postoperative pain. The commonest technique is perhaps giving a strong opioid towards the end of surgery. This is certainly effective for immediate pain, but is not without unwanted side-effects and a single dose does not provide long-lasting analgesia. For example, Tomecka et al. [3*] found that intraoperative morphine reduced pain in PACU after laparoscopic appendectomy, but, as would be expected, there was no evidence for an effect thereafter. Regional blockade has also been suggested, but once again, the greatest effect is seen in the early recovery period. The transversus abdominus plane (TAP) block is a relatively new technique that may reduce pain after abdominal surgery. An excellent recent review summarizes the current experience in children [5]. The review discusses three relevant randomized trials. The first trial by Carney et al. [6] found that TAP block reduced morphine consumption by up to 50% in the first 48 h. However, Sandeman et al. [7] found no evidence for a difference in morphine consumption after laparoscopic appendectomy. Lastly, Fredrickson et al. [8] compared TAP and ilioinguinal block for inguinal hernia repair and found more pain in the group randomized to TAP block. In summary, TAP blocks may be promising for some abdominal surgery, but there is still a need for effective analgesia when the block subsides.

Stewart et al. [4] highlighted that for some procedures, considerable pain persists after discharge home. For these cases, effective analgesia needs to be provided by the parents. This involves knowing which drug regimen is likely to be most effective, getting the drugs to the parents in a convenient way, the parents being adequately informed about what to expect, how to assess pain and when to give analgesia and lastly the parents actually giving the medication. Hegarty et al. [9] addressed some of these issues in a study comparing a ‘take home pack’ of analgesia with information on where to purchase it if required. Interestingly, analgesia was no better with the take home pack and most parents did not recall any of the advice that was given. This study confirms that effective analgesia after discharge requires more than just identifying effective analgesics.

**The Full Stomach and Emergency Surgery**

The possibility of a full stomach and hence increased risk of aspiration is a common problem with emergency surgery. The classic rapid sequence induction is difficult to perform in children. Intravenous (i.v.) access may be difficult to establish, preoxygenation is ineffective in a child who refuses to accept a mask, children become hypoxemic quickly due to their higher metabolic rate relative to functional residual capacity and cricoid pressure is of questionable efficacy. Succinylcholine is associated with many unwanted effects, although increasingly it is being replaced with rocuronium or larger doses of propofol; however, these too have some disadvantages such as cost and marginally longer recovery and time to intubation for the former, and hypotension and possibly less than ideal laryngoscopy conditions for the latter. For example, a recent retrospective cohort study by Ghazal et al. [10] found that in children undergoing laparoscopic pyloromyotomy, use of rocuronium was associated with a longer recovery time than succinylcholine.

For elective surgery, gastric volume and thus risk of aspiration is reduced through appropriate fasting; however, an interesting study by Cantellow et al. [11*] found that an alarming proportion of parents...
either misinterpreted or intentionally ignored the fasting instructions. Delaying surgery is not an option for many emergency procedures, and in some emergency conditions, fasting will not reliably reduce gastric contents. An alternative approach is to actually assess the gastric volume with ultrasound. Ultrasound is a skill increasingly acquired by anesthesiologists and may be a useful tool to assess gastric volume [12]. Schmitz et al. [13] investigated the correlation between ultrasound and MRI-assessed gastric fluid volume. They found evidence for a correlation but were unable to reliably predict gastric volume. They conclude that the technique is currently not useful with simple ultrasound technology and vascular landmarks; however, more advanced technology and other landmarks may prove more reliable.

It is widely accepted that i.v. access is not mandatory prior to induction for all pediatric cases, and indeed in some cases may not be needed at all [14,15]. However, an effective rapid sequence induction in emergency cases requires i.v. access. i.v. access can be difficult in emergencies. Both ultrasound and various transilluminences techniques have been proposed to help. Benkhadra et al. [16] found that in children under 3 years of age, ultrasound does not improve overall success rate; however, time to access is faster with a higher success at first puncture. Cuper et al. [17] found that near infrared imaging did not improve rate of access. In both studies, the children were not identified as having difficult veins to access. Thus, these negative findings in normal children may not translate to children with difficult venous access. Furthermore, in practice, anesthesiologists tend to limit the use of these technologies to cases of difficult access. Thus, it would be premature to deny their possible utility in difficult situations such as emergency surgery, and future studies should concentrate on children in whom a vein is not obvious to the naked eye or by palpation.

TRACHEO-ESOPHAGEAL FISTULA AND OESOPHAGEAL ATRESIA

There are several challenges in the anesthetic management for repair of tracho-esophageal fistula and oesophageal atresia and different anesthetic techniques have been advocated. Knottenbelt et al. [18] retrospectively reviewed the anesthesia management and complications for 101 cases at four hospitals in New Zealand and Australia. Forty-two percent of children were born premature and 57.5% had significant comorbidities. Fourteen percent of children died, although none of the deaths were due to anesthesia-related events.

There was a range of anesthetic techniques. Of the 101 with complete anesthesia records, 81 were induced in the operating room, 26 with i.v. induction and 55 with inhalational induction; 21 had succinylcholine at induction and eight had a non-depolarizing neuromuscular blocking agent. All except two were given a neuromuscular blocking agent during maintenance. Bronchoscopy was performed in 43 cases; however, there were no attempts at occluding the fistula at bronchoscopy. In two cases in which there was no bronchoscopy, a second fistula was missed requiring further surgery. There was difficulty with ventilation in seven cases, four of which had large fistulae and one required an urgent open gastric decompression. Two of the seven cases required urgent gastric decompression with a cannula after intubation that occurred shortly after birth. Thirty-five of the 101 were extubated within 2 days, and of these, 13 were extubated at the end of the procedure in the operating room. Twenty had extrapleural catheters for postoperative analgesia, three had caudal catheters and one had a thoracic epidural. In conclusion, anesthesia is complicated by the increased risk of significant comorbidity, the incidence of significant ventilatory complications on induction is just under 10%, bronchoscopy is useful prior to repair, and if a large fistula is seen, it may be worthwhile attempting a bronchoscopic balloon occlusion. (Table 1).

INTUSSUSCEPTION

Intussusception is a common cause of bowel obstruction in small children and the management has evolved over the last few decades. The preferred primary management was open repair, but was steadily replaced by contrast enema and now air enema, though in some cases, open repair is still performed as the primary procedure. Anesthesia may be required for primary open repair or for open repair after failed reduction at enema. In the latter case, the child may have significant cardiovascular compromise. Anesthesia or sedation may also be required for the enema. Purenne et al. [19] performed a single centre retrospective review to determine whether general anesthesia increased the rate of successful reduction with enema. Five episodes in 433 children were reviewed. Under general anesthesia, the success rate was 90%, and using multivariate analysis with propensity scoring, they found that general anesthesia was associated with an increased rate of success odds ratio 5.66, 95% confidence interval (CI) 2.85–12.89. Similar to all cohort studies, they found evidence for an association which, due to possible confounding factors, may or may not relate to causation. Another finding
was that failure increased with delay from diagnosis to first attempt at enema. Thus, although general anesthesia may increase the rate of success, this may not be the case if this results in any delay.

**AIRWAY FOREIGN BODY REMOVAL**

Foreign body aspiration is a common and life-threatening event in children. Several anesthetic techniques have been described to aid bronchoscopic removal [20]. Practices vary between spontaneous and controlled ventilation, in mode of controlled ventilation, between inhalational and total i.v. anesthesia delivery (or a combination thereof) and in ways to provide topical local anesthesia to the airway. A recent study suggests that adding topical fentanyl to lignocaine provides more haemodynamic stability than topical lignocaine alone, though the authors concede that the effect may well be due to systemic absorption of the fentanyl [21].

In a large Chinese single centre cohort study, Hu et al. [22*] describe their experience with 586 children undergoing sevoflurane and remifentanil anesthesia and spontaneous ventilation assisted with high frequency jet ventilation. Lidocaine was sprayed into the larynx and trachea under direct vision. Foreign bodies were successfully removed in 558, with 28 children having no foreign body found. There were no severe complications, with laryngospasm occurring in only five children and hypoxemia (SpO$_2$ <90) in only 15 (3%).

In another Chinese study, Shen et al. [23] reported their experience using propofol and remifentanil in 60 children who had preoperative respiratory impairment. They also reported no serious complications; however, they reported a higher rate of hypoxemia (SpO$_2$ <90), occurring in 10 cases (17%). This is not surprising, as in this cohort, all children had respiratory impairment prior to the procedure. The same group had previously published a large cohort study looking at 505 children anesthetized with propofol and remifentanil and a variety of ventilation strategies. In that study, there were four pneumothoracies and one death [24].

**TRAUMATIC BRAIN INJURY**

Traumatic brain injury is a major cause of death and morbidity in children. The incidence is increasing. Anesthesia management may include anesthesia for skull fracture, evacuation of haematoma, decompressive cranietomy or insertion of intracranial pressure monitoring. Decompressive cranietomy has been shown to worsen outcome in adults [25], but the effectiveness in children is still unclear [26]. Children with traumatic brain injury may also require anesthesia for a variety of other procedures or surgeries related to other injuries. Understanding the principles of the management of traumatic brain injury is thus essential for all pediatric anesthesiologists. Bhalla et al. [27**] recently wrote a comprehensive and clear review of this topic. The review lists key evidence-based anesthesia-related management points.

A crucial element of protecting the brain is maintaining the cerebral perfusion pressure above the lower limit of autoregulation. This is important for all emergency surgery. Unfortunately, we have

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**Table 1. Description of cases in which there was difficulty with ventilation in children with oesophageal atresia/tracheo-esophageal fistula**

<table>
<thead>
<tr>
<th>Event causing difficulty with ventilation</th>
<th>Management</th>
<th>Contributing disease (if recorded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fistula inadvertently intubated</td>
<td>Tracheal tube withdrawn, hand ventilated until fistula ligated</td>
<td>Large distal fistula found at surgery</td>
</tr>
<tr>
<td>Gastric distension</td>
<td>Emergent gastric decompression</td>
<td>Large fistula at the carina</td>
</tr>
<tr>
<td>Fistula inadvertently intubated</td>
<td>Tracheal tube withdrawn, hand ventilated until fistula ligated</td>
<td>Large fistula found at surgery</td>
</tr>
<tr>
<td>Preferential ventilation through fistula</td>
<td>Tracheal tube manipulated and rotated</td>
<td>Large fistula at the carina</td>
</tr>
<tr>
<td>Intubated at birth, gastric distension</td>
<td>Emergent gastric decompression with cannula followed by emergent clipping of distal oesophagus</td>
<td>Not recorded</td>
</tr>
<tr>
<td>Intubated at birth, gastric distension,</td>
<td>Emergent decompression with cannula, then emergent gastrostomy and ligation of fistula</td>
<td>Not recorded</td>
</tr>
<tr>
<td>gastric perforation and tension</td>
<td>Presumed preferential ventilation through fistula</td>
<td>Not recorded</td>
</tr>
<tr>
<td>pneumoperitoneum</td>
<td>No ETT manoeuvres recorded, low oxygen saturation (&lt;75%) persisted until fistula ligated</td>
<td>Not recorded</td>
</tr>
</tbody>
</table>

Adapted with permission from [18*].
very little data on the lower limit of autoregulation in children. This is especially the case in neonates. We also have little idea how autoregulation changes in children following neurotrauma or cerebral hypoxia. Lee et al. [28] used a neonatal piglet model to demonstrate that the lower limit of autoregulation remained unchanged in the 2 days after cardiac arrest and global cerebral hypoxia, thus refuting the theory that the lower limit of autoregulation would rise after such an injury. They also found that NIRS-derived indices of autoregulation accurately reflected those derived from laser-Doppler flowmetry. Hopefully, similar studies will continue to expand our knowledge base in this important area. NIRS may prove to have a crucial role, though it is too early to recommend its routine use.

RESUSCITATION

Lastly, pediatric anesthesiologists also need to keep abreast of advances in acute pediatric resuscitation. Although intraoperative cardiac arrest is rare, emergency surgery has a higher risk for cardiac arrest. Anesthesiologists may also be involved in resuscitation outside the operating room. An editorial by Allan de Caen and Farhan Bhanji [29] provides an excellent review of recent developments in line with the guidelines published by the International Liaison Committee on Resuscitation. The review lists the key points in pediatric resuscitation as follows:

1. Do not delay resuscitation while feeling for a pulse
2. Start chest compression in the presence of bradycardia before the pulseless state; a change of priority from airway-breathing-circulation to compression-airway-breathing
3. Use a compression to ventilation ratio of 30 : 2 for a sole rescuer but 15 : 2 when two rescuers are present
4. Use a compression rate of 100 per minute for all ages, pushing down 4 cm for infants and 5 cm for children, and minimizing interruption of compression
5. Aim for an end-tidal CO₂ of more than 10–15 mmHg
6. If intubated, ventilate at 8–10 breaths per minute and do not pause compression for ventilation
7. If intravenous access is not available, establish intraosseous access rather than deliver drugs intratracheally
8. Give epinephrine 0.01 mg/kg, repeat if needed
9. Defibrillate with 4 J/kg if initial 2 J/kg is ineffective
10. If available, consider and organize extracorporeal life support early.

The use of hypothermia remains controversial. Recent advances in fluid resuscitation are discussed in another article in this issue.

Anesthesiologists may also be called upon to assist with resuscitation of the newborn. The principles are subtly different to those of a cardiac arrest outside the delivery suite and have been recently revised [30]. The most striking new recommendation is to initially use room air rather than 100% oxygen.

CONCLUSION

Little has been recently published about the anesthetic management of specific pediatric emergencies. Practices vary and are based on little hard evidence. In spite of this, rates of serious complications are low. In a broader sense, there is an increased interest in postoperative pain, which in many cases is poorly managed. There is also an interest in investigating new technologies to assess gastric volume and to assist with difficult venous access. Although promising, these technologies have yet to be proven to be clinically effective in the emergency settings. One of the most urgent areas for investigation is in the management of traumatic brain injury. Some new data are emerging to guide our anesthesia management, in particular minimal acceptable blood pressure, but much further work needs to be done.

Acknowledgements

This study is funded through Royal Children’s Hospital Melbourne departmental funds.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

• of special interest

** of outstanding interest

   An excellent review of pediatric emergencies that anesthesiologists are likely to encounter at a district hospital level.
   An important review highlighting the unmet pain needs of children having this common procedure.
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A retrospective cohort study demonstrating the variety of practice and the incidence of complications.


A large cohort study demonstrating a low complication rate with this technique.


An excellent review and a clear list of the key principles in the management of children with traumatic brain injury in the operating room.


A good outline of essential points in the new guidelines for pediatric resuscitation.