Review Article:

Comparing Supraglottic Airway Devices for Airway Management During Surgery in Children: A Review of Literature

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Citation: Hendinezhad MA, Babaei A, Gholipour Baradari A, Zamani A. Comparing Supraglottic Airway Devices for Airway Management During Surgery in Children: A Review of Literature. Journal of Pediatrics Review. 2019; 7(2):89-98. http://dx.doi.org/10.32598/jpr.7.2.89

doi: http://dx.doi.org/10.32598/jpr.7.2.89

Funding: See Page 94

Article info:
Received: 18 March 2018
First Revision: 05 April 2018
Accepted: 15 May 2018
Published: 01 April 2019

Keywords:
Supraglottic airway device, Children, Fiberoptic Bronchoscopic View (FBV), Oropharyngeal Leakage Pressure (OLP)

ABSTRACT

Context: Supraglottic Airway Devices (SADs) are applied in airway management of pediatric emergency conditions.

Objective: This review study aimed to examine the literature regarding pediatric supraglottic airway devices, to introduce the optimal devices in terms of Oropharyngeal Leak Pressure (OLP), risk of insertion failure on the first attempt and risk for blood staining of the device.

Data Sources: An electronic search was conducted on MEDLINE, EMBASE, CINAHL and PubMed databases. We also searched the Cochrane database (CENTRAL) and Web of Science up to July 1, 2017.

Study Selection: Of 112 potential studies, the full texts of 53 articles were available, in which 15 were duplicated and omitted, accordingly. Papers which did not directly discuss SADs were also excluded. In total, 30 papers were identified related to the children supraglottic devices.

Data Extraction: The current review was conducted and reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement.

Results: The LMA ProSeal may be the best supraglottic airway device for children due to its high oropharyngeal leakage pressure and low risk of insertion failure. It seems that i-gel is a very functional tool as well.

Conclusions: Further research is recommended to investigate the most appropriate supraglottic airway in diverse clinical situations and various conditions among children.

1. Context

Supraglottic Airway Devices (SADs) are widely used for airway management (1). Children who undergo surgeries benefit most from the use of SADs. A variety of SGAs are used for the management of a difficult airway as well as a conduit for tracheal intubation in children (2). Advantages of endotracheal intubation assisted by SADs such as effortless insertion, improved alignment of the glottic opening, and continuous patient oxygenation and ventilation, have been well documented. In addition, hemodynamic stress

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response to intubation by SADs is less than the conventional methods (3). Such devices could be an excellent alternative for patients with previous history of difficult intubation, limited neck movement, and unstable cervical spine (4). Moreover, SADs facilitate overcoming upper airway obstruction and provide a hands-free airway support with a relatively straightforward path to the larynx (5). However, despite all evidence, choosing the optimal SAD is not a simple decision.

2. Objective

The present review study aimed to examine the literature regarding pediatric SADs, to draw recommendations for future investigations and integrate the evidence.

3. Data Sources

The following steps were taken to thoroughly review the relevant literature. We conducted an electronic search was conducted on MEDLINE, Embase, CINAHL and PubMed databases. We also searched the Cochrane database (CENTRAL), and Web of Science up to July 1, 2017.

4. Study Selection

Studies on subgroups like those comparing devices in children and reports of their usage were included. The keywords used for the search strategy were "supraglottic device", "supraglottic airway device", "laryngeal mask", "children", "child," and "pediatric". A review of reference lists of articles was performed to identify further references. Two authors independently scanned the titles and abstracts identified by the above-mentioned search strategies. All randomized trials comparing any types of supraglottic airway devices in children were included. Similarly, cost-effectiveness analysis and case reports of rare complications in the emergency ward were also included in this review to consider every chance of adverse effects for clinicians.

5. Data Extraction

Of 112 potential studies, 53 full texts of papers were accessible. Initially, the full text versions of potentially eligible studies selected by at least one reviewer were assessed. Any disagreement was resolved through discussion. Papers in English were considered eligible. Then, the extracted data were sorted into prepared data extraction tables. We extracted such data as patients' frequency, type of Laryngeal Mask Airway (LMA), study design and predominant findings. Finally, a structured narrative summary of the studies was conducted using 30 papers related to the supraglottic devices for children.

6. Results

A comprehensive search was conducted. The following SADs were included in the review: LMA Classic, LMA ProSeal™, LMA Supreme, LMA Flexible™, LMA Unique, i-gel, Laryngeal Tube™, self-pressurized air-Q™, Cobra perilaryngeal airway™, and Ambu Aura-i™. In total, 30 papers related to supraglottic devices for children were identified. These qualitative studies were conducted in various settings, including accident and emergency department or operating rooms. A review of recent literature is presented in Table 1 and further discussed in the article.

A brief review of the recent literature indicate that SADs such as the i-gel, LMA ProSeal and Cobra perilaryngeal airway demonstrate higher OLP in most studies focusing on OLP. Evidence also revealed that the risk of device failure may be lower with LMA ProSeal, LMA-Classic and LMA-Unique (34-36), but higher with i-gel (37, 38). Moreover, the risk of blood staining of the device was greatly lower with i-gel compared to LMA-Classic and LMA ProSeal. In summary, the LMA ProSeal seems to be the best supraglottic airway device for children because of its high OLP and low risk of insertion failure. Also, i-gel appears to be a very functional tool.

6.1. Outcome measures for rating success in LMA insertion

6.1.1. Cuff pressure

When the supraglottic cuff pressure is more than the mucosal perfusion pressure, postoperative pharyngolaryngeal symptoms such as a sore throat (dysphagia or dysphonia) or local mucosal trauma and nerve injuries are expected (39). SGAs with inflatable cuffs are prone to over inflation and may cause pressures higher than 60 cm H_2O (40). Elevated pressures do not provide better seal, and are conversely liable to cause more morbidity (41, 42).

6.1.2. Oropharyngeal Seal Pressure (OSP)

An effective glottic seal is necessary for efficient ventilation. Moreover, an appropriate seal facilitates the maintenance of preferred anaesthetic depth without polluting the environment with the leaked gases. It also decreases leak into the esophagus, preventing rise in intragastric pressure and the risk of regurgitation (43).

6.1.3. Fiberoptic view through a supraglottic device

Most studies have correlated the Fiberoptic BronchosCopy (FOB) view through the SGA with the ease of intubation and ventilation (36). However, the FOB scoring

is challenged, as a dependable tool for SGA positioning (17) (Figure 1). The usage of fiberoptic score was suggested by Cook and Cranshaw (44). Left to right view: View I (I = ideal), View H (H: too high), and View L (L: too low), respectively; Arrow: lingual tonsils. Further evidence about FOB in different studies are demonstrated in Table 1 A full glottic view (although it seems unnecessary) is recommended for primary ventilation, to avoid possible trauma.

6.1.4. Problems and failures

Airway obstruction can arise due to malposition, obstruction by the epiglottis, laryngospasm, biting, or kinking of the tube. Light plane of anesthesia can also lead to laryngospasm and airway obstruction in children (37). Lingual edema and aspiration of stomach contents are other potential complications. The younger and smaller the child, the higher the risk of developing problems in this area (25, 30). Higher experience significantly decreases such problems (18).

7. Discussion

The main findings of the current study were as follows: i-gel, LMA ProSeal, and Cobra perilaryngeal airway had a higher OLP than the other devices; the risk of device failure may be lower with LMA-ProSeal, LMA-Classic, and LMA-Unique (34, 35), but higher with i-gel (37, 38). On the other hand, most studies demonstrated that the risk of blood staining device was considerably lower with using i-gel, compared to the LMA-Classic and LMA-ProSeal (40). However, high quality randomized trials are required to confirm the results regarding laryngeal tube.

Table 1. Characteristics of the papers on pediatric LMAs practice

Source	Year of Study	Samples	Device	Study Design	Result
Ahn (6)	2016	789	Air-Q (air-Q)	Meta-analysis	There were no differences between Air-Q and the classic form, in terms of leakage pressure and device insertion time; notably less ease of insertion, and success rate and better Fiberoptic Bronchoscopy View (FBV).
Jagannathan (1)	2010	100	air-Q™	Prospective study	Main findings were easy placement, quick removal of the Intra Laryngeal Airway (ILA) after successful intubation without dislodgement of the tracheal tube and recommendation of fiber-optic bronchoscopy-assisted tracheal intubation insertion through this device.
Darlong (7)	2015	64	air-Q vs. Ambu Aura-i	Prospective study	Air-Q ILA provided significantly higher Oropharyngeal Leakage Pressure (OLP) than the Ambu Aura-I, but longer insertion time. No differences were observed in the rate of initial insertion success, FBV, and postoperative complications.
Jagannathan (8)	2012	50	Supreme™ vs Unique™	Clinical trial study	LMA Unique showed higher success rate in insertion time. Airway leak pressures of the Supreme and Unique devices were 20 and 15 cm H_2O, respectively. Gastric insufflation was lower with the Supreme device. Supreme and unique devices showed same performances, especially by evacuation of gastric content during anesthesia.
Kleine Brueggeney (9)	2015	80	Ambu Aura-i vs. Air-Q	Clinical trial study	Blind intubation was possible in 15% with the Air-Q and in 3% with the Ambu Aura-i. Rates of insertion success were 95% (Air-Q) versus 100% (Ambu Aura-i). There were no differences in FBV. Fibreoptic guidance is recommended with both devices.
Pejovic (10)	2016	25	i-gel LMA vs. face mask	Manikin study	Staff successfully inserted i-gel in all 3 occasions. However, the face mask was not effective enough to maintain positive pressure ventilation and failed in the first, second and third attempts.
Beylacq (11)	2009	50	i-gel	Prospective study, observational study	Device insertions were completely successful on the first attempt. The mean seal pressure was 25 cm H_2O and there was no gastric inflation.
Bortone (12)	2006	30	laryngeal tube (LT) vs. LMA Classic™	Prospective study	LMA showed better efficacy compared to the LT group in achieving spontaneous or assisted ventilation after initial positioning and after head extension or device. Moreover, the LMA group showed better FBV than LT group.
Jagannathan (13)	2011	2	air-Q ILA	Case report	Successful blind tracheal intubation via the lumen of the air-Q ILA was performed on both cases of failed laryngoscopy in pediatric patients with blood in the airway.
Szmuk (14)	2005	1	CobraPLA™	Case report	This study was the first report of successful management of difficult airway (mask ventilation).

Source	Year of Study	Samples	Device	Study Design	Result
Baker (15)	2010	100	cLMA™ Ambu AuraOnce™, Portex Soft Seal™, Boss silicone LM LMA Unique™	Clinical trial	Resistance to bronchoscope manipulation during flexible bronchoscopy was higher using Ambu, Unique™, and Portex devices than cLMA™. The Unique™ and Ambu were clinically inferior to the cLMA™ at all levels of the airway. Single-use LMAs were less effective than the cLMA™ and laryngeal masks for flexible bronchoscopy in children.
Gaitiani (16)	2008	80	Airway-Unique (LMAU) Vs. Cobra PLA™	Prospective cohort study	Cuff seal pressure and end-tidal CO_2 were significantly higher for CobraPLA™ than LMAU. Oxygenation, respiratory variables, time and ease of insertion were similar in both devices. Fiberoptic scores were excellent with both devices. There was a low rate of mucosal blood staining and no sore throat due to the use of devices.
Goyal (17)	2012	120	Size 2 i-gel vs. ProSeal Laryngeal Mask Airway (PLMA) and Classic_ Laryngeal Mask Airway(cLMA)	Prospective cohort study	Success rate for first attempt was 95% in the i-gel group and 90% in the two laryngeal mask airway group. No clinically important complications was reported in the postoperative period. Pediatric size 2 i-gel insertion is easy and provides higher OSP compared to the same size PLMA and cLMA in spontaneously breathing children under elective surgery.
Hughes (18)	2012	154	i-gel	Observational study	First and second insertion attempts were successful in 93.5% and 5.8% of patients, respectively. Leak pressure was 20 cm H_2O. Gastric tube was inserted in 90% of the cases. The vocal cords were visible in 97% of patients in fiberoptic examination. Complications arose in 20% of patients, but the majority were minor. Anesthetists commented that the device shifted for upward displacement out of the mouth and that extension toward the forehead and flexion toward the feet of the proximal tube decreased the quality of the airway.
Yeoh (19)	2015	70	i-gel	Case series	The rate of insertion success and insertion time were 96% and 25 s, respectively. Complication occurred in 24.3% of the cases. Optimizing ventilation with i-gel was possible.
Jagannathan (20)	2012	168	i-gel™ vs. Supreme	Clinical trial	Airway leak pressure, number of attempts and insertion time for the i-gel were higher than the Supreme device. There were no differences in the time for device insertion, fiberoptic grade of view, quality of airway, and complications.
Nirupa (21)	2016	100	i-gel™ vs. ProSeal™	Prospective study	The Oropharyngeal Leak Pressure (OLP) for the i-gel™ group was 29.5 ± 2.5 cm H_2O, compared to 26.1 ± 3.8 cm H_2O in the PLMA™ group. Insertion time and quality of initial airway were greater with i-gel™ but the number of attempts, ease of insertion of supraglottic device, insertion of orogastric tube and pulmonary mechanics were similar in both devices.
Jagannathan (22)	2012	100	i-gel™ vs. Supreme	Prospective cohort study	The leak pressures (22), possibility of gastric decompression and insertion success rate suggest that the supreme device may be a more effective device for positive pressure ventilation in children.
Jagannathan (23)	2009	5	air-Q	Case series	The study reported a case series of patients with anticipated difficult airway and the air-Q ILA was successfully used for them as a conduit for fiberoptic intubation.
Jagannathan (24)	2011	354	air-Q ILA_ (ILA-SP)	Prospective cohort study	Three patients reverted to use a standard laryngeal mask airway or a tracheal tube. The mean initial airway leak pressure for all patients was 17.8, and changed to 20.4 when re-checked 10 minutes later. Complications were limited to 14 patients.
Jagannathan (25)	2012	120	Aura-i vs. the air-Q	Prospective study	There were no differences in the successful insertion time, leak pressure, and time of removal. However, with the size 1.5 Aura-i, the pilot balloon of the tracheal tube was removed to facilitate taking out of the device after tracheal intubation.
Jain (26)	2015	30	i-gel™	Prospective cohort study	OPLP was significantly higher in flextion and lower in extension, in comparison to the neutral position. However, it was worse in the fiberoptic view and ventilation in flexion compared to the neutral position.

Source	Year of Study	Samples	Device	Study Design	Result
Sunder (27)	2012	90	Flexible laryngeal mask airway (LMA™) vs. CobraPLA™	Prospective cohort study	A higher incidence of intraoperative device displacement was noted with the CobraPLA™ in comparison to flexible LMA™ especially in strabismus operation. Insertion characteristics and ventilation parameters were equivalent. Higher surgeon discontent was seen in the Cobra group.
Kelly (28)	2008	100	ProSeal LMA	Prospective cohort study	The overall success rate of the first attempt was 93%. Median leak pressure was 25 cm H_2O. No episodes of regurgitation and complication were recorded.
Kim (29)	2015	80	i-gel™ vs. the self-pressurized air-Q™	Clinical trial	i-Gel had easier insertion and better sealing, and the air-Q improved fiberoptic views.
Kus (30)	2014	60	i-gel™ vs. Supreme LMA	Clinical trial	OLP and the success rate of first attempt for the LMA-S was significantly higher than i-gel. Insertion time of the LMA and gastric tube for the LMA-S were shorter than i-gel. However, fibreoptic laryngeal views were similar in both groups.
Al-Mazrou (31)	2010	60	ETT vs. LMA	Prospective cohort study	LMA is an appropriate tool for pediatric patients undergoing sinonasal surgery due to its acceptable airway protection from blood contamination.
Mitra (32)	2012	60	Size 2.5 i-gel vs. ProSeal LMA	Prospective cohort study	Hemodynamic parameters, ease of insertion and postoperative complications were similar between i-gel and PLMA. However, the airway sealing pressure was significantly higher in i-gel.
Pandey (33)	2015	60	Air-Q vs. ETT	Prospective study	Air-QILA is an easy way to place SAD with tremendous airway seal and low airway morbidity. It seems to be a useful conduit for blind orotracheal intubation in supine position and can be used as an alternative to FOB in poor resource settings.

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A variety of modern SGAs for using in children have emerged. It is important to introduce those into practice and assess the potential advantages and disadvantages of each device through clinical evaluations. Table 1 summarizes the discussed SGAs and outlined potential areas of concern. Despite the variety of modern devices, the cLMA, ProSeal, and Unique are still the best devices in pediatric use for different conditions. The cLMA has been the standard SGA for many years. However, many other first generation devices have been available in small sizes with further features and better performance, since 2003 (18, 30, 45). For example, Cobra PLA was designed to be placed in the hypopharynx and composed of a breathing tube with a wide distal end and a number of slots or bars (46).

A cuff is attached proximal to the wide part, and serves to seal off the distal end from the upper airway when it is inflated and a softened 'tongue', which bends for better passage (16). Variations of LMAs like ProSeal, Unique, Supreme, and iLMA have been marketed in practice and discussed in the literature (47). The i-gel is rather an exceptional SAD with a gel-like thermoplastic and a non-inflatable cuff (48) which achieves an effective perilaryngeal

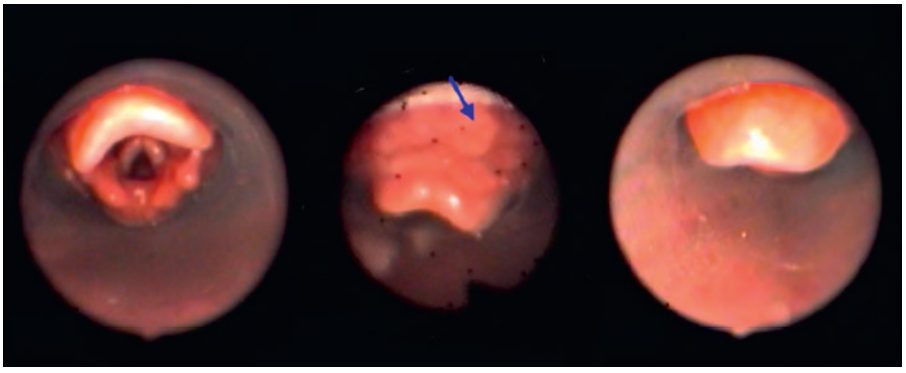

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Figure 1. The positioning of LMA; using the fiberoptic score suggested by Cook and Cranshaw (44). Left to right show View I (I=ideal), View H (H=too high) and View L (L=too low) respectivly; Arrow=lingual tonsil.

seal because of its feasibility to shape patient's airway structure (20). In addition, the device is equipped with a bite block and a buccal cavity stabilizer that stop the device malrotation and a gastric channel (22).

The recent studies demonstrated the efficacy and safety of the device, for example, Pejovic in a manikin study, compared i-gel with face mask and reported that the i-gel accomplished a 100% success rate on all occasions by trainees (10). Yeoh, et al. also reported the advantages of size 2 i-gel™ in children in terms of ease of insertion and low number of attempts on insertion (19). Novel design of i-gel made it a suitable tool with an appropriate OLP and low risk of complication.

LMA Supreme is similar to LMA ProSeal except its single usage and its introducer shaft features. Various studies have declared acceptable airway characteristics of LMA supreme to apply in children (20, 22, 35, 36). Jagannathan et al. (49) and Francksen et al. found it comparable with the LMA ProSeal and i-gel, respectively and recommended it as a useful alternative to ProSeal LMA (50). A prospective cohort study by Gaitini et al. compared the Supreme size II with LMA ProSeal and found it similarly effective on higher oropharyngeal seal pressure during spontaneous ventilation in children (51) that make it an optimal tool in difficult or emergency airway management.

The air-Q™ LMA is also a modern SAD that allows passage of cuffed tracheal tubes and has the option of successive removal. In addition, the airway tube is broader, more rigid, and curved. Air-Q features facilitate the use of ILA as a conduit for tracheal intubation (23). Finally, the Ambu Aura-i is easy to insert and provides equal or better OSP than CLMA and Unique, respectively, in adults (52, 53). It is also a suitable tool for blind endotracheal intubation (44). Therefore, it has become a frequently used device for various short surgical procedures, even in children. These devices are definitely appropriate to apply on children undergoing many surgical procedures. Further research is required to investigate the most appropriate supraglottic airway devices in diverse clinical situations and various conditions among children.

8. Conclusions

The LMA ProSeal and i-gel may be the best optimal supraglottic airway devices for children due to their unique features. However, there is little knowledge in this regard and more research studies must be conducted to recognize the most appropriate supraglottic airway devices in diverse clinical situations and various conditions in children.

Ethical Considerations

Compliance with ethical guidelines

There is no ethical principle to be considered doing this research.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors contributions

The authors contributions is as follows: Investigation, writing review and edit: Mir Ahmad Hendinezhad, Anahita Babaei; and Supervision: Afshin Gholipour Baradari.

Conflict of interest

The authors declare no conflict of interest.

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