Is inhalational induction justifiable in paediatric emergencies?

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“The beginning of wisdom is the definition of terms.”

–Socrates
“If you wish to converse with me,” said Voltaire, “define your terms.”

—Will Durant
The story of philosophy
Chapter 2 part 3: the foundation of logic, page 59
Emergencies

- A B C

- Intervention required within 24 hours
Anatomical Airway Obstruction

- **Principle**: maintain spontaneous ventilation until the airway is secure

- **Rationale**: to retain some muscle tone in the upper airway and allow time for laryngoscopy and intubation

- Why not give a muscle relaxant? - to avoid the scenario where a muscle relaxant has been given, bag-mask ventilation proves difficult or impossible, the child becomes hypoxaemic, and cannot be intubated - CICO

*The management of difficult intubation in children.*

*Paediatric Anesthesia 2009; 19 (Suppl. 1): 77 - 87*

*RM Walker and J Ellwood.*
Anatomical Airway Obstruction

• Inhalational induction still popular in paediatrics

• **NAP 4 census report** - management of the predicted difficult airway in children:
  
  ○ Inhalational induction - 63%
  
  ○ Intravenous induction - 37%
  
  ○ Awake intubation - 0%
Anatomical Airway Obstruction

*Canadian paediatric anesthesiologists prefer inhalational anesthesia to manage difficult airways: a survey*

*Canadian Journal of Anesthesia 2005; 52:3 pp 285 - 290*

*Peter Brooks et al.*

- 6 scenarios - web-based survey
- 63 responses from 136 invitations- experienced paediatric anaesthetists
- 2 scenarios - emergencies with a compromised airway
- 2 year old child with potential epiglottis needing emergency endotracheal intubation - 95% of respondents chose to keep the patient breathing spontaneously and 97% would use an inhalational agent to do this.
Anatomical Airway Obstruction

*Rigid bronchoscopy for foreign body removal: anaesthesia and ventilation*

*Pediatric Anesthesia 2004 14: pp84 -89*

*PT Farrell*

• “in an emergency situation or with a distressed infant, establishing iv access immediately after inhalation induction is acceptable”

• “spontaneous ventilation must be maintained until it is certain that the child can still be ventilated under anaesthesia”

• “most experienced anaesthesiologists prefer inhalational rather than intravenous induction”
Anatomical Airway Obstruction

*A child with a difficult airway: what do I do next?*

*Current Opinion in Anesthesiology 2012; 25(3): 326 -332*

*T Engelhardt and M Weiss*

“the recent NAP 4 audit suggests that spontaneously breathing adult patients who lost the airway do not recover rapidly. Full recovery of a child with lower oxygen reserves is even more unlikely and as yet not reported in the literature.”
Anatomical Airway Obstruction

**NAP 4 report**: Chapter 13 management of the CICV situation, page 113

*Recommendation*: Even if it was not part of the initial airway management strategy, if CICV occurs and waking the patient up is not an option, a muscle relaxant should be given before determining the need to proceed to a surgical airway.
Anatomical Airway Obstruction

*DAS 2015 guidelines for the management of the unanticipated difficult intubation in adults*

**Plan C - the final attempt at face-mask ventilation**

- If face-mask ventilation is impossible - paralyze

- ensuring full paralysis offers a final chance of rescuing the airway without recourse to Plan D

- airway rescue via the front of neck should not be attempted without complete neuromuscular block
Anatomical Airway Obstruction

**Cannot ventilate - paralyze!**

*Pediatric Anesthesia 2012 22 1147 - 1149*

*M Weiss and T Engelhardt*

• Treat functional airway obstruction

• Functional airway obstruction is the leading cause of difficult or failed facemask ventilation

• “a deeply anesthetized, hypoxic brain is unlikely to restart spontaneous breathing and establish airway patency. There is no way back…”
Anatomical Airway Obstruction

**APA/DAS guidelines for the management of the unanticipated difficult airway in paediatric practice**

*Pediatric Anesthesia 2015 25 346 - 362*

AE Black et al.

- “the CICV scenario is considered in the context of the paralysed child”

- “sugammadex should not be given to reverse rocuronium or vecuronium if the child is rapidly deteriorating with decreasing SpO2 and haemodynamic compromise”
Functional Airway Obstruction

Which port in a Storm? Use of suxamethonium without intravenous access for severe laryngospasm

RWM Walker and R Sutton

Anesthesia 2007 62: 757 -759

Suxamethonium 4 mg/kg into the deltoid muscle - should work within 1 min
Anterior mediastinal mass
Anterior mediastinal mass

Anesthetic management of children with an anterior mediastinal mass

Journal of Clinical Anesthesia 2010 22: 159 -163

PA Stricker, HG Gurnaney, and RS Litman

- **Spontaneous ventilation** was maintained in 21 of 46 cases
- 26 patients had signs and symptoms suggestive of cardiopulmonary compromise as well as radiologic evidence of respiratory or cardiovascular compression
  - muscle relaxant was avoided in 18 of these cases
  - 17 of these case received **iv sedation with spontaneous ventilation and a natural airway, often in the Semi-Fowler’s position**
  - one complication in the 8 patients who received muscle relaxant and IPPV - bronchospasm that resolved with administration of a bronchodilator
Anterior mediastinal mass

The anaesthetic management of children with anterior mediastinal mass

Anaesthesia 2008, 63: 837 - 846

HA Hack, NB Wright, and RF Wynn

- 53 anaesthetic charts available for inspection
- **25/53 - inhalational induction**; 2 of these in the sitting position, 1 in the lateral position.
- 28/53 - iv induction in the supine position
- **18/53 - maintained spontaneous ventilation**; FM, LMA, ETT.
- 35/53 - IPPV
- no significant difference in the tracheal cross-sectional area
Risk of aspiration

- **NAP 4** - aspiration was the main cause of adverse outcome at induction

- **NAP 4** - aspiration was the cause of 50% of anaesthesia deaths and 53% of outcomes of death or brain damage

- **Recommendation:** On balance, rapid sequence induction should continue to be taught as a standard technique for protection of the airway. Further focused research might usefully be performed to explore its efficacy, limitations and also explore the consequences of its omission.

*Chapter 19, page 163*
Risk of Aspiration

*Pulmonary Aspiration in pediatric anesthetic practice in the UK: a prospective survey of specialist pediatric centres over a one year period*

*Pediatric Anesthesia 2013 23: 702-711*

*Robert W.M. Walker*

- 1 year, 11 paediatric centres, denominator 118 371
- 2 per 10 000 cases for elective work
- 2.2 per 10 000 cases for non-elective work
- **no deaths**
- 5 cases with serious morbidity - needing PICU
Risk of Aspiration

Pulmonary Aspiration in pediatric anesthetic practice in the UK: a prospective survey of specialist pediatric centres over a one year period

Pediatric Anesthesia 2013 23: 702-711

Robert W.M. Walker

• 12 / 24 cases of pulmonary aspiration of gastric contents occurred at induction

• 7 /12 cases of pulmonary aspiration of gastric contents at induction = iv induction

• 5 / 12 cases of pulmonary aspiration of gastric contents at induction = inhalational induction

• 8 /12 cases of pulmonary aspiration of gastric contents at induction = elective cases (3 had inhalational induction)

• 4 /12 cases of pulmonary aspiration of gastric contents at induction = non-elective (2 had inhalational induction)
Risk of aspiration

*Perioperative pulmonary aspiration in infants and children*

*Anesthesiology* 1999; *90*: 66 - 71

*MA Warner et al.*

- 3.8 per 10 000 cases
- 2 per 10 000 for elective cases
- 25 per 10 000 for emergency cases
- 63 180 consecutive anaesthetics

*no deaths*
Risk of aspiration

*Pulmonary aspiration in pediatric patients during general anaesthesia: incidence and outcomes*

*Journal of Clinical Anesthesia 1998; 10: 95 - 102*

*LM Borland et al.*

- 10.2 per 10 000 cases
- 50,880 anaesthetics
- no deaths
Risk of aspiration

Pulmonary aspiration under GA: a 13-year audit in a tertiary pediatric unit

Z Tan and SY Lee

Pediatric Anesthesia 2016, 26: 547-552

• 22 cases of pulmonary aspiration / 102 425 general anaesthetic

• 2.15 per 10 000

• 12/ 22 - iv induction

• 10/ 22 - inhalational induction

• iv vs inhalational induction odds ratio 1.139 (95%CI 0.457 - 2.818)

• emergency surgery vs elective surgery odds ratio 4.321 (95% confidence interval 1.735 - 10.687)
Risk of aspiration

- minimise the **gastric volume** - fasting, prokinetics, and NG tube; use ultrasound to check

- increase the **pH** of gastric contents - sodium citrate, ranitidine, PPI

- **RSI** - cricoid pressure; apnoeic induction

*Effects of different combinations of H2 receptor antagonists with gastrokinetic drugs on gastric fluid pH and volume in children - a comparative study*

*Int J Pharmacol Ther 1997; 35: 561-654*

*Kulkarni PN, Batra YK, Wig J*
Risk of aspiration

Avoid:

• Decreasing intrathoracic pressure: airway obstruction, hiccup

• Elevating intra-abdominal pressure: laryngoscopy during light anaesthesia, coughing or straining during induction or intubation, inflating the stomach during bag-mask ventilation

• Oesophageal intubation

• Haste

• Hypoxaemia
Risk of aspiration - apnoeic induction?

*Controlled rapid sequence induction and intubation - an analysis of 1001 children*


*Pediatric Anesthesia 2013, 23: 734 - 740*

- gentle face-mask ventilation prior to intubation, avoidance of cricoid pressure, non-depolarising neuromuscular blocking agent
- moderate hypoxaemia (SpO\textsubscript{2} 80 - 89%) in 0.5%; n = 5
- severe hypoxaemia (SpO\textsubscript{2} < 80%) in 0.3%; n = 3
- 1 episode of regurgitation without aspiration
Is cricoid pressure harmful?

- airway occlusion
- distorted anatomy
- failed intubation
- difficult or impossible face-mask ventilation
- relaxation of the lower oesophageal sphincter
- a trigger for vomiting?
- may provoke bucking or straining
- interferes with a smooth induction

*Cricoid pressure: apply - but be ready to release*

*Anaesthesia 2016, 71, 999-1003*

*J Turnbull, A Patel, V Athanassoglou, JJ Pandit*
Cricoid pressure

*Aspiration and regurgitation prophylaxis in paediatric anaesthesia*

*Pediatric Anesthesia* 2001; **11**: 147-150

*Engelhardt T, Strachen L, Johnston G*

- “Up to 50% of paediatric anaesthetists would not use cricoid pressure in the “full stomach” situation”

- Do you *routinely* employ the following *prior to anaesthesia* in *all children regardless of risk factors*?

  - 42% (37 / 88 replies) would *routinely apply cricoid pressure* in *children < 1 year of age* having *emergency surgery*

  - 49% (43 / 88 replies) would *routinely apply cricoid pressure* in *children aged 1 - 14 years* having *emergency surgery*
Cricoid Pressure

Effect of cricoid force on airway calibre in children: a bronchoscopic study

British Journal of Anaesthesia 2010; 104: 71-74

Walker RWM, Ravi R, Haylett K

• 5N = the force required to cause 50% occlusion of the subglottic airway with the application of cricoid pressure in infants
“Rapid sequence induction has no use in paediatric anesthesia”

Pediatric Anesthesia 2015; 25: pp 5-8

Thomas Englehardt

- “Regurgitation and vomiting with aspiration are processes elicited by direct laryngoscopy under light anaesthesia and incomplete muscle paralysis”

- Advocates mask ventilation with pressures not exceeding 10 -12 cmH₂O following induction and before intubation in paediatric RSI

- induction of sufficiently deep anaesthesia

- avoid cricoid pressure

- confirm complete muscle paralysis before laryngoscopy
Is cricoid pressure effective

- No RCTs
- Absence of evidence is not evidence of absence
- Argument from ignorance - a proposition is true because it has not yet be proved false
- Aspiration does occur despite the application of CP
- Anatomy - the oesophagus is postero-lateral to the cricoid ring in 50% of people; lateral displacement increases with CP, but it is the post-cricoid hypo pharynx that is compressed and occluded - MRI, videolaryngoscopy, attempts to pass 4mm NG tube
http://gastricultrasound.org/index.html
Gastric Ultrasound

• Gastric antrum

• Right lateral decubitus position – only the RLD antrum CSA and age were shown to be independent predictors of endoscopically suctioned gastric volume

• Sagittal or right para-sagittal

• Between the left lobe of the liver and the pancreas at the level of the aorta and superior mesenteric artery or inferior vena cava

*Ultrasound assessment of gastric volume in the fasted pediatric patient undergoing upper gastrointestinal endoscopy: development of a predictive model using endoscopically suctioned volumes*

*Pediatric anesthesia 2015; 25: 301 - 308

Gastric Ultrasound

Qualitative assessment

• Grade 0: no fluid visible in the antrum in either the supine or RLD position

• Grade 1: antral fluid visible in the RLD position but not in the supine position

• Grade 2: antral fluid visible in both the supine and RLD position

Quantitative assessment

• Antral cross-sectional area in the RLD position

• Volume = \(-7.8 + (3.5 \times \text{RLD CSA}) + (0.127 \times \text{age in months})\)

*Ultrasound assessment of gastric volume in the fasted pediatric patient undergoing upper gastrointestinal endoscopy: development of a predictive model using endoscopically suctioned volumes*

*Pediatric anesthesia 2015; 25: 301 - 308*

Gastric ultrasound in babies with hypertrophic pyloric stenosis undergoing pyloromyotomy

- 34 infants
- Ultrasound of gastric antrum in the right lateral decubitus position before and after aspiration of gastric contents through 10Fr gastric tube
- Ultrasound examination before aspiration failed in 3/34 - gas in the stomach or infant agitation
- No failed examinations after gastric aspiration
- 9/31 empty stomach on first ultrasound
- 22/31 full stomach on first ultrasound
- The aspirated gastric volume correlates with the antral cross sectional area measured in the RLD – Pearson correlation coefficient 0.83 (95% CI 0.62 -0.93; p<0.0001)
- 30/34 non-rapid sequence induction

*Ultrasound assessment of the gastric contents for the guidance of the anaesthetic strategy in infants with hypertrophic pyloric stenosis: a prospective cohort study*

*British Journal of Anaesthesia* 2016; **116**(5): 649-54

A.C. Gagey, M. de Queiroz Siqueira, F.P. Desgranges, et al.
The humane argument
The pragmatic argument

• Have you ever induced anaesthesia via an IO?

• Careful assessment, good judgement, good decision making, smooth execution
Conclusion
Is inhalational induction justifiable in paediatric emergencies?

• Anatomical Airway Obstruction – yes
• Anterior mediastinal mass – yes
• Hypertrophic pyloric stenosis – yes
• Neonatal surgery – yes
• Older children at risk of aspiration – not my first choice but I would seldom rule it out completely
Conclusion
To reduce the risk of aspiration

- Reduce the gastric volume
- Increase the pH of the gastric contents
- Smooth induction
- Ensure an adequate depth of anaesthesia before attempts at intubation
- Complete muscle paralysis before laryngoscopy