British Journal of Anaesthesia **112** (4): 742–8 (2014)
Advance Access publication 8 December 2013 · doi:10.1093/bja/aet411

BJA

RESPIRATION AND THE AIRWAY

Elective use of supraglottic airway devices for primary airway management in children with difficult airways†

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Editor's key points

- Limited data are available concerning the utility of supraglottic airway (SGA) devices for primary management of the child with a difficult airway.
- This retrospective review of data from a single centre showed that SGA devices were successfully used in 96% of paediatric difficult airway patients receiving an SGA for primary airway management.

Background. Supraglottic airways (SGAs) have an established role in airway management of difficult airways in both adults and children. However, there are limited data regarding the use of SGAs for primary airway management in children. The aim of this study is to assess the success rates and adverse events related to the use of SGAs for primary airway management during anaesthesia in children with difficult airways.

Methods. A retrospective analysis of SGA use for primary airway management in the difficult airway population in a single centre over a 4-yr period was performed. Difficult airway was defined as either a history of difficult direct laryngoscopy (a documented Cormack and Lehane Grade 3 or greater and the need for an alternate device to direct laryngoscopy for successful tracheal intubation), a history of difficult mask ventilation, or both. The difficult airway condition, patient characteristic data, type and length of procedure, type and size of SGA placed, number of attempts for successful device placement, success/failure associated with the device during anaesthetic maintenance, and complications were recorded.

Results. A total of 77 272 children received general anaesthesia in a free-standing paediatric institution. Four hundred and fifty-nine patients were reported to have a difficult airway. Of those, 109 received general anaesthesia and an SGA for primary management, meeting the inclusion criteria for this study during a 4-yr period. An SGA was successfully used in 96% of these patients. In four patients, an alternative airway was needed.

Conclusions. SGAs can be effectively utilized for airway maintenance in the paediatric difficult airway population.

Keywords: difficult airway; laryngeal masks, paediatric; supraglottic airway

Accepted for publication: 17 July 2013

A difficult airway is characterized by an inability or difficulty to adequately establish bag mask ventilation and/or difficulty with conventional direct laryngoscopy.[1] Since their introduction in the 1980s, supraglottic airways (SGAs) have an established role in both routine and emergent airway management of difficult airways in both adults[2–6] and children.[7–10] In the difficult airway population, SGAs can provide adequate oxygenation and ventilation, while simultaneously acting as a conduit for fibreoptic-guided tracheal intubation. Additional advantages include the ability to overcome upper airway obstruction[11 12] and the possibility of maintaining the airway without the need for tracheal intubation.[3 13] These benefits have resulted in adoption of SGAs as standard practice in many difficult airway guidelines for both adults[1 14 15] and children.[16 17] In the literature on the difficult airway, there are more reports on the use of SGAs as a conduit for tracheal intubation than on the use of SGAs alone as the primary means for airway management in both adults and children.[1 8 9 17 18] In adults, it has been shown that SGAs can be successfully used as an alternative to tracheal intubation in the difficult airway, both electively, and for rescue of failed airways.[1 18–24] However, there are only a few reports regarding SGA use for primary airway management in children with difficult airways. There is minimal evidence regarding the prolonged use of SGAs in children with known difficult airways, and is limited to isolated case reports on their use in a failed airway,[25] and neonatal resuscitation.[26 27] Given the minimal data regarding elective use of an SGA for primary airway management in the anticipated paediatric difficult airway, we sought to examine the effectiveness of this technique as an

† This article is accompanied by Editorial III.

alternative to tracheal intubation. Therefore, the aim of this retrospective cohort study is to assess the success rates and adverse events related to the use of SGA devices for primary airway management during anaesthesia in children with difficult airways.

Methods

After receiving approval from the Ann & Robert H. Lurie Children's Hospital of Chicago Institutional Review Board, a retrospective analysis of our institution's electronic medical records was conducted. The inclusion criteria included all children between 1 day and 18 years of age with a difficult airway undergoing at least one surgical or medical procedure using an SGA for primary airway management during general anaesthesia, from 1 January 2009 to 1 January 2013. This period followed a practice change at this institution where use of an SGA for primary airway management became an alternative approach to tracheal intubation for some procedures in paediatric patients with a difficult airway.

Patient selection

All patients receiving general anaesthesia during this 48-month period were filtered by International Statistical Classification of Diseases and Related Health Problems (ICD)-9 codes on Epic (Epic Systems Corporation, Verona, WI, USA) using the following diagnoses associated with a difficult airway: Pierre Robin sequence, Treacher Collins, Hemifacial microsomia (Goldenhar syndrome), Sticklers syndrome, Mobius syndrome, Apert syndrome, Crouzon syndrome, Pfeiffer syndrome, Saethre–Chotzen syndrome, CHARGE syndrome (coloboma, heart defects, choanal atresia, growth retardation, genitourinary problems, and ear abnormalities), mucopolysaccharidoses (Hurler, Hunter, Sanfilipo, Morquio, Maroteaux–Lamy syndromes), Beckwith–Wiedemann syndrome, Freeman–Sheldon, Hallermann–Streiff, De Lange syndrome, tracheo/laryngomalacia, glottic web, subglottic stenosis, cystic hygroma, temporomandibular/cervical joint disease, and pharyngeal/laryngeal masses. These lesions were further classified into functional defects and include: supraglottic abnormalities (maxillary hypoplasia and mandibular hypoplasia), infiltrative diseases, chronic subglottic abnormalities, limited jaw, mouth, neck mobility, or all. A subsequent filter of 'difficult airway' as a keyword was then used to narrow the search further. Additionally, a second search strategy was conducted using the 'difficult airway' keyword without any other ICD-9 diagnosis to select for children with a history of difficult airway without an apparent aetiology. The electronic medical records of these final patients were then interrogated for an anaesthesia event using an SGA for primary airway management during their procedure.

The filter of difficult airway encompassed any patient with one or more of the above diagnoses with a description of difficult airway (difficult direct laryngoscopy defined as a documented Cormack and Lehane Grade of 3 or greater and the need for an alternate device for successful tracheal intubation (fibreoptic intubation, videolaryngoscopy, or both), difficult mask ventilation (defined as inadequate ventilation with the need for two-handed mask ventilation or impossible mask ventilation), or presence of both conditions. The exclusion criteria included any anaesthesia event where the trachea was primarily intubated using an SGA as a conduit for fibreoptic-guided tracheal intubation, and a description of isolated physical findings such as micrognathia or macroglossia in the chart without any other suggestion of a difficult airway. Successful use of the SGA was defined as use of the device to maintain anaesthesia without the need for replacement with an alternative airway (tracheal intubation or another SGA). In patients that received multiple anaesthetics, only the first anaesthetic was included in the study.

Patient characteristics such as age, sex, weight, height, ASA physical status, type of procedure, method of induction, type and size of SGA device placed, number of attempts for successful device placement, method of ventilation, success/failure associated with the device during anaesthetic maintenance, or the need to intubate the trachea, complications (regurgitation, laryngospasm, bronchospasm, airway obstruction, and oxygen desaturations); and anaesthetic depth on removal of the SGA were also recorded.

All data were entered into Microsoft Excel 2010 (Redmond, WA, USA) and statistical analysis was performed using the statistical software SAS (SAS 9.3; SAS Institute). Data are expressed as mean [standard deviation (SD)]. Descriptive statistics were calculated on both continuous and categorical data. Descriptive statistics for continuous variables were calculated using mean (SD) through univariate analysis, and categorical variables were calculated using their frequencies, *n* (%).

Results

A total of 77 272 patients received general anaesthesia during a period of 4 yr in this free-standing paediatric hospital. Four hundred and fifty-nine patients were reported to have a difficult airway. Of those, 109 received $\geq$1 general anaesthetics using an SGA for primary airway management meeting the inclusion criteria for this study. Figure 1 represents a flow chart for children meeting the inclusion criteria.

The principal conditions associated with a difficult airway were craniofacial syndromes related to maxillary hypoplasia (n=11), mandibular hypoplasia (n=39), infiltrative diseases (n=16), chronic subglottic abnormalities (n=21), and limited jaw, mouth, neck mobility (n=8). Fourteen patients did not have any reported disorder related to a difficult airway and were classified as unanticipated difficult laryngoscopy (Table 1).

Patient characteristics are represented in Table 2. Of the 109 patients using an SGA for primary airway management, 69 had multiple anaesthetics with an SGA. The success rate of SGA use was 105/109 or 96%. In four patients, an alternative airway was needed; in two patients the SGA was replaced by another SGA type or size, and in the other two patients, the trachea was intubated using a fibreoptic bronchoscope through the SGA (Table 3).

Procedures requiring general anaesthesia were radiology [including computerized tomography (CT) scans, magnetic resonance imaging (MRI), and interventional radiology (IR) procedures], general surgery, medical procedures (including

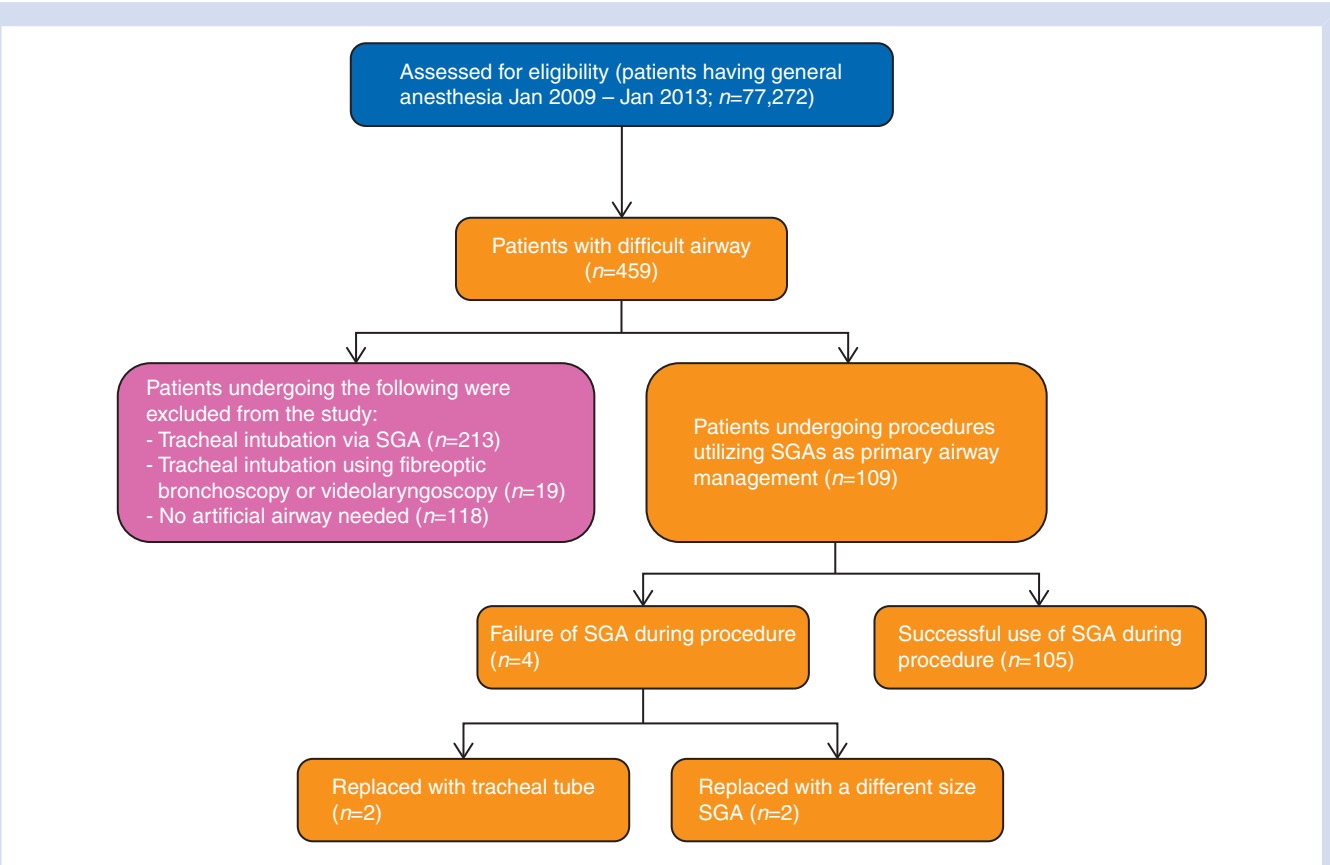

Figure 1 Flow chart representing inclusion criteria of patients with a difficult airway utilizing a SGA for primary airway management.

electromyography, auditory brain response testing, cardiac catheterization, and upper/lower gastrointestinal endoscopy), orthopaedic surgery, plastic surgery, urology, ophthalmology, and neurology. Table 4 represents the types of SGAs used and length and type of procedure. Mask induction was performed in 92 patients, of whom 13 also received additional i.v. agents. Seventeen patients underwent i.v. induction alone (Table 2). Spontaneous ventilation was utilized in all patients, with 43 patients requiring pressure support ventilation.

The SGAs used were: LMA Unique™ (Teleflex; Triangle Park, NC, USA): size 1 (n=1), size 1.5 (n=5), size 2 (n=33), size 2.5 (n=14), size 3 (n=14), and size 4 (n=2); air-Q™ (Mercury Medical Clearwater, FL, USA): size 1 (n=4), size 1.5 (n=16), size 2 (n=7), size 2.5 (n=6), size 3.5 (n=2), size 4.5 (n=1), and one case without documented size; and LMA Supreme™ (Teleflex): size 2 (n=2) and size 3 (n=1).

Oxygen desaturation (Sp_{O_2}<85%) during placement was documented in two patients. One patient had laryngospasm on inhalation induction which was successfully broken with continuous positive airway pressure, followed by successful use of the SGA. In the other patient, the SGA was removed at the conclusion of the procedure under a deep plane of anaesthesia, and the clinician was unable to adequately ventilate the lungs and immediate direct laryngoscopy was performed with a Grade IV laryngoscopic view. Subsequently, the air-Q™ was placed with successful fibreoptic-guided tracheal intubation. There were no episodes of regurgitation of gastric contents, bronchospasm, or death reported. Removal of the SGA was performed in the awake state in 42% (n=46) of the cases, and under a deep anaesthetic plane in 56% (n=61) of the cases.

Discussion

The main finding in this study is that in children with difficult airways, SGAs can be effectively utilized for airway maintenance for an extended period of time and for various medical and surgical procedures.

SGAs already have an established role in the management of difficult airways, and there are several reports on the use of SGAs (LMA and air-Q) for fibreoptic-guided tracheal intubation in the paediatric difficult airway population.[7–9 11 17 28–31] We and others have previously reported on the effectiveness of SGAs for oxygenation and ventilation in the difficult airway population before fibreoptic-guided tracheal intubation.[8 9] The results of this study further suggest that the airway can be maintained with the SGA alone without the need for tracheal intubation in cases where risk of pulmonary aspiration is low. Although some difficult airway algorithms suggest the use of these devices for primary airway maintenance if the trachea cannot be intubated,[1 15 16] reports on the feasibility of using an SGA in this setting is limited in children.

The relatively high success rates of SGA use observed in this study could be attributed to the fact that children with difficult

Table 1 Functional classification of the difficult airway conditions in the study cohort ($n=109$)

Functional problem	Anatomic features	*n* (%)
Supraglottic abnormalities	*Maxillary hypoplasia*:	
	Apert syndrome	8 (7.4)
	Crouzon syndrome	1 (0.9)
	Pfeiffer syndrome	1 (0.9)
	Saethre–Chotzen syndrome	–
	DiGeorge syndrome	1 (0.9)
	Mandibular hypoplasia:	
	Pierre Robin sequence	8 (7.4)
	Treacher Collins	3 (2.8)
	Goldenhar syndrome	14 (12.8)
	Sticklers syndrome	1 (0.9)
	Mobious syndrome	1 (0.9)
	Micrognathia	10 (9.2)
	CHARGE association	2 (1.8)
Infiltrative diseases	*Mucopolysaccharidoses:*	
	Hurler syndrome	4 (3.7)
	Hunter syndrome	3 (2.8)
	Sanfilipo syndrome	1 (0.9)
	Morquio syndrome	5 (4.6)
	Maroteaux–Lamy syndrome	1 (0.9)
	Other:	
	Beckwith–Wiedemann syndrome	–
	Sturge–Weber syndrome	2 (1.8)
Chronic subglottic abnormalities	Subglottic stenosis	8 (7.4)
	Tracheal stenosis	3 (2.8)
	Laryngo/tracheomalacia	7 (6.4)
	Masses (neck/parapharyngeal)	3 (2.8)
Limited jaw, mouth neck mobility	Freeman–Sheldon	1 (0.9)
	Noonan syndrome	1 (0.9)
	Spinal fusion	1 (0.9)
	Cervical stenosis	1 (0.9)
	Cervical instability	2 (1.8)
	Alagille syndrome	2 (1.8)
Unanticipated difficult airway	Difficult direct laryngoscopy	14 (12.9)
Total		109 (100)

airways often have anatomic lesions affecting the face, jaw, tongue, mouth, upper airway, or all, with unlikely disease involving the lower airways. The successful use of the SGA in these children suggests that the device can bypass these anatomic defects to seat in the hypopharynx and maintain a patent airway during anaesthetic maintenance. It was not possible to definitely include all cases where the clinician might have opted not to attempt the use of an SGA because of anticipated difficulty or failure of the device. Therefore, the unintentional exclusion of these patients might overestimate the efficacy of our results. For these reasons, the results in this study cannot be extrapolated to all children with difficult airways.

The practical utility of SGAs for primary airway management in the difficult airway population has several clinical implications: first, the SGA can be used as a ventilation and oxygenation conduit, and, if intraoperative conditions change, offers

Table 2 Patient, surgical, and anaesthetic characteristics of the study cohort ($n=109$). Values are reported as number (percentage) unless otherwise denoted as mean (SD). ENT ear, nose, and throat; SGA, supraglottic airway; SD, standard deviation

Characteristics	*n* (%)
Age, yr; mean (SD)	6.4 (5)
Gender	
Female	44 (40.4)
Male	65 (59.6)
Weight, kg; mean (SD)	23.8 (16.5)
Height, cm; mean (SD)	111.0 (30.6)
ASA status	
I	–
II	43 (39.5)
III	64 (58.7)
IV	2 (1.8)
History of difficult airway	
Difficult direct laryngoscopy	98 (89.9)
Difficult direct laryngoscopy and mask ventilation	11 (10.1)
Type of procedure	
ENT	14 (12.8)
General surgery	14 (12.8)
Medical/minimal invasive	11 (10.1)
Neurosurgery	1 (0.9)
Ophthalmologic	4 (3.7)
Orthopaedic	10 (9.2)
Plastic	5 (4.6)
Radiologic	47 (43.1)
Urologic	3 (2.8)
Type of anesthetic agent used for induction	
Sevoflurane	79 (72.5)
Propofol	16 (14.7)
Sevoflurane and propofol	13 (11.9)
Propofol and ketamine	1 (0.9)
SGA used	
LMA Unique™	69 (63.3)
Air-Q™	37 (33.9)
LMA Supreme™	3 (2.8)
Number of attempts for successful SGA placement	
1	105 (96)
2	1 (1)
3	3 (3)
Successful use of SGA during the procedure	
Yes	105 (96.3)
No	4 (3.7)
Need for tracheal intubation	
Yes	2 (1.8)
No	107 (98.2)
Complications	
Regurgitation	–
Laryngospasm	2 (1.8)
Bronchospasm	–
Airway obstruction	–
Oxygen desaturation ($Sp_{O_2}<85\%$)	2 (1.8)
Total	4 (3.6)

Table 3 Cases of SGA failure during anaesthesia. FOI, fibreoptic intubation; SGA, supraglottic airway; CPAP, continuous positive airway pressure; MRI, magnetic resonance imaging

Age (months)	Cause of difficult airway	SGA type	SGA size	Reason for replacing the SGA	Definitive airway device used for the procedure	Type of procedure	Complications	Comments
3	Mandibular hypoplasia. History of difficult direct laryngoscopy needing FOI	LMA Unique™	2	Difficult placement of initial devices→SGA downsized	LMA Unique™ size 1	Transthoracic echocardiogram	Laryngospasm desaturation (lowest: Sp_{O_2} of 40%)	Difficulty seating of LMA size 1.5 and air-Q™ size 1. Laryngospasm broken with CPAP, LMA size 1 then placed for remainder of case
126	Parapharyngeal Rhabdomyosarcoma	LMA Unique™	3	Large airway leak→SGA upsized	LMA Unique™ size 4	Venous port insertion	None	Large airway leak during procedure, LMA size 3 replaced by LMA size 4
11	Hurler syndrome	LMA Unique™:flexible	2	Surgeon unable to position mouth gag→partial airway obstruction	Cuffed 4.0 tracheal tube	Bilateral ear irrigation/ MRI/adenoidectomy/ central line placement	None	Difficult direct laryngoscopy: Grade IV view. FOI through LMA Unique™ then performed successfully on first attempt
77	Hunter syndrome	Air-Q™	2.5	Desaturation/loss of end tidal CO_2→complete airway obstruction	Cuffed 6.0 tracheal tube	Bilateral carpal tunnel release	Desaturation (lowest: Sp_{O_2} of 94%)	Air-Q™ removed and replaced allowing marginal ventilation. Replaced by another air-Q™ size 2 with FOI through air-Q™, despite ongoing poor ventilation

Table 4 Time and type of procedure performed and type of successful use of SGA (n=105). ENT, ear, nose and throat; SD, standard deviation; SGA, supraglottic airway

Type of procedure	Mean time in minutes (SD)	Type of SGA		
		LMA Unique™	Air-Q™	LMA Supreme™
ENT	123.1 (79.6)	12	1	0
General surgery	61.6 (34.7)	10	4	0
Medical/minimal invasive	90.5 (27.3)	6	3	0
Neurosurgery	32	1	0	0
Ophthalmologic	141.7 (31.4)	0	4	0
Orthopaedic	93 (34.2)	6	3	0
Plastic	80 (36.6)	0	5	0
Radiologic	76.2 (36.3)	29	16	2
Urologic	97.7 (55.8)	2	0	1
Total	86.2 (47.2)	66	36	3

a relatively straightforward path to intubate the trachea. As a result, the clinician's 'Plan A' (SGA alone for airway maintenance) and 'Plan B' (conversion to tracheal intubation through the SGA) is encompassed with one airway management strategy (as seen with two of the failures in this study). Secondly, during off-site general anaesthetics (i.e. CT, MRI, and IR), children with a difficult airway may need to have their trachea intubated in the operating theatre before being transported to an off-site location, then subsequently transported back to the operating theatre for tracheal extubation. This process can be precarious, present scheduling challenges, and require additional resources and equipment. The use of an SGA in this setting can reduce the need to transport these patients. Thirdly, as children with a difficult airway often present for multiple procedures requiring general anaesthesia, the successful use of these devices in one anaesthetic might influence the decision to use an SGA for a subsequent general anaesthetic. Finally, SGAs offer a less invasive option when compared with tracheal intubation. In this study, the rates of complications were relatively low, even with its use in children with a known diagnosis of a difficult airway.

There are several limitations to this study: (i) the relative under- and over-reporting of patients inherent in a retrospective study design, including inconsistent documentation of anaesthesia records; (ii) the possibility that certain difficult airway lesions improved from the time of initial difficult airway documentation to the time the child underwent anaesthesia with an SGA; and (iii) the use of an SGA is a decision based on multiple factors including type/length of procedure and comfort level of the clinician. These confounding factors could have influenced our results and the decision to proceed with tracheal intubation *vs* using an SGA for some procedures.

In conclusion, SGAs can be an effective option for airway maintenance in the paediatric difficult airway population. Future prospective studies are now indicated to stratify the factors that might be associated with failure of an SGA and which type(s) of patients, procedures, and SGAs are best suited for children with difficult airways.

Authors' contributions

N.J., L.S.-R., L.S. contributed to the conception and design of the study, data acquisition, analysis and interpretation of the data, drafting the article, and the final approval of the version to be published. A.S. and B.W. contributed to data acquisition, drafting the article, and the final approval of the published version. K.S. contributed to analysis and interpretation of the data, drafting the article, and approval of the final version to be published.

Declaration of interest

None declared.

Funding

None.

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