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*Review Article*

# Supraglottic airway devices: a powerful strategy in airway management

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**Abstract:** The escalating airway management demands of cancer patients have prompted us to continually curate airway devices, with supraglottic airway devices (SADs) playing a significant role in this regard. SADs serve as instrumental tools for maintaining an open upper airway. Since the inception of the earliest SADs in the early 1980s, an array of advanced and enhanced second-generation devices have been employed in clinical settings. These upgraded SADs integrate specific features designed to enhance positive-pressure ventilation and mitigate the risk of aspiration. Nowadays, they are extensively used in general anesthesia procedures and play a critical role in difficult airway management, pre-hospital care, and emergency medicine. In certain situations, SADs may be deemed a superior alternative to endotracheal tube (ETT) and can be employed in a broader spectrum of surgical and non-surgical cases. This review provides an overview of the current evidence, a summary of classifications, relevant application scenarios, and areas for improvement in the development or clinical application of future SADs.

**Keywords:** Tumour, supraglottic airway devices, difficult airway, extubation

## Introduction

Cancer continues to rank as the leading cause of mortality and a substantial impediment to life expectancy enhancement globally. The prevalence of malignant tumours is notably high, with female breast cancer, lung cancer, colorectal cancer, prostate cancer, and stomach cancer representing the majority of cases [1]. Head and neck tumours exhibit a considerable incidence rate, exceeding 380,000 new diagnoses annually worldwide, necessitating proficient airway management. Moreover, the majority of oncology patients undergo general anesthesia or intensive care unit (ICU) sedation for surgical procedures. Therefore, it is essential to ensure the safety of airway management in these patients.

Good airway management is a necessary means to keep the airway unobstructed, which is crucial to ensure the life safety of patients [2]. Difficult airway is one of the most prevalent challenges in airway management. For example, respiratory arrest or respiratory failure can occur in patients with advanced malignancy, where an airway cannot be maintained due to an altered level of consciousness, and endotracheal intubation may be difficult in an emergency situation, so it is important to have an appropriate back-up strategy. In many cases, supraglottic airway devices (SADs) can replace endotracheal intubation to manage airway [3, 4].

In accordance with the 2022 Practice Guidelines for Management of the Difficult Airway published by the American Society of Anesthesiologists (ASA), various observational studies have demonstrated successful supraglottic airway insertion and intubation rates ranging between 65% and 100% among anticipated difficult airway patients [5]. The SAD finds its application in both pre- and in-hospital environ-

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**Table 1.** Cook's classification

| Classification | Introduction | Examples |
|---|---|---|
| 1st Gen SAD [14, 20, 21, 31, 43, 65] | Simple breathing tube, usually with some form of mask or opening at the larynx. | Classic LMA, LMA-Unique, Cobra-PLA, laryngeal tube airway |
| 2nd Gen SAD [22, 26, 27, 35, 48] | Features of 1st generation plus provision for gastric drainage and improved protection against aspiration. | Combitube, LMA ProSeal, LMA Supreme, I-gel |
| 3rd Gen SAD [19] | Features of 2nd generation plus Incorporates dynamic sealing mechanism. | Baska |

ments, encompassing elective and emergency anesthesia, intubation tubes, serving as a bridge to extubation, and airway rescue [6]. Consequently, the SAD offers medical professionals a broader spectrum of approaches and techniques to attain optimal airway management.

SADs mainly refer to the artificial ventilation tools used for the upper respiratory tract of the glottis but not intruding into the trachea, representing a group of single-use or reusable devices for elective and emergency airway management [7]. Notable for their operability and versatility, SADs currently include prominent devices such as laryngeal mask, esophageal tracheal combitube, larynx tube, easy tube and other such devices, which enable alleviation of upper respiratory obstruction and prompt establishment of assisted ventilation via artificial airways. The introduction of SADs has led to a shift in airway management during anesthesia, and SADs can be used instead of the endotracheal tube (ETT) in some short procedures to improve intraoperative stability and reduce complications such as improved haemodynamics, intracranial pressure, and intraocular pressure [8-13]. Two meta-analyses showed that the laryngeal mask airway (LMA) increases the speed of placement by the surgeon, improves haemodynamic stability, and presents a lower incidence of sudden cough and postoperative sore throat compared to the ETT [14, 15]. However, a recent review of the literature noted no significant advantage of the LMA over the ETT, but the LMA Supreme was associated with the lowest rate of airway complications [16].

SADs have no universally accepted nomenclature, definition, or classification. Brimacombe proposed a classification system for extraglottic airway devices (EADs) based on three criteria: the presence or absence of a cuff, mode of insertion (oral or nasal), and the anatomic location of the distal portion of the device in relation to the hypopharynx [17]. A classification system prevalent in use is Cook's classification (**Table 1**), which categorizes SADs into three generations based on their distinctive features. The first generation of SADs are simple airway tubes with no specific design features to reduce the risk of lung aspiration of stomach contents. The second generation of SADs incorporates specific features to improve positive pressure ventilation, thereby reducing the risk of aspiration [18]. The third generation of SADs usually refer to improvements or advantages over the second generation of SADs, such as the self-pressuring sealers (Air-Q mask) and the Baska Mask's additional bite block and novel drain design features [19].

## The classification of SADs

### *Laryngeal mask airway family*

The development of the LMA is a significant milestone toward widespread use and acceptance of the SADs (**Table 2**) [20]. The invention and development of the LMA can be traced back to 1981, when invented by Dr. Archie Brain. The notion originated from the Goldman Dental Mask prototype, which went through a series of complex parameters to produce the original factory-made silicone cuff in 1986, and finally John Nunn from Northwick Park Hospital introduced classic LMA (cLMA) into clinical practice in the UK in 1988 [20, 21]. The cLMA features an elliptical mask with a soft and silicone cuff attached to a ventilation tube. Its aperture bars in the mask serve to prevent the epiglottis from blocking the airway and obstructing ventilation. When inserted, the LMA moves along the hard and soft palate to the hypopharynx, then reaches the proximal end of the esophagus and forms a closure [22]. According to J Brimacombe, the advantages of

**Table 2.** Comparison of LMAs

| Device | Date introduced | Size | Reusable | Lumen | MRI conditional | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|
| LMA Classic [20, 21] | 1988 | Eight sizes, from neonate to adult | Reusable | Single | Yes | The original, reusable, first-generation airway | Possible aspiration due to insufficient high seal pressure |
| LMA Unique [14, 31] | 1997 | Seven sizes | Single use | Single | Yes | Sterile, soft, flexible, cause minimal haemodynamic response | The cost is relatively high compared to the LMA classic |
| LMA Proseal [26, 27] | 1999 | Seven sizes | Reusable | Single | Yes | The most versatile re-usable airway, with a high seal pressure of 32 cm $H_2O$ | A smaller fiberoptic scope must be used if laryngoscopy is required |
| LMA Supreme [35] | 2007 | Seven sizes | Single-use | Single | Yes | Minimizing flatulence and reducing the risk of aspiration | Compared with LMA Proseal, the seal pressure is not high enough |
| LMA Flexible [31] | | Six sizes | Reusable and single use | Single | Yes | Its airway tube can be moved out of the surgical field without displacement of the cuff | More difficult insertion |
| LMA Fastrach [29] | 1997 | Three sizes | Reusable and single use | Single | No | Making the process of blind intubation highly successful, unhurried and safe | Not for patients with structural abnormalities |

the LMA over ETT are: it is easier for less experienced personnel to use; it helps the anesthetists to carry out the placement quickly; it increases haemodynamic stability during induction of anesthesia and resuscitation; it prevents postoperative elevation of intraocular pressure (IOP); it reduces the need for airway tolerance; and there is a significant reduction in coughing and dysphagia [23]. Among its benefits over facemasks are the ease of use for individuals with minimal training, enhanced oxygen saturation levels, reduced fatigue in the hands, and suitability for pediatric otological procedures of minor nature [14]. Besides, LMA is included in the airway management algorithms of the ASA and the Difficult Airway Society of the UK [24, 25].

The cLMA exhibits a moderate oropharyngeal leak pressure (OLP) of less than 20 cm $H_2O$, it correlates with pulmonary aspiration of regurgitated fluid and negatively impacts pulmonary mechanics [20]. To elevate OLP, mitigate the risk of aspiration and improve other shortcomings, second-generation LMAs have been developed. LMA ProSeal (pLMA), invented in 1999, exhibits a median seal pressure of 32 cm $H_2O$ [26]. The most prominent improvement of LMA is its ability to prevent aspiration and stomach overfilling, which allows ventilating at higher airway pressure. In addition, pLMA has a built-in drain tube that allows expelled gastric content to bypass the pharynx, increasing the safety of anesthesia [26, 27]. One study suggests that the pLMA performs better in maintaining airway closure compared to the cLMA, making it perhaps a superior choice for positive pressure ventilation applications. Although the cLMA may have a more rapid insertion process, this speed advantage may not make a significant difference in actual clinical practice [28]. LMA Fastrach (FT-LMA), also known as the intubating LMA (ILMA), was introduced in 1997. Compared with cLMA, the primary distinguishing features of the FT-LMA include an anatomically curved rigid airway tube, an integrated guiding handle and an epiglottic elevating bar [29]. These features provide a conduit for ETT and allow anesthetists to introduce the ETT into the trachea via blind, semi-blind, or indirect visualization techniques [30]. LMA Flexible (fLMA) is designed to provide shared airways, enabling the airway tube to be removed from the surgical field without displacing the cuff [31]. It consists of a flexible ventilation shaft attached to a cuffed mask similar to the cLMA, but this flexible shaft may make insertion more difficult [29]. Moreover, research indicates that the fLMA also provides better protection from blood and secretions from above the trachea [32, 33]. The LMA Unique (uLMA) was introduced in 1997 as a disposable, ready-to-use device particularly suitable for field settings, thereby mitigating cross-contamination and disease transmission risks. Its structure closely mirrors that of the cLMA, incorporating aperture bars to prevent epiglottic obstruction of airflow [14]. The soft and flexible cuff facilitates smooth extubation following surgery [34]. The LMA Supreme (sLMA), developed in 2007, represents a modified single-use version of the pLMA. Its preformed curved shaft consists of a double lumen, wherein the airway lumen facilitates respiratory tract access, while the digestive tract access is afforded by a separate lumen [35]. The device forms an effective oropharyngeal seal and an innovative esophageal seal with the upper esophageal sphincter, thus effectively prevent reflux aspiration [26, 36]. To summarize the above, a common feature of these SADs is the improved seal which enables positive airway pressure ventilation at a higher level. Second generation SADs further offer the option of incorporating a gastric tube through a distinct drainage tube [37].

*I-gel*

The I-gel, manufactured by Intersurgical in Berkshire, UK, was pioneered by Muhammed Nassir in 2003 [22]. The I-gel is fabricated from a medical-grade thermoplastic elastomer, featuring a soft, gel-like cuff that yields an anatomical impression fit around the laryngeal inlet. This design aims to establish a non-inflatable anatomical seal while minimizing compression trauma. Like the pLMA, it has an airway tube and a gastric drain tube [38, 39]. Investigations have demonstrated that the insertion time of I-gel is decreased, resulting in a lower incidence of sore throat [34, 40], but its success rate and complications are similar to other SADs [41]. Owing to the firmness and natural or pharyngeal curvature of the tube section, the device can be placed into the pharynx by gripping the proximal end against the hard palate without putting the fingers into the patients' mouths [40]. This

enables swift insertion and optimal ventilation [42].

*Laryngeal tube*

The laryngeal tube (LT) is a reusable, single-lumen silicon tube equipped with a distal cuff that establishes a low-pressure seal around the esophagus, aiding in the prevention of reflux. A proximal cuff envelops the oral and nasal cavity, assisting in tube stability. There are many vents between these cuffs for ventilation. The cuffs are linked together and sequentially inflated to a pressure of 60 cm $H_2O$ via a unique connector. The LT exhibits a superior seal within the oropharynx compared to the cLMA [43], but its efficacy does not quite match that of the pLMA [44]. The device is available in various sizes, accommodating individuals from neonates to adults. The laryngeal tube suction (LTS) represents an advancement of the LT. Crafted from medical-grade silicon, it boasts an additional posteriorly situated gastric channel tube, enabling the separation of the respiratory and gastrointestinal tracts [45]. The main improvement of the Laryngeal Tube Suction II (LTS II) over the LTS is that it has a longer shaft, a smaller tip, and an oval-shaped distal cuff. This design element permits superior adaptation to the anatomical structure of the esophageal entry site. But Gaitini et al. reveals substantial variability in the positioning of the LTS II, with instances of gas leakage around the cuff being notably more prevalent when compared to the PLMA [45]. The Laryngeal Tube Suction Disposable (LTS-D) is made of medical-grade polyvinyl chloride and is available in seven distinct sizes. Its insertion can be aided by the use of a stylet, and it facilitates insertion by lifting the tongue, even if the range of motion of the cervical spine is constrained [46]. The LTS-D is easy to operate and may also serve as a pre-hospital emergency device [47].

*Esophageal tracheal combitube*

The esophageal tracheal combitube (ETC) is a double-tube and double-cuff device [48]. It contains a large syringe for inflation of the proximal oropharyngeal cuff, and a small syringe for filling the distal tracheoesophageal cuff. Notably, the combitube enables ventilation and oxygenation irrespective of its positioning-within the esophagus (common) or the trachea (infrequent) [49]. Upon insertion, the tube facilitates ventilation through the distal lumen if it traverses the trachea, or via multiple proximal openings above the distal cuff when it enters the esophagus. In more than 95% of cases, combitube can be effectively inserted into the esophagus with blind insertion, enabling a rapid insertion [50]. Blood gas measurements showed a significantly higher mean arterial oxygen tension during ventilation with the ETC [51, 52]. The combitube represents a non-surgical airway alternative within the arsenal of anesthesiologists and emergency practitioners, particularly in the context of anticipated or unanticipated challenging airways in patients who are unable to be intubated or mask-ventilated [50, 53].

*EasyTube*

The EasyTube (EzT) is a sterile, disposable double lumen tube accompanied by a pharyngeal proximal cuff and a distal cuff [54, 55]. It is designed for emergency airway management, addressing challenging intubations and accommodating patients with an elevated risk of airway complications [56]. When inserted blindly, the patient's head must be in a neutral position, which may be beneficial in trauma patients [55]. For individuals suffering from esophageal pathologies or gastrointestinal hemorrhage, the EzT deployment should be limited to situations where direct visual control is feasible, notably under laryngoscopic guidance [54]. The primary benefits of the EzT encompass a shorter insertion duration, superior ventilation compared to ETC, enhanced aspiration protection relative to a laryngeal mask, and the capability of blind insertion in patients confined to a seated position [57].

*Air-Q*

The air-Q, introduced by Daniel Cook in 2005 [58], is primarily employed as an airway maintenance aid and can also serve as a ventilation conduit during general anesthesia [58]. The design of air-Q exhibits distinct features: a large airway tube inner diameter (ID), a short airway tube length, and a detachable standard 15 mm circuit adapter [59, 60]. These characteristics enable the direct insertion of larger tracheal tubes through the airway tube and mitigate the length requirements imposed by SADs, ensuring that the tracheal tube cuff is situated below the vocal cords [60]. In the event of main

tube obstruction, safety holes located on the periphery preserve gas exchange.

*Cobra perilaryngeal airway*

The Cobra Perilaryngeal Airway (Cobra PLA) is a cuffed, disposable, sterile, and latex free SAD designed for spontaneous and controlled ventilation [61-63]. Manufactured from polyvinyl chloride, the device comprises three principal components: a head, a circumferential pharyngeal cuff, and a breathing tube [64]. The distal end of the Cobra PLA is characterized by a snake-like "cobra head" that interfaces with the aryepiglottic folds, situating itself directly adjacent to the glottis entrance [65]. The anteroposterior width of the head is more compact than the distal end of the LMA. This design enables insertion with a smaller mouth opening and may be simpler to introduce than the LMA, thereby facilitating successful usage in patients with limited mouth opening and restricted head extension [66]. The breathing tube of the Cobra PLA possesses a broad distal end and a proximal attachment to the cuff. When inflated, the cuff serves to isolate the distal end from the upper airway [61], exhibiting a superior sealing pressure compared to the cLMA [64]. In 2006, the second generation of the Cobra PLA was introduced. Notable enhancements include a distal curve in the breathing tube to prevent kinking and a softer tube for easier insertion and minimized mucosal trauma [64]. More recently, the Cobra PLUS was introduced, offering additional features such as a temperature probe for measuring core temperature and a gas sampling line for the three smallest pediatric sizes [67].

*Streamlined liner of the pharynx airway*

The Streamlined Liner of the Pharyngeal Airway (SLIPA) is a non-cuffed, single-use, latex-free SAD [64]. It is characterized by a hollow boot-shaped design, obviating the need for a cuff to ensure pharyngeal sealing. The SLIPA's shape closely mimics a pressurized pharynx, necessitating a precise fit between the airway's dimensions and the patient's pharyngeal anatomy. When the selected size of the SLIPA is appropriate, it has a sealing pressure similar to pLMA, up to 30 cm $H_2O$ [64]. The hollow chamber of the SLIPA can accommodate up to 50 mL of drained stomach fluid, effectively reducing the risk of aspiration should secretions and blood accumulate in the pharynx, or in the event of limited volume regurgitation [68, 69]. In terms of insertion success rate, hemodynamic response, and postoperative airway morbidity, the SLIPA exhibits similarities to the LMA, particularly when used by novice personnel [68]. The first attempt and successful insertion times for the SLIPA are notably shorter than those for the LMA, primarily due to the elimination of cuff inflation time and other factors. Consequently, the SLIPA offers an economical alternative to the LMA and a convenient primary SAD for individuals with limited experience [70].

*Ambu Aura-i*

The Ambu Aura-i is a newly available disposable SAD made of polyvinyl chloride. It comprises an airway tube featuring a 90° bend to accommodate the natural curvature of the orohypopharyngeal cavity, a softly rounded tip, a thin 0.4 mm cuff, and a bowl devoid of aperture bars, facilitating direct endotracheal intubation [71, 72]. The device is designed to serve as an independent ventilation system and a conduit for traditional cuffed tracheal tubes [71], demonstrating its efficacy in managing challenging airways [72]. Research of Agrawal et al. proved that the Aura-i performs favorably compared to the LMA Supreme, exhibiting similar first-attempt insertion success rates, equivalent insertion time, and leak pressures [73].

## Clinical applications of SADs

SADs play multiple roles in airway management, serving as a conduit for intubation, a transitional tool for extubation, a rescue mechanism in pre- and in-hospital settings, a definitive instrument in elective and emergency anesthesia, and a viable option for patients undergoing spontaneous or mechanical ventilation [74].

Compared to ETT, SADs offer reported advantages such as simplicity in insertion, elimination of neuromuscular blocking agents, enhancement of spontaneous respiration, and avoidance of translaryngeal positioning accompanied by cardiovascular effects and close vocal cord contact. Evidence from a meta-analysis shows a reduced rate of laryngospasm and a lower incidence of postoperative hoarse voice, coughing and sore throat [6, 23].

*Difficult airway*

Difficult airway guidelines recommend the employment of SADs to maintain the airway and to allow rescue ventilation. Difficult airways include clinical situations of anticipated or unanticipated difficulty or failure experienced by a physician trained in anesthesia care, including but not limited to one or more of the following: facemask ventilation, laryngoscopy, ventilation using a supraglottic airway, tracheal intubation, extubation, or invasive airway [5]. Wilson integrated five individual factors that may anticipate a challenging airway: body weight; mobility of the head and neck; jaw movement; retruding mandible; and "buck teeth" [75]. SADs offer dependable and efficient ventilation, and to a certain degree, mitigate aspiration [76]. Numerous studies and case reports or series have been published illustrating the effectiveness of SADs in the context of difficult ventilation and failed intubation [4]. Randomized controlled trials with SADs flexible intubation reports a higher success rate for initial SADs intubation than those using the flexible intubation range alone [5]. A retrospective cohort study showed that SADs were used in 12.4% of difficult airway management and 65.1% were successfully ventilated. In cases where "cannot intubate, cannot facemask ventilate", SAD was used in 18.9% of patients and 62.8% were successfully ventilated. This points to the fact that SAD, although a good tool for dealing with difficult airways, is not widely used in the management of difficult airways [77]. In addition, a retrospective analysis of difficult airways in children suggests that SAD can be used effectively for airway maintenance in the paediatric difficult airway population [78]. The SAD can also be used as a catheter for fibreoptic-guided ETT, which is a technique that can be used for both anticipated and unanticipated difficult airway management. Colas et al. implemented a randomized controlled trial and found that second-generation SADs were superior to first-generation SADs in assisting with fibreoptic-guided ETT, but that clinicians should select their SAD based on clinical experience [79].

*Special patients*

*Cancer patients:* One of the prevalent complications following lobectomy is persistent air leakage, particularly in lung cancer cases. To mitigate coughing during extubation, a less irritating SAD can be substituted for the ETT under profound anesthesia. Ishibashi et al. showed that the use of SADs was effective in preventing cough-induced air leakage during routine extubation of patients undergoing lobectomy, and that air leakage from the lung parenchyma of patients could be as high as 66.7% with the use of a conventional double-lumen ETT [80]. In addition, they went further and found that SAD was effective in preventing prolonged coughing or sore throat after lobectomy [81]. During complex thyroid surgery, an ETT is withdrawn under deep anesthesia and substituted with a cLMA as an interim device to facilitate bronchoscopy. The patients emerge from anesthesia and was extubated seamlessly [82]. Alternatively, a LT can be employed for temporary oxygenation and ventilation during pharyngo-esophageal and bronchoscopic examinations in patients with supraglottic airway tumours, and may prove invaluable in "can't intubate" scenarios [83].

*Cesarean section patients:* General anesthesia remains a crucial anesthetic approach in emergency cesarean sections due to the inadequate time for lumbar anesthesia procedures [84]. The Obstetric Anesthetists' Association and the Difficult Airway Society (OAA-DAS) difficult airway guidelines recommend using a second-generation SAD for airway maintenance and for rescue ventilation after failed intubation [85]. Surgery can be performed directly with SAD, or flexible bronchoscopic intubation (FBI) via the SAD. Employing a SAD alone for surgery poses two primary risks. First, if the airway becomes occluded due to edema, hemorrhage, or SAD displacement, serious airway complications may arise. Second, maintaining a SAD in the obstetric population may expose the woman to risks of reflux and aspiration of gastric contents [85]. In a randomized controlled equivalence trial, Yao et al. compared sLMA with ETT for managing the obstetric airway during caesarean section. They found that for a low-risk obstetric population, the sLMA could be an alternative airway management technique with the advantages of similar insertion success rates, shorter ventilation times and fewer haemodynamic changes [86]. Similarly, a meta-analysis reported the insertion success and safety of SADs in a low-risk obstetric population

[87]. However, current guidelines for obstetric airway management still place SAD in a second-line position [86].

*Pediatric patients:* Pediatric patients exhibit distinct anatomical and physiological aspects in airway management, which amplify the complexity of handling challenging airways [88]. In the past decade, the progression of pediatric SADs specifically engineered for intubation has augmented the arsenal of pediatric anesthesiologists, enabling appropriate size devices even for neonates. Following a failed laryngoscopy, intubation utilizing continuous oxygenation and ventilation through SADs may offer the optimal balance between success and patient stability. The preliminary step in this approach is to successfully insert the SAD and verify oxygenation and ventilation, and once the ETT is successfully placed in the trachea, the flexible range can be removed and the SAD removed [88].

Since the early 1990s, pediatric anesthesia practice has undergone a transformation due to the expanded utilization of cLMA and fLMA. A majority of the newer SADs, with the exception of pLMA, seem to provide limited advantages to either clinicians or patients in comparison to existing SADs [89]. In a study involving pediatric patients aged 1 year to 12 years, I-gel emerged as a suitable alternative to pLMA for pediatric patients under controlled ventilation conditions [90]. A systematic review and meta-analysis of randomized controlled trials comparing SADs with ETTs was conducted by Bandyopadhyay et al. They stated that for short pediatric laparoscopic procedures, the SAD could be an alternative to the ETT and reduced the incidence of postoperative sore throat and accelerated postoperative recovery [91]. In pediatric laparoscopic surgery, I-gel may be a better choice in cases of higher ventilation pressure [92]. However, a randomized controlled trial showed a higher likelihood of vocal cord injury when using I-gel compared to air-Q [93]. From a clinical point of view, SAD can be an option for airway maintenance in high-risk pediatric patients during anesthesia [94, 95].

About a quarter of all newborns globally, or about 2.5 million people a year, die from asphyxia at birth [96]. Neonatal ETT is a major test of a technique that requires a high degree of experience on the part of the anesthetists. The relatively less invasive LMA has been used for quite some time in neonatal resuscitation, and it has been recommended as a preferred alternative to ETT because of its ease of insertion and high reliability of ventilation [97, 98]. Mani et al. conducted an experiment in which they demonstrated that LMA was comparable to ETT in performing chest compressions in an animal model. The use of LMA for neonatal CPR may help to improve the outcome of advanced resuscitation in a resource-constrained medical setting [99]. Several randomized controlled trials compared the difference in effectiveness between LMA administration and ETT administration in preventing mechanical ventilation in premature infants with respiratory distress syndrome. The results showed that the use of LMA administration reduces the risk of early failure and may be more effective than ETT administration in some cases, which offers the possibility of reducing adverse effects [100-103]. Therefore, LMA is considered to be an ideal channel for the application of surfactant.

*Obese patients:* Obese patients frequently encounter challenges in airway management, including rapidly declining oxygen saturation, mask ventilation, and difficulties with laryngoscopy and intubation, which places them at a higher risk of airway morbidity compared to nonobese individuals [104]. In cases where intubation or mask ventilation is not feasible for obese patients, the ASA Task Force on Management of the Difficult Airway recommends a LMA as the primary rescue device [105]. The SADs may be also used for positive pressure ventilation in a setting of elective surgery. Notably, studies have demonstrated that the cLMA is superior to endotracheal intubation in enhancing postoperative saturation and lung function, but the lower sealing pressure and higher frequency of gastric gas injection are its unique disadvantages [14]. In comparison, the pLMA offers a higher seal pressure (up to 30 cm $H_2O$) and drainage channels for stomach contents compared to the cLMA, and has been observed to assist in extending the safe apnea duration during intubation procedures in morbidly obese patients prior to intubation [106].

SAD can be used as an alternative to ETT in anesthesia for obese patients [107]. Nicholson et al. conducted a review of clinical trials and

found that patients using pLMA had better oxygenation and enhanced lung function during and after surgery. Additionally, patients using this method had a reduced frequency of postoperative coughing, thus promoting rapid recovery [108]. A comparative study showed that in morbidly obese individuals, trainee physicians were more adept at utilizing the sLMA for stable patient ventilation compared to face masks, and that the sLMA may be an effective and applicable option, particularly in airway management and resuscitation of morbidly obese patients [109]. The pLMA also plays a good role in ventilation of obese patients due to the presence of an optimal airtight seal. A clinical trial verified that pLMA may have advantages over cLMA in obese patients [110]. In addition, I-gel is also effective in obese patients when used for ventilation during surgery [111]. Although many studies have demonstrated the effectiveness of SAD in airway management in obese patients, more evidence is needed to validate its safety [108].

*Pre-hospital airway management*

Emergency airway management is a crucial aspect in the intensive care unit (ICU), where patients are severely ill and possess limited physiological reserves, as well as in other hospital settings that often lack advanced equipment and personnel [112]. The out-of-hospital environment introduces variables such as cervical immobilization, dental trauma, and airway obstruction by secretions, making airway management more intricate and increasing the likelihood of tracheal intubation failures. Failure rates for out-of-hospital tracheal intubation have been reported up to 25% [113], even when performed by experienced physicians, it could be shown that the rate of unrecognized ETT misplacement was as high as 17.4% [114]. The 2010 European Resuscitation Guidelines stipulate that tracheal intubation should only be attempted if a proficient individual can execute the procedure with a high degree of skill and assurance [115], however, a considerable number of emergency medical personnel lack adequate training for emergency intubation [4]. In prehospital airway management, SADs can serve as complementary or substitutive measures for mask or ETT placement, or both. Lee et al. compared the benefits of prehospital advanced airway management in patients with out-of-hospital cardiac arrest (OHCA) using either ETT or SAD, and they found that SAD could be equivalent to ETT in terms of metrics such as ventilation success and return of spontaneous circulation, and that the two could be substituted for each other [116]. Furthermore, the initial LT insertion strategy was associated with significantly higher 72-hour survival in adult patients with OHCA [117]. However, random assignment to a prior airway management strategy using SAD did not produce favorable functional outcomes at 30 days compared with ETT [118].

However, a randomized clinical trial conducted by Wang et al. has demonstrated that among adult patients experiencing OHCA, both tracheal intubation and SADs administration were associated with a diminished probability of favorable neurological outcomes [119]. This phenomenon might be attributed to the elevation of intrathoracic pressure induced by hyperventilation, resulting in a reduction of coronary and cerebral perfusion pressure in intubated OHCA patients [120]. In several previous studies, patients with OHCA who underwent ETT were more likely to achieve survival to hospitalization and maintain neurological integrity compared to SAD [121, 122]. This may require more research to validate the differences between SAD and ETT.

*Use in extubation*

Extubation failure is characterized as the “inability to endure a translaryngeal resection” or the necessity for re-intubation within 24-72 hours post-extubation [123]. This often leads to upper respiratory tract obstruction, and edema, soft tissue collapse, in which laryngeal spasm is the most common reason. There is mounting evidence suggesting that extubation failure can negatively impact patient outcomes, irrespective of the severity of the underlying disease [124]. Conditions such as obesity, obstructive sleep apnea, and major head, neck, and upper respiratory surgeries significantly elevate the risk of extubation failure and often accompany difficulties in airway management [125].

In addition to extubation under general anesthesia, airway exchange catheter-assisted extubation and other methods to avoid extubation failure [123], among the recommendations in the ASA Practice Guidelines for difficult

Airway Management is the consideration of short-term use of a device that can serve as a guide for rapid reintubation [125], such as a laryngeal mask. This approach helps prevent extubation failure and is particularly useful in situations where surgical repair might be interrupted due to cardiovascular stimulation. Utilizing a laryngeal mask airway has been demonstrated to mitigate hemodynamic pressure, coughing, and flexion compared to tracheal extubation during wakeful and deep anesthesia [126]. Common techniques for laryngeal mask exchange include first placing the laryngeal mask airway after a tracheal intubation, this procedure is often named after Dr. Bailey, called the Bailey operation [123, 126]. A retrospective cohort study noted that in patients undergoing general anesthesia, the use of a SAD was associated with a lower risk of needing emergency postoperative intubation [127]. Modir et al. compared three SADs (LMA, SLIPA, I-gel) for tracheal extubation. They found that all three tools can be used as effective and safe ventilatory control devices after extubation and have similar side effects, but the LMA has a lower degree of side effects [128].

*Intubation at prone position*

The use of SADs is gradually increasing, not only in routine elective surgery, but their use in prone patients is also receiving a lot of attention. The use of SADs in the prone position is challenging and carries the risk of airway displacement, obstruction, desaturation or hypercapnia. Valero et al. analyzed a number of studies and found that overall insertion and ventilation success rates with SADs in the prone position were high, with fewer reported adverse events, which could be attributed to the extensive experience of the users and appropriate patient selection [129]. And they recommended strategies such as the use of second or third generation SADs, adequate training and safety management measures to ensure ventilation whenever possible. When SADs are used in the prone position, measures must be taken to prevent possible ventilation failure. Another clinical trial examining the performance of the pLMA and I-gel airways in the prone position similarly confirmed this finding. Insertion of the SAD was feasible in the prone position [130]. pLMA demonstrated superior closure, whereas I-gel demonstrated an easier insertion process.

SADs have also shown their application in the emergency management of accidental extubation in the prone position during surgery [131]. Gupta et al. conducted a comparative study on the performance of cLMA, pLMA and I-gel for insertion in the prone position and found that all the three SADs can be effectively used as emergency resuscitation devices [132]. However, I-gel was superior to the other two in the study in terms of bronchoscopic view and insertion score. However, more literature is needed to consider the selective use of any SAD as a first-line tool in the prone position. And there is a need for physicians to practice inserting SADs in the prone position extensively to minimize patient harm.

## Conclusions

Over the past few decades, significant advancements in the design of SADs have led to their widespread incorporation as vital airway management tools in patients undergoing general anesthesia. The functionalities and proposed applications of these devices have expanded exponentially, allowing for their use in various scenarios including hospital-based surgical and non-surgical ventilation, pre-hospital emergency care, elective and emergency anesthesia, management of all types of difficult airways, intubating catheters, and bridging extubation. Nevertheless, SADs possess numerous potential complications, the most severe of which, although uncommon, include aspiration and ventilation failure. As technology continues to evolve, the future may witness a decreased reliance on endotracheal intubation. Anesthetists should become well-acquainted with the specific details of the equipment they choose to ensure patient safety, particularly in light of their growing expertise in its operation.

As the technology of SADs continues to advance, we can anticipate that their safety will continue to improve. Recent improvements in the design of SADs are expected to lead to their wider use in general anesthesia procedures, for example, by optimizing the design to reduce breathing problems caused by failed intubation, reducing the risk of sore throat and tongue damage after surgery, and reducing the possibility of aspiration of gastric contents into the lungs during positive pressure ventilation. However, the improvements in SADs are not intended to replace the full functionality of tracheal

intubation, but are more suited to surgical patients who do not require tracheal intubation. This is because no device can fully fulfil all the requirements of ideal SADs.

Clinicians should increase their focus on SADs, the effective use of which depends on operator experience and accurate patient matching. The following are some recommendations:

i. Having an extensive background in SAD use and anesthesia is essential to prevent, detect and resolve airway obstruction and other emergencies.

ii. When selecting a SAD, special care should be taken with patients who are at risk for regurgitation and aspiration, as well as dyspnea. Typically, decisions should be based on patient characteristics, the nature and duration of the procedure, the practicality of rescue options, and personal experience.

iii. Develop an appropriate airway management plan and prepare for failed rescue options. Since there is no technique that can guarantee a consistently patent airway, adequate tools need to be prepared.

iv. Prioritize the use of second- or third-generation SADs, which provide better airway closure and allow higher levels of positive pressure ventilation without gas leakage. In addition, they are designed to help flush out reflux and reduce the potential for aspiration.

v. Complications are prevented by adequate training and the use of appropriate devices.

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## Disclosure of conflict of interest

None.

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