

- in the operating theatre and in intensive care units. *Br J Anaesth* 2015; **114**: 297–306
18. Natt BS, Malo J, Hypes CD, Sakles JC, Mosier JM. Strategies to improve first attempt success at intubation in critically ill patients. *Br J Anaesth* 2016; **117**(Suppl. 1): i60–i68
  19. Mercer SJ, Jones CP, Bridge M, Clitheroe E, Morton B, Groom P. Systematic review of the anaesthetic management of non-intubation acute adult airway trauma. *Br J Anaesth* 2016; **117**(Suppl. 1): i49–i59
  20. Ucisik-Keser FE, Chi TL, Hamid Y, Dinh A, Chang E, Ferson DZ. Impact of airway management strategies on magnetic resonance image quality. *Br J Anaesth* 2016; **117**(Suppl. 1): i97–i102
  21. Asai T. Videolaryngoscopes: do they truly have roles in difficult airways? *Anesthesiology* 2012; **116**: 515–7
  22. Zaouter C, Calderon J, Hemmerling TM. Videolaryngoscopy as a new standard of care. *Br J Anaesth* 2015; **114**: 181–3
  23. Kleine-Brueggene M, Greif R, Schoettker P, Savoldelli GL, Nabecker S, Theiler LG. Evaluation of six videolaryngoscopes in 720 patients with a simulated difficult airway: a multicentre randomized controlled trial. *Br J Anaesth* 2016; **116**: 670–9
  24. Jagannathan N, Sequera-Ramos L, Sohn L, et al. Randomized comparison of experts and trainees with nasal and oral fiberoptic intubation in children less than 2 yr of age. *Br J Anaesth* 2015; **114**: 290–6
  25. Baker PA, Weller JM, Baker MJ, Hounsell GL, Scott J, Gardiner PJ, Thompson JMD. Evaluating the ORSIM® simulator for assessment of anaesthetists' skills in flexible bronchoscopy: aspects of validity and reliability. *Br J Anaesth* 2016; **117**(Suppl. 1): i87–i91
  26. Asai T. Is it safe to use supraglottic airway in children with difficult airways? *Br J Anaesth* 2014; **112**: 620–2
  27. Jagannathan N, Sequera-Ramos L, Sohn L, Wallis B, Shertzer A, Schaldenbrand K. Elective use of supraglottic airway devices for primary airway management in children with difficult airways. *Br J Anaesth* 2014; **112**: 742–8
  28. Saito T, Chew STH, Liu WL, Thinn KK, Asai T, Ti LK. A proposal for a new scoring system to predict difficult ventilation through a supraglottic airway. *Br J Anaesth* 2016; **117**(Suppl. 1): i83–i86
  29. Noppens RR. Ventilation through a 'straw': the final answer in a totally closed upper airway? *Br J Anaesth* 2015; **115**: 168–70
  30. Asai T. Emergency cricothyrotomy: toward a safer and more reliable rescue method in "cannot intubate, cannot oxygenate" situation. *Anesthesiology* 2015; **123**: 995–6
  31. Paxian M, Preussler NP, Reinz T, Schlueter A, Gottschall R. Transtracheal ventilation with a novel ejector-based device (Ventrain) in open, partly obstructed, or totally closed upper airways in pigs. *Br J Anaesth* 2015; **115**: 308–16
  32. Berry M, Tzeng Y, Marsland C. Percutaneous transtracheal ventilation in an obstructed airway model in post-apnoeic sheep. *Br J Anaesth* 2014; **113**: 1039–45
  33. Rosenstock CV, Nørskov AK, Wetterslev J, Lundstrøm LH, the Danish Anaesthesia Database. Emergency surgical airway management in Denmark. A cohort study of 452 461 patients registered in the Danish Anaesthesia Database. *Br J Anaesth* 2016; **117**(Suppl. 1): i75–i82
  34. Duggan LV, Ballantyne Scott B, Law JA, Morris IR, Murphy MF, Griesdale DE. Transtracheal jet ventilation in the 'can't intubate can't oxygenate' emergency: a systematic review. *Br J Anaesth* 2016; **117**(Suppl. 1): i28–i38
  35. Howes TE, Lobo CA, Kelly FE, Cook TM. Rescuing the obese or burned airway: are conventional training manikins adequate? A simulation study. *Br J Anaesth* 2015; **114**: 136–42
  36. Kristensen MS, Teoh WH, Baker PA. Percutaneous emergency airway access; prevention, preparation, technique and training. *Br J Anaesth* 2015; **114**: 357–61
  37. Chrimes N. The Vortex: a universal 'high-acuity implementation tool' for emergency airway management. *Br J Anaesth* 2016; **117**(Suppl. 1): i20–i27
  38. Chrimes N. The Vortex: striving for simplicity, context independence and teamwork in an airway cognitive tool. *Br J Anaesth* 2015; **115**: 148–9
  39. Kristensen MS, Teoh WH, Rudolph SS. Ultrasonographic identification of the cricothyroid membrane: best evidence, techniques, and clinical impact. *Br J Anaesth* 2016; **117**(Suppl. 1): i39–i48

*British Journal of Anaesthesia* 117 (S1): i3–i5 (2016)

Advance Access publication 19 April 2016 · doi:10.1093/bja/aew054

## Paediatric difficult airway management: what every anaesthetist should know!

N. Jagannathan<sup>1,\*</sup>, L. Sohn<sup>1</sup> and J. E. Fiadjoe<sup>2</sup>

<sup>1</sup> Department of Pediatric Anesthesia, Ann & Robert H. Lurie Children's Hospital of Chicago, 225 E. Chicago Avenue, Box 19, Chicago, IL, USA, and

<sup>2</sup> Department of Pediatric Anesthesia, The Children's Hospital of Philadelphia, 34th Street and Civic Center Boulevard, Philadelphia, PA 19104, USA

\*Corresponding author. E-mail: simjag2000@gmail.com

Airway management remains a significant cause of morbidity and mortality in anaesthetized children. Children with difficult direct laryngoscopy are an especially vulnerable group. However, most paediatric anaesthetics are administered by generalists without advanced paediatric training. This editorial is aimed at

all practitioners who care for children, particularly those without advanced paediatric anaesthesia training. Our goal is to convey three important points: (i) the contributing factors for severe complications in this population; (ii) the important role of the supraglottic airway (SGA) in managing these patients; and (iii) the

ideal method of invasive airway access when oxygenation is compromised. We hope this editorial enhances the care and outcomes in this vulnerable patient population.

## The paediatric difficult airway is associated with a high risk for complications during airway management

A multicentre study of 1018 children with difficult airways in 13 paediatric centres (Paediatric Difficult Intubation registry) demonstrated that more than two direct laryngoscopy attempts in children with difficult tracheal intubation is associated with high failure rates and an increased incidence of severe complications.<sup>1</sup> In fact, every additional attempt beyond the first increased the proportion of patients with complications. This extensive study was the first to confirm that airway management in a paediatric difficult airway population cared for mostly by paediatric anaesthetists is associated with significant complication rates. In these children, tracheal intubation failed in 19 (2%) patients, and 204 (20%) children had at least one complication. The most common severe complication was cardiac arrest, which occurred in 2% of these children. The most common complication overall was transient hypoxaemia (oxygen saturation <85%). The results of this study should prompt anaesthetists caring for children to consider the following strategies: (i) minimize the number of direct laryngoscopy attempts, and transition to an indirect technique (videolaryngoscope/fibreoptic bronchoscope) when direct laryngoscopy fails; and (ii) consider a means for oxygenation of the lungs during tracheal intubation attempts (nasal cannula or supraglottic airway) to reduce the risk of complications and enhance patient safety. Lastly, this study also identified the following four independent risk factors that are associated with the increased risk of complications: more than two tracheal intubation attempts; weight less than 10 kg; short thyromental distance (micrognathia); and three direct laryngoscopy attempts before an indirect technique.<sup>1</sup>

## Supraglottic airways for the difficult airway: what is the evidence?

Use of an SGA is a distinctive step in many airway management algorithms.<sup>2-4</sup> An SGA may be used in situations where difficult ventilation, failed intubation, or both occur. The paediatric airway guidelines published by the Difficult Airway Society/Association of Paediatric Anaesthetists of Great Britain and Ireland suggests the use of an SGA, if feasible, when failed tracheal intubation occurs in children with difficult airways.<sup>5</sup> In the paediatric practice, general anaesthesia is often required for brief procedures (e.g. radiology, ophthalmological, or general surgery) which would typically not need any form of anaesthesia in adults. For these procedures, it may not always be necessary to intubate the trachea. In children with difficult airways, an SGA alone can be used to provide an adequate airway with low failure rates and should be considered for airway maintenance in this population.<sup>6</sup> Additionally, in the paediatric population, the SGA failure rate is lower than in the adult population (0.86<sup>7</sup> vs 1.1%<sup>8</sup>). Supraglottic airway failure in children is more likely in the presence of the following risk factors: ear/nose/throat surgery, inpatient procedures, prolonged surgical duration, congenital/acquired airway abnormalities, and patient transport.<sup>7</sup> Although these risk factors for failure have been identified, clinicians should have sufficient experience with the routine use of these devices and know how to recognize and troubleshoot causes for inadequate ventilation of the lungs, such as improper position or fit, and should remain vigilant for subtle signs of poor

device performance.<sup>9</sup> Additionally, all equipment necessary to perform tracheal intubation should be readily on hand and checked in the unlikely event that tracheal intubation is needed. Supraglottic airways have been very useful as a conduit for tracheal intubation in children with difficult airways.<sup>10-11</sup> Future analysis of the multicentre Paediatric Difficult Intubation registry may help to answer questions about the efficacy of SGAs in specific difficult airway populations; for instance, is fibre-optic tracheal intubation through an SGA superior to using a videolaryngoscope in the Pierre Robin infant?

## 'Cannot intubate, cannot oxygenate' in an infant: invasive airway access in children

The need for an emergency surgical airway in infants is very rare. Most anaesthetists may never even encounter this clinical situation in their career, especially in smaller children. There is a dearth of literature regarding invasive airway techniques in this patient population, and very little equipment development in this area. Most studies to date incorporate the use of rabbit<sup>12-13</sup> or pig models.<sup>14-15</sup> Moreover, the cricothyroid membrane is difficult to identify in this age group, and expeditious performance of a surgical airway is challenging even for a skilled paediatric otolaryngologist. In a crisis, therefore, the fastest option to oxygenate the lungs is most likely to be through a needle cricothyroidotomy. However, the use of 14, 16, or 18 gauge angiocatheters for needle cricothyroidotomy is not without risk. Animal studies demonstrate that, although invasive tracheal access may be successful on the first attempt in about 60-70%, placement of the needle is associated with perforation of the posterior tracheal wall.<sup>13-14</sup>

Once a needle cricothyroidotomy is appropriately placed in the trachea (pig model), adequate oxygenation has been demonstrated with a low-pressure oxygen supply (e.g. wall oxygen at 1-15 litres min<sup>-1</sup>) attached to an Enk Oxygen Flow Regulator (Cook Medical, Bloomington, IN, USA). This technique has been shown to provide effective oxygenation for at least 15 min<sup>16</sup> when oxygen is administered through an 18 gauge or larger diameter angiocatheter.<sup>17</sup>

In the event of complete upper airway obstruction, it has been shown that the Ventrain device (Dolphys Medical, Eindhoven, The Netherlands) may provide adequate oxygenation and ventilation through a small-bore transtracheal catheter.<sup>15</sup> This device may be of use in the 'cannot intubate, cannot oxygenate' situation in an infant but has yet to be studied in the infant animal model.

Lastly, although scalpel cricothyroidotomy is the recommended surgical airway technique in the new Difficult Airway Society airway algorithm for adults,<sup>4</sup> the evidence in children is lacking. One rabbit study demonstrated that the first attempt success rate was 100% but was associated with significant complication rates (posterior tracheal wall damage).<sup>12</sup> More studies on both techniques are still needed to help determine the best practice for smaller children, but currently, needle cricothyroidotomy remains the technique of choice in the 'cannot intubate, cannot oxygenate' situation in infants.<sup>5</sup>

In conclusion, although airway management strategies for children have come a long way during the past few years, with improvements in technique and equipment, management of the difficult paediatric airway still remains a problem associated with significant risks and complications. Future multicentre studies in this high-risk group may help us to determine the best airway practices for these children.

## Authors' contributions

Conception and design of the editorial, drafting the article, and final approval of the version to be published: N.J., L.S., J.E.F.

## Declaration of interests

N.J. is on the editorial board of *Pediatric Anesthesia* and *Journal of Anesthesia* (Japan). He has received products free of charge from Ambu and Teleflex corporations. He serves on the Medical Advisory board of Teleflex and has received travel support for meetings involving future developments for upcoming airway devices. J.E. F. and L.S.: none declared.

## Funding

Department of Pediatric Anesthesia at the Ann & Robert H. Lurie Children's Hospital of Chicago.

## References

1. Fiadjoe JE, Nishisaki A, Jagannathan N, et al. Airway management complications in children with difficult tracheal intubation from the Pediatric Difficult Intubation (PeDI) registry: a prospective cohort analysis. *Lancet Respir Med* 2016; **4**: 37–48
2. Law JA, Broemling N, Cooper RM, et al. The difficult airway with recommendations for management – part 2 – the anticipated difficult airway. *Can J Anaesth* 2013; **60**: 1119–38
3. Apfelbaum JL, Hagberg CA, Caplan RA, et al. Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway. *Anesthesiology* 2013; **118**: 251–70
4. Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. *Br J Anaesth* 2015; **115**: 827–48
5. APAGBI Paediatric Airway Guidelines. Available from <http://www.apagbi.org.uk/publications/apa-guidelines> (accessed 13 January 2015)
6. Jagannathan N, Sequera-Ramos L, Sohn L, Wallis B, Shertzer A, Schaldenbrand K. Elective use of supraglottic airway devices for primary airway management in children with difficult airways. *Br J Anaesth* 2014; **112**: 742–8
7. Mathis MR, Haydar B, Taylor EL, et al. Failure of the Laryngeal Mask Airway Unique and Classic in the pediatric surgical patient: a study of clinical predictors and outcomes. *Anesthesiology* 2013; **119**: 1284–95
8. Ramachandran SK, Mathis MR, Tremper KK, Shanks AM, Kheterpal S. Predictors and clinical outcomes from failed Laryngeal Mask Airway Unique: a study of 15,795 patients. *Anesthesiology* 2012; **116**: 1217–26
9. Asai T. Is it safe to use supraglottic airway in children with difficult airways? *Br J Anaesth* 2014; **112**: 620–2
10. Asai T, Nagata A, Shingu K. Awake tracheal intubation through the laryngeal mask in neonates with upper airway obstruction. *Pediatr Anesth* 2008; **18**: 77–80
11. Jagannathan N, Kho MF, Kozlowski RJ, Sohn LE, Siddiqui A, Wong DT. Retrospective audit of the air-Q intubating laryngeal airway as a conduit for tracheal intubation in pediatric patients with a difficult airway. *Pediatr Anesth* 2011; **21**: 422–7
12. Prunty SL, Aranda-Palacios A, Heard AM, et al. The 'can't intubate can't oxygenate' scenario in pediatric anesthesia: a comparison of the Melker cricothyroidotomy kit with a scalpel bougie technique. *Pediatr Anesth* 2015; **25**: 400–4
13. Stacey J, Heard AM, Chapman G, et al. The 'can't intubate can't oxygenate' scenario in pediatric anesthesia: a comparison of different devices for needle cricothyroidotomy. *Pediatr Anesth* 2012; **22**: 1155–8
14. Holm-Knudsen RJ, Rasmussen LS, Charabi B, Böttger M, Kristensen MS. Emergency airway access in children – trans-tracheal cannulas and tracheotomy assessed in a porcine model. *Pediatr Anesth* 2012; **22**: 1159–65
15. Paxian M, Preussler NP, Reinz T, Schlueter A, Gottschall R. Transtracheal ventilation with a novel ejector-based device (Ventrain) in open, partly obstructed, or totally closed upper airways in pigs. *Br J Anaesth* 2015; **115**: 308–16
16. Wong CFP, Yuen VM, Wong GTC, To J, Irwin MG. Time to adequate oxygenation following ventilation using the Enk oxygen flow modulator versus a jet ventilator via needle cricothyrotomy in rabbits. *Pediatr Anesth* 2014; **24**: 208–13
17. Baker PA, Brown AJ. Experimental adaptation of the Enk oxygen flow modulator for potential pediatric use. *Pediatr Anesth* 2009; **19**: 458–63

*British Journal of Anaesthesia* 117 (S1): i5–i9 (2016)

Advance Access publication 4 May 2016 · doi:10.1093/bja/aew055

# Airway management in the critically ill: the same, but different

A. Higgs<sup>1</sup>, T. M. Cook<sup>2</sup> and B. A. McGrath<sup>3,\*</sup>

<sup>1</sup> Department of Anaesthesia and Intensive Care Medicine, Warrington & Halton Hospitals NHS Foundation Trust, Lovely Lane, Warrington, Cheshire WA5 1QG, UK,

<sup>2</sup> Department of Anaesthesia, Royal United Hospitals Bath Foundation Trust, Combe Park, Bath BA1 3NG, UK, and

<sup>3</sup> Department of Anaesthesia and Intensive Care Medicine, University Hospital South Manchester, Southmoor Road, Wythenshawe, Manchester M23 9LT, UK

\*Corresponding author. E-mail: [brendan.mcgrath@manchester.ac.uk](mailto:brendan.mcgrath@manchester.ac.uk)

Airway management has had a central role in intensive care medicine even from its origins. When Danish Anaesthetist Björn Ibsen

applied his airway skills to victims of the 1952–3 Copenhagen poliomyelitis epidemic, the era of Critical Care Medicine was born.<sup>1</sup> The