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Place of rapid sequence induction in paediatric anaesthesia

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Key points

- Preoxygenation may not prevent hypoxia during classical rapid sequence induction (RSI) in children.
- Cricoid pressure is effective at reducing gastric insufflation.
- The sequelae of aspiration are less severe in children.
- ‘Controlled’ RSI, with careful mask ventilation, may decrease the risks associated with the classical approach.

Stept and Safar[1] introduced the concept of rapid sequence induction (RSI) in 1970 after Snow and Nunn had found that the commonest cause of anaesthesia-related deaths in 1958 were because of aspiration.[2]

The perceived benefit of RSI in reducing the risk of aspiration, in high-risk patients, has led to it becoming the standard level of care, despite the lack of quality evidence.[3]

The development of the RSI technique is based upon adult practice. In children a ‘classical’ RSI may not always be the correct choice because of psychological, anatomical, and physiological differences. A survey of UK anaesthetists found that only around 50% would routinely perform an RSI for a child with a presumed full stomach despite having comparable aspiration risk as an adult.[4]

This article examines the evidence for the use of ‘classical’ RSI and its place in contemporary paediatric anaesthetic practice.

History of RSI

Pulmonary aspiration of gastric contents under anaesthesia was not described as a problem until Mendelson famously described its deleterious effects in 1946. However, practice at that time included many risks for aspiration: no routine fasting combined with placing patients in a 20° head down position, undoubtedly increased the number who suffered from passive regurgitation. The first neuromuscular blocking agent, tubocurarine, was invented in the early 1940s. Although not used widely in 1946, it is only fully effective after 2–3 min, thereby allowing a prolonged period without protective airway reflexes.

Despite the consideration of fasting times and gastric emptying taking a more prominent place since the 1940s and the invention of succinylcholine in 1951, aspiration was still the number one cause of adult anaesthetic related deaths in 1958.[2] Sellick described cricoid pressure in 1961, but it was not until 1970 that Stept and Safar combined the individual components to develop the concept of the ‘classical’ RSI, with the aim of reducing the risk of aspiration as it was designed to minimize the time the airway was unprotected.

What is perhaps surprising is that despite these advances aspiration is still a significant problem. The NAP-4 study showed that the risk of aspiration in adults was 1:2–3000 for elective surgery and as high as 1:6–800 for emergency surgery.[5] In paediatric anaesthesia, it appears that the risk of aspiration is slightly lower.[6]

Aspiration

A recent study from the UK investigated the incidence, risk factors, and outcomes from aspiration in paediatric patients.[6] It found an incidence of 1:5076 for elective and 1:4498 for emergency paediatric cases. Children who had aspirated suffered less severe sequelae than adults. Of the 24 patients who aspirated there was no deterioration in 8 patients, mild deterioration in 11 patients (requiring only basic medical management) and severe deterioration in 5 patients (all requiring intubation and ventilation). The additional finding that all children who deteriorated after aspiration did so within 2 h concurred with previous studies.[7] No mortality was reported from pulmonary aspiration in either study.

Aetiology

Aspiration of gastric contents occurs either passively or by active vomiting.

Passive regurgitation occurs mainly because of a distended or incompetent lower oesophageal sphincter. Common causes for this are attributable to gastric distension during bag mask ventilation or after accidental oesophageal intubation. Other important causes of abdominal distension include intestinal obstruction, intra-abdominal tumours, and ascites.

Active expulsion of gastric content occurs mainly because of instrumentation of the airway before adequate depth of anaesthesia is reached, leading to coughing and vomiting. Cricoid pressure should be removed on active vomiting to avoid oesophageal rupture.

Risk of aspiration

Recent studies have highlighted a failure to recognize significant risk factors (Table 1) and use an RSI when indicated in such cases.[5,6]

Anatomical variations in children

There are several anatomical factors that predispose infants to gastro-oesophageal reflux (GOR). Infants have a shorter oesophagus, thereby the stomach is that much closer to the larynx. The angle of His (made by the oesophagus and the axis of the stomach) is obtuse in newborns but decreases as infants develop. Infants also have decreased gastric compliance, which is believed to lead to lower oesophageal sphincter relaxation at lower intra-gastric volumes. It was initially thought that infants have an immature lower oesphageal sphincter (LOS), which predisposes them to GOR, but it has now been shown that it is because of periods of transient lower oesophageal relaxation. Abdominal muscle contraction coinciding with an episode of LOS relaxation may increase the risk of aspiration.

Behavioural differences

Babies and older, distressed children may cry and scream, thereby swallowing air and predisposing to abdominal distension. This may compound the risk of regurgitation and aspiration.

Reducing the risk of aspiration

The pH and volume of gastric contents can be reduced by pharmacological treatments such as prokinetics, H_2 blockers, proton pump inhibitors and non-particulate antacids. However, there is no evidence to show any benefit in children.

Table 1 Risk factors for aspiration in the paediatric population,[6] in ascending order of importance of risk

	Anxiety, inadequate/light anaesthesia
	Gastric distension from bag valve mask ventilation
	Increased intra-abdominal pressure
	Difficult airway, GI pathology, obesity
	GOR, oesophageal disease
	Sepsis, renal failure, opioids before operation

Insertion of a nasogastric tube and aspiration of gastric contents, before commencement of anaesthesia, reduces the volume but does not reliably empty the stomach completely.

Fasting guidelines

Widely, although not universally, accepted fasting recommendations for children undergoing elective surgery are 6 h for solids, formula, and cow's milk, 4 h for breast milk, and 2 h for clear fluids. Children are more prone to gastric stasis with minimal trauma, opioid analgesia, and pain. In one study 49% of children who suffered trauma still had significant aspirates after 8 h of starvation.[8] These guidelines cannot be relied upon to produce complete gastric emptying in all non-elective cases. Additionally prolonged fasting period may lead to an irritable, uncooperative child at increased risk of hypoglycaemia and dehydration.

The 'classical' RSI

Classical RSI, as described in adults, consists of preoxygenation, application of cricoid pressure followed by induction with a predetermined dose of thiopental and succinylcholine. Avoidance of positive pressure ventilation together with rapid tracheal intubation with a cuffed tube before removal of the cricoid pressure swiftly follows. The success of this technique requires scrupulous attention to detail of each component.

Preoxygenation

Preoxygenation is designed to increase the reserves of oxygen within the lungs by denitrogenation of the functional residual capacity (FRC). This prolongs the apnoeic period before hypoxaemia ensues. The efficacy of preoxygenation can be measured by the end-tidal oxygenation fraction, which provides an approximation of the alveolar oxygen fraction. To achieve full denitrogenation of the lungs, an end-tidal oxygenation fraction of >0.9 is required. Maintenance of a patent airway during the apnoeic period allows oxygen to reach the alveoli by the process of bulk flow. This occurs as a result of differences in the volume of oxygen consumption and CO_2 production and their respective solubility in blood. During apnoea, it is estimated that CO_2 enters the alveoli at a rate of 0.12–0.25 ml kg^{-1} min^{-1} whilst O_2 is removed at a rate of 4–8 ml kg^{-1} min^{-1} in paediatric patients and 2–3 ml kg^{-1} min^{-1} in the adult population. This net removal of gas volume from the alveoli during periods of apnoea results in a reduction in barometric pressure in the alveoli that facilitates the bulk flow of oxygen from the upper airway to the alveoli. Studies in adults have shown that oxygen administered by nasal prongs and also by facemask, with a patent airway, prolongs the time to desaturation.

Owing to the negative pressure gradient that bulk flow causes, it is important to maintain the application of continuous positive airway pressure via a tight fitting mask, in order to reduce atelectasis. This is emphasized in children, as they are more prone to atelectasis and hypoxaemia on induction because of the combination of a reduced FRC, increased closing volume, and higher respiratory rate.

Time to complete preoxygenation is theoretically shorter in children because of a smaller lung volume and an increased respiratory rate, creating a faster 'turnover' of ambient respiratory gases. However, a non-compliant and sometimes combative child may make full denitrogenation and preoxygenation unobtainable whilst simultaneously increasing oxygen consumption. During apnoea in a term baby who is 1 month old, the rate of decline of Pa_{O_2} is three times more rapid than in an adult. Infants tolerate even very short periods of apnoea badly and can desaturate after <100 s despite adequate preoxygenation.[9] Failure to achieve full preoxygenation/denitrogenation because of non-compliance from the child compounds this risk. Sedation to improve mask acceptance may be an option after careful consideration in a select few. This practice is not recommended routinely, as a small amount of sedation may cause respiratory depression.

In adults, preoxygenation may be best achieved with the patient in a 20–25° head up position. This had been shown to improve efficacy and consequently produce an increased time to desaturation.[10] Although such an effect is unproven in the paediatric population, it would seem sensible to consider its use more frequently in children.

Cricoid pressure

There has been much controversy about the benefits and risks of cricoid pressure recently in the literature. A recent survey showed that only 50% of anaesthetists would routinely apply cricoid pressure in paediatric patients aged 1–14 and only 40% if they were <1.[11]

Cricoid pressure relies on the alignment of the trachea and the oesophagus so that when the cricoid cartilage is depressed it is displaced backwards onto the oesophagus and occludes it, in order to stop aspiration of gastric contents. A study examined CT scans of the neck of 120 children to assess the alignment.[12] In children <8 yr old, 45% had lateral displacement of the oesophagus at the level of cricoid cartilage as opposed to only 15% of children over the age of 8. This questions the efficacy of cricoid pressure in children, particularly in younger children. In children the cricoid cartilage is smaller and more cephalad in position, making it harder to identify. In addition, when the cricoid cartilage is depressed, it decreases the lower oesophageal sphincter tone, predisposing to aspiration.

Application of forces as low as 7.7 N may adequately compress a child's airway, and higher forces (typically 30 N) as recommended for use in adult practice may worsen or obscure the view of the larynx.[13]

However, the use of cricoid pressure may prevent insufflation of the stomach during bag mask ventilation. Effectively applied cricoid pressure may prevent gastric insufflation up to a maximal pressure of 40 cm H_2O in children between 2 weeks and 8 yr old.[14]

Induction agents

The paediatric population exhibits different, age-related pharmacokinetic and pharmacodynamic activity compared with adults.

No single drug possesses all of the attributes as the agent of choice for RSI in children. All have undesirable side-effects and choice depends upon the specific clinical circumstance. Detailed discussion is beyond the scope of this article. The predominant agents used are thiopental and propofol although alternative agents may be preferred in haemodynamically unstable patients. Both require larger doses compared with adults. Thiopental has a faster onset of hypnosis than propofol. Issues with propofol include potentially significant hypotension and pain on injection (ameliorated by co-administration of lidocaine). One major advantage of propofol over thiopental is that it suppresses the laryngeal reflexes. On balance, in the haemodynamically stable patient, propofol is commonly the favoured drug of choice.

Very little is written about inhalation induction for a child with a full stomach. Many paediatric anaesthetists would recommend an inhalation induction for a child undergoing emergency surgery only in cases of difficult airway or difficult vascular access. Sevoflurane's non-irritant smell and rapid onset make it the agent of choice in such situations.

Neuromuscular blocking drugs

Traditionally succinylcholine, in a dose of at least 2 mg kg^{-1}, is used for RSI as it rapidly provides excellent intubating condition with a rapid offset in effect. The average recovery time from administration of succinylcholine to spontaneous breathing is 4.7 min.[15] Such an offset time cannot be relied upon as a mechanism to prevent desaturation even in fully preoxygenated small children.

Rocuronium in a dose of 1.2 mg kg^{-1} can provide similar intubating conditions to succinylcholine. Rapid reversal of rocuronium's effects required in a 'cannot intubate, cannot ventilate' situation requires the prompt use of 16 mg kg^{-1} sugammadex. Full reversal can take several minutes, in addition to any time required to locate and draw up the drug. Prevention of significant desaturation is not guaranteed, particularly in babies.

Premedication with atropine

The routine use of atropine before intubation in children, in an attempt to prevent bradycardia associated with administration of succinylcholine, manipulation of the airway or reflex bradycardia associated with hypoxia, has been advocated. A retrospective study examined the effects of atropine on the prevention of bradycardia during laryngoscopy.[16] The children who received atropine had a similar incidence of bradycardia and atropine did not prevent bradycardia in all children.

Risks of RSI

RSI has risks associated with it, perhaps even more pertinent in the paediatric population.

Frank *et al.*[17] tried to establish the risks associated with the 'classical' approach to RSI in children. A retrospective study of over a thousand children aged 3–12 yr showed an overall risk of hypoxia (saturations <90%) of 3.6% with 1.7% demonstrating severe hypoxaemia (saturations <80%). Children <20 kg were at greater risk.

The same study showed an incidence of hypotension (systolic <70 mm Hg) as 0.8% and bradycardia (heart rate <60 beats min^{-1}) of 0.5%. The incidence of these risks is higher than the published risks of aspiration.

RSI in children may differ in the following ways when compared with adults

Classical RSI
- Preoxygenation
  - Difficult to achieve in uncooperative children and even preoxygenation creates minimal reserve
- Administration of induction agent
  - Difficult i.v. access
- Application of cricoid pressure
  - Correct timing is difficult
  - Can distort airway
  - Conflicting evidence regarding efficacy
- Administration of neuromuscular blocking agent
  - If succinylcholine is used a larger dose kg^{-1} is needed
- Period of apnoea with no positive pressure ventilation
  - Even brief period of apnoea can lead to profound hypoxaemia

An alternative approach

Classical RSI in children presents the anaesthetist with a unique set of potential challenges. RSI with a desaturating child can be a very stressful time for the personnel involved. There is emerging evidence that the use of a 'controlled RSI (cRSI)', without the use of cricoid pressure may offer an effective and potentially safer alternative. By utilizing this technique, it allows the operator optimal conditions, with ideal respiratory and haemodynamic conditions.[17] Significant differences between RSI and cRSI include:

- Continuous aspiration of an NG tube if *in situ*. If no NG, then one should be inserted after the tracheal tube is secured.
- Patients in a 20° head up position during preoxygenation and induction.
- Titration of induction agent to produce hypnosis followed by administration of a non-depolarizing relaxant. Atracurium at 1 mg kg^{-1} is traditionally described in cRSI but any neuromuscular blocking agent may be used as it is more important to guarantee optimal relaxation, guided by monitoring of neuromuscular block.
- Gentle bag mask ventilation (insufflation pressure <12 cm H_2O) before intubation.
- Intubation only after there is no response to a train-of-four stimulus from a nerve stimulator, thus allowing time for a deep level of anaesthesia and complete muscle paralysis.

Summary

Children are at risk of aspiration of gastric contents under anaesthesia, particularly at induction. Classical RSI has been adopted from adult practice without any modifications required to allow for significant differences in risk factors in children. The adoption of a controlled RSI may reduce the potentially significant risks of hypoxaemia associated with classical RSI whilst providing rapid intubating conditions.

Declaration of interest

None declared.

MCQs

The associated MCQs (to support CME/CPD activity) can be accessed at https://access.oxfordjournals.org by subscribers to *BJA Education*.

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