Supraglottic airway devices

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Supraglottic airway devices are developed with increasing frequency following the overwhelming success of the laryngeal mask airway (LMA). Currently, the LMA, the ProSeal laryngeal mask airway (PLMA), the laryngeal tube (LT), the laryngeal tube with integrated suctioning tube (LTS) and the oesophageal tracheal combitube (OTC) are the best evaluated and most widespread devices. Both the LMA and the PLMA have been shown to be perfectly suitable for routine anaesthesia and emergency airway management. While the LMA is limited by the lack of reliable protection against aspiration, the value of the PLMA in this respect remains undetermined yet. LT and LTS are primarily intended as emergency airway devices, but have also been successfully used during controlled ventilation in adults. The OTC, though advocated for emergency as well as routine use, is limited by high airway morbidity and possible serious complications.

Key words: laryngeal mask airway; laryngeal tube; oesophageal tracheal combitube; airway device; routine anaesthesia.

For the maintenance of life there is nothing more necessary than a sufficient supply of fresh air. Robert Hooke, 1667

INTRODUCTION

Since the beginning of modern anaesthesia, airway management has been a challenge. Following the enthusiasm raised by the first successful ether anaesthesias and the subsequent widespread use, disastrous complications were reported.1 These could be
attributed, at least in part, to hypoxia due to airway obstruction. Therefore, a variety of airway devices were developed to ensure airway patency. However, none of these devices gained general acceptance, and apart from the Guedel airway they are nowadays only of historical interest. The revolutionary advances of modern anaesthetic practice are largely perceived by both anaesthesiologists and other specialties as associated with the development of tracheal intubation. Consequently, for decades there was only little interest in alternative airway devices, and airway management focused on providing ventilation by bag mask, laryngoscopy and intubation. This attitude has changed after the introduction of the laryngeal mask airway, which can be denoted a milestone in the field of airway management.

Over the past decade, novel options for airway management have evolved and numerous devices and techniques are currently available. For proper characterization and classification, a definition is needed which criteria qualify a device as being 'supraglottic'. Recently it has been suggested to replace the term ‘supraglottic’ by the term ‘extraglottic’ in order to clarify the relationship between function and anatomical position. Apart from its position relative to the glottis, criteria for supraglottic airway devices include: appropriate bridging of the oral/pharyngeal space, low resistance to respiratory gas flow, protection of the respiratory tract from gastric and nasal secretions, suitability for positive pressure as well as spontaneous ventilation, and finally lack of adverse events associated with its use. More specifically, for the judgement of any new airway device we should first define what we would expect from an ‘ideal’ airway device (Table 1) and how these expectations or criteria are accomplished by the new device. The accept–reject profile is of paramount importance in this respect. This property of a device, first mentioned by AlJ Brain reporting on the development of the LMA, describes the relative potential for acceptance or rejection of a foreign body by the oropharynx. Although patient-specific factors may be relevant, this property largely depends on device shape, cuff position, cuff volume and material and finally decides on the success of a device in daily clinical routine. For the purpose of this review, we will focus on devices advocated for routine use, which have already been evaluated based on a sufficient number of publications allowing for reliable conclusions.

<table>
<thead>
<tr>
<th>Table 1. Criteria for an ‘ideal’ airway device.</th>
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<tr>
<td>• Efficient bypass of the upper airway for ventilation</td>
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<td>• Easy insertion by beginners, steep learning curve</td>
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<td>• Efficacy not extremely affected by suboptimal placement</td>
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<td>• Stable in use (i.e. suitable for ‘hands-free anaesthesia’)</td>
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<td>• Good ‘accept–reject’ profile</td>
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<td>• Minimal/no aspiration risk</td>
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<td>• Effective upper airway seal allowing for positive pressure ventilation</td>
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<td>• Cuff pressure and shape necessary for sealing does not distort/distend the pharynx</td>
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<td>• Low airway morbidity</td>
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<td>• Good quality (i.e. no device failure due to malfunction)</td>
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Modified according to Ref. 4.
Laryngeal mask airway (LMA)

The LMA is an ingenious supraglottic airway device that was developed by Alj Brain and first described in 1983.\(^6\) The LMA emerged from a research project aimed to evaluate more comfortable and less invasive alternatives to the established facemask and tracheal tube, respectively.\(^5\) It consists of a curved tube, which is attached to the lumen of a small, ellipsoid bowl with an inflatable cuff designed to provide a seal around the laryngeal inlet. Two elastic bars are positioned over the bowl aperture to prevent obstruction by the epiglottis. The device is available in the appropriate size to fit the larynx of neonates up to large adults. After ensuring an adequate anaesthetic depth and lubrication of the dorsal part of the mask the recommended standard procedure for device insertion is with the mask aperture facing the base of the tongue and the cuff tip pressed against the posterior pharyngeal wall. The index finger of the dominant hand is used to guide the LMA in the hypopharynx until a resistance is felt which means that the tip of the mask has reached the upper oesophageal sphincter. Alternative techniques have been described, especially for use in children, which rely on introducing the device upside down, followed by rotation.\(^7\) The cuff is then inflated with air until an effective airway is established allowing appropriate ventilation of the lungs without relevant leakage. The recommended cuff volume differs according to the LMA size used (for a size 4 LMA for example < 30 ml). Typical first time insertion success ranges between 90 and 95%.\(^8,9\), and time to achieve an effective airway is approximately 30 seconds.\(^10\)

Airway leak pressure mostly lies between 20 and 25 cm H\(_2\)O.\(^10,11\) Malposition of the LMA resulting in low airway leak pressure often is erroneously treated with cuff over inflation. This, however, does not solve the problem but puts oropharyngeal mucosa at risk of damage provoked by huge intracuff pressure transmitted to tissue. The manufacturer, therefore, has recommended an upper intracuff pressure of 60 cm H\(_2\)O. It has been shown, that even at recommended cuff volumes, intracuff pressure may result in cuff pressures largely above recommended values.\(^12\) This may be of clinical significance, since in daily clinical practice, recommended intracuff pressure often is ignored and cuff over inflation unnoticed, especially during short procedures with spontaneously breathing patients.\(^13\) A reasonable approach is to inflate the cuff with the lowest volume resulting in an effective airway followed by cuff pressure control. Cuff pressure exceeding the recommended value should be treated by adjusting device position (for example by gently pushing or pulling or a jaw thrust manoeuvre) or a reinsertion attempt.

The LMA has an impressive performance, both regarding its application in daily clinical routine and number of publications.\(^8,9,14\) More than 1500 publications deal with the LMA in various patient populations including neonates and children, during a variety of surgical procedures and different anaesthetic agents. At present, the LMA has been used in approximately 150 million patients without an apparent death directly associated with it. Currently, about 30–60% of all general anaesthetic procedures are performed with a LMA. It may serve primarily as a substitute for the facemask, thereby allowing for ‘hands free’ anaesthesia. Importantly, the LMA must not been used in patients at an increased risk of aspiration regardless of the underlying reason. Further contraindications comprise a decreased lung and/or thoracic compliance, an increased airway resistance (chronic obstructive lung disease, acute bronchospasm), glottic or subglottic airway obstruction, limited mouth opening and any oropharyngeal pathology.
Compared with the classical facemask, the LMA offers several advantages.\textsuperscript{15} After proper placement, ‘hands free’ anaesthesia is possible. Low flow anaesthesia may be performed, and waste of anaesthetics as well as pollution of the operating theatre endangering the personnel are decreased. Since oxygenation is easier accomplished with the LMA compared with the facemask particularly in case of difficult patient anatomy and at the beginning of resident training, a reduced incidence of hypoxia with the LMA has been reported.\textsuperscript{16} With the LMA in correct position, the laryngeal inlet may be visualized which allows for tracheal intubation in case of a difficult laryngoscopy.\textsuperscript{17} Compared with the tracheal tube, insertion of the LMA is not as painful as direct laryngoscopy followed by inflating a cuff in the irritable tracheal lumen. Therefore, the sympathetic activation is less pronounced which may be especially important in patients with coronary artery disease.\textsuperscript{18,19} The incidence of post anaesthesia airway morbidity is reduced, and coughing and retching are less often during emergence from anaesthesia.\textsuperscript{20,21} Muscle relaxants are not applied, and thus neuromuscular monitoring is not necessary and a residual block at the end of the surgical procedure not present. Since the LMA has a favourable accept–reject profile compared with the tracheal tube, the consumption of analgesics and anaesthetics is decreased.\textsuperscript{15} Therefore, the LMA is cost-effective compared to both face mask and tracheal tube.\textsuperscript{22}

Laryngeal mask airway Proseal (PLMA)

The PLMA is a meanwhile well known and established modified laryngeal mask which has been improved especially with respect to airway seal and protection against aspiration (Figure 1).\textsuperscript{23} Briefly, compared to the classic LMA, the PLMA features a new dorsal cuff designed to push the ventral cuff into the periglottic tissue to form a better seal than the classic LMA. Additionally, a drainage tube has been added, which allows

\textbf{Figure 1.} Laryngeal mask airway Proseal. A gastric catheter has been inserted in the drain tube.
passage of a $\leq 18$ Charriere gastric tube for emptying the stomach thus protecting against regurgitation. The airway tube has been wire-reinforced to reduce stiffness of the double-lumen configuration. The PLMA does not have the mask aperture bars since the drainage tube is thought to serve for this purpose. The PLMA is marketed with a special guiding handle to facilitate placement. Alternatively, placement may be accomplished as described for the classic LMA or with an elastic bougie inserted in the tube aimed at guiding the PLMA through the oropharyngeal inlet. The PLMA was primarily designed to improve airway seal thus offering protection against aspiration. This issue was addressed in a cadaver study comparing the LMA and the PLMA during increasing oesophageal pressure. In this study, the correctly placed PLMA allowed fluid to bypass the pharynx, and no fluid was seen above or below the cuff. Comparing the efficacy of seal after clamping the drainage tube, the PLMA attenuated liquid flow between oesophagus and pharynx significantly more than the LMA. It should be emphasized, however, that protection against aspiration depends on an optimal PLMA position on the laryngeal inlet. In a large multicenter trial comparing the PLMA with the LMA regarding efficacy of seal and time to achieve an effective airway, in 4 patients in the PLMA group (2%) the upper oesophageal sphincter could be visualized within the mask bowl. In another 3 patients, folding over of the drainage tube occurred which prevents fluid from being drained effectively. Therefore, the PLMA does not offer a reliable protection against aspiration in all patients. Similar to the cadaver study, the PLMA formed a more effective seal compared with the LMA, but time to achieve an effective airway was shorter and fibre optic determined anatomic position better with the LMA. Since handling is more complex and the PLMA is more expensive, its future value has yet to be determined.

**Intubating laryngeal mask (ILMA)**

The LMA has been used successfully for the management of the difficult airway. In 1997, a modified LMA was developed, the intubating laryngeal mask airway (ILMA, FastTrach™). The ILMA, specifically designed to allow for tracheal intubation through the device, is apparently not intended for routine use as an airway device for ventilation, but rather for management of difficult tracheal intubation. Since the device is described in detail in another chapter of this issue (Emergency Airway Management), it is not further discussed here.

**Laryngeal mask disposable**

There is an increasing demand for disposable airway devices, since the process of washing and preparation for repeat use is time consuming. More important, it has been shown that even repeat autoclaving does not remove protein deposits from the reusable LMA, thus potentially allowing disease transmission through residual biological debris. On the other hand, it is conceivable that different materials used in the reusable and disposable device may influence the accept–reject profile. In a recent case report, the airway tube became completely separated from the distal mask during use of a disposable LMA Unique™, which raised concerns regarding device quality. However, in three recent trials comparing disposable laryngeal mask airways by different manufacturers with the classic LMA, the disposable devices performed comparable with respect to ease of insertion, fibre optic view, incidence of blood on the mask at the time of removal, and the incidence of postoperative sore throat.
Interestingly, cuff pressure of the disposable LMAs did not increase during anaesthesia with nitrous oxide, while there was a large increase with the classic LMA. Thus, disposable devices apparently offer a good laryngeal seal and similar clinical performance.

Laryngeal tube (LT)

The LT is a reusable, single-lumen, silicon tube with an oropharyngeal and oesophageal low-pressure cuff, and a ventilation outlet between these cuffs (Figure 2). The device is available in different sizes for use in neonates up to adults. The proximal tube is equipped with a standardized 15 mm tracheal tube connector for attaching a bag valve or breathing circuit. The colour of this connector differs according to LT size. The distal lumen is positioned in the oesophageal inlet and equipped with a low pressure cuff to prevent regurgitation and aspiration. A second, pharyngeal cuff seals the airway proximally, and air is insufflated between these cuffs thus entering the glottic aperture.

After positioning the patient's head in a neutral position, the LT is placed into the oropharynx until a distinct resistance is felt. Following placement, both cuffs are inflated via a common connecting tube using a pressure gauge up to an intracuff pressure of 60–80 cm H₂O. Alternatively (especially in an emergency) a special syringe with coloured ring marks may be used to inflate a volume of 70 ml. It has been reported, that the insufflated cuff volume closely matches the resulting in vivo cuff pressure. Nitrous oxide may increase LT cuff pressure, and thus it is advisable to monitor and adjust intracuff pressure during anaesthesia to minimize possible ischaemic damage to the oropharynx. Since the diameter of the connecting tubes of the proximal and distal

![Figure 2. Laryngeal tube (below) and laryngeal tube S (above). A gastric catheter has been introduced in the drain tube.](image)
cuff are different, the oropharyngeal cuff is inflated first to accommodate in the oropharyngeal cavity, and the distal cuff is filled thereafter.

The LT, although primarily designed as a device for emergency and out of hospital use, has also been investigated during routine surgical procedures. During controlled ventilation, it performed comparable to the LMA in most studies with respect to insertion time, oropharyngeal leak pressure and peak airway pressure. One study reported a decreased postoperative pharyngeal morbidity, which is unlikely given the higher mucosal pressures applied. In contrast, during spontaneous ventilation, the LT was found inferior to the LMA in all three studies currently available, mostly due to repeated manipulations necessary to maintain a patent airway. Compared to the PLMA, the LT was found inferior in several clinical aspects, since efficacy of ventilation was higher and number of airway interventions and airway obstruction was significantly less frequent for the PLMA.

The LT has also been studied in children and was found suitable for that purpose by the authors. A failure rate between 5–12% and the need for subsequent manipulations in 20–35% of patients, however, are significantly worse compared to the results obtained in adults. Recently, a disposable LT has been developed, but available data are limited. In conclusion, the LT is a suitable device for controlled ventilation in adults, but both LMA and PLMA are superior in most technical aspects of airway management.

**Figure 3.** Laryngeal tube S. The proximal cuff is positioned in the hypopharynx, while the distal cuff seals the oesophageal inlet. Gastric drainage is accomplished by a separate lumen.
Since sealing the oesophagus in case of excessive vomiting may be dangerous, the LT has been modified and equipped with a suctioning tube (LTS).

**Laryngeal tube S (LTS)**

The device was developed based on the LT, and the main difference between both is rooted in the second lumen of the LTS, allowing for free gastric drainage and evacuation of stomach contents by an oesophageal catheter, but not for ventilation. The second tube is suitable for insertion of a gastric tube up to a diameter of 14 Charriere (Figures 2 and 3). Technique of insertion and handling are as described previously for the LT. After its initial description in 2002, several studies have compared the LTS with the PLMA.12,35,46,47 There seem to be some advantages for the PLMA in terms of patient comfort as reflected by a lower incidence of sore throat and dysphagia.12,46 While three out of four studies indicated that the PLMA and LTS are similar with respect to both physiologic and clinical function (insertion success and time, oropharyngeal leak pressure, peak and plateau airway pressures, ability to pass a gastric tube), the study by Cook and co-workers found the LTS inferior to the PLMA regarding these measures.35 On the other hand, the laryngeal tube S may offer an advantage in patients at an increased risk of aspiration (non-fasted, gastro oesophageal reflux disease, emergency cases) due to the safe airway seal together with the possibility of free gastric drainage. In a former study comparing the LMA and LT using a model rubber pharynx, the LT showed significantly increased storage capacities for regurgitated fluids.48 The LTS and the PLMA have not been compared in this respect yet. From the data presented it can be concluded that the LTS can be used to establish a safe and effective airway in mechanically ventilated anaesthetized adult patients.

![Figure 4. Oesophageal tracheal combitube. A gastric catheter has been introduced in the distal tube.](image-url)
Oesophageal-tracheal combitube (OTC)

The OTC, first described in 1987 by Frass and co-workers, has been introduced into clinical practice as an emergency airway device. The OTC is a double-lumen, double-cuffed tube that allows ventilation independent of its position, either in the oesophagus or the trachea (Figure 4). This unique feature is achieved by two independent tubes fused together both equipped with the standardized 15 mm tracheal tube connector. It comprises a small volume tracheooesophageal and a large volume oropharyngeal cuff, both equipped with a separate connecting tube for inflation. Between both cuffs, there are eight small ventilation outlets allowing ventilation if the distal end of the OTC is placed in the oesophagus. The OTC is available in two different sizes, 37 French and 41 French. The 37 French OTC is recommended for patients up to 180 cm height, while the larger OTC is intended for use in taller patients. For insertion, the patient's head should be in the neutral position. The thumb of the non-dominant hand subsequently opens the mouth, puts the tongue forward and performs a chin lift together with the index finger. The OTC is then advanced along the tongue until the teeth are positioned between the ring marks. The proximal cuff is inflated with 85 ml (100 ml), and the distal cuff with 10 ml (15 ml). In most cases (90–95%), the distal lumen is positioned in the oesophagus (which means that the OTC is extraglottic). Lung ventilation through the proximal lumen and, therefore, oesophageal position of the distal lumen has to be assured by capnography, chest movement and chest auscultation during ventilation of the proximal lumen.

The OTC is primarily intended for use in an emergency and/or out of hospital situation. In this environment it has proven useful and, therefore, has been implemented in the ASA difficult airway algorithm. Moreover, some investigators suggest the OTC for routine anaesthesia. The use of the OTC in daily routine, however, is highly controversial. Apart from serious complications, (i.e. oesophageal or pharyngeal injury) a significantly increased airway morbidity and stress response were reported comparing the OTC with both the LMA and the tracheal tube during routine surgery, which may be explained by the unphysiologically high cuff pressures applied. Consequently, in its current application the OTC cannot be recommended for this purpose urging calls for a modified design.

According to the use of a device in daily clinical routine, a different proportion of anaesthesiologists will become familiar with alternative airway devices. LMA, PLMA, LT and LTS all show acceptable times for device insertion, airway leak pressures and postanaesthesia airway morbidity. In contrast, the OTC has been shown to be inferior in most aspects of practical use such as time to successful ventilation, number of failed attempts, and handling as well as in terms of patient satisfaction and comfort. The high cuff pressures necessary may be harmful for the oropharyngeal mucosa if applied for a longer period of time. Postanaesthesia airway morbidity has gained widespread attention, especially in a health environment where cost containment is essential and patient satisfaction of high priority. A high incidence of sore throat and dysphagia as reported with the OTC, may therefore discourage anaesthesiologists from using a device probably causing patient dissatisfaction and increased length of hospital stay. This has important ramifications also for OTC use in an emergency. Since appropriate training is required, a device not suitable for daily clinical routine will have a disadvantage compared with a device in which training may be accomplished during regular working hours.
**FUTURE DEVELOPMENTS**

Today, new airway devices are introduced with ever-increasing frequency. PAXpress™, Laryvent™, CobraPLA™, Airway Management Device™, ELISHA™ and others have recently been developed. Every device claims an ‘edge’ over established or novel competitors, in terms of either technical aspects or costs or both. However, anaesthetists are unlikely to have the opportunity to use all of them and, more important, do not have the time to become proficient in all of them. Therefore, it is a reasonable approach to develop expertise in one or two tried and tested and universally applicable techniques. Given appropriate training, the type of device is not that important for clinical acceptable outcome. It should be emphasized, however, that every new device first has to prove to be at least equivalent to the current clinical gold standard, the LMA, with respect to physiologic properties and airway morbidity.

**CONCLUSIONS**

Both the LMA and the PLMA are established supraglottic airway devices with a large body of evidence proving safety and efficacy. The PLMA may be advantageous with respect to the efficacy of seal and protection against aspiration. Disposable LMAs perform comparable to the reusable devices. The relatively new LT and LTS both are suitable for routine use. Compared with the LMA and PLMA, they may be inferior with respect to airway morbidity and technical aspects of ventilation while offering a better protection against aspiration. The OTC, designed for emergency use, should not be used in routine anaesthesia due to high airway morbidity. For the performance of all devices it is important to realize that efficacy of seal may vary dependent on the

**Research agenda**

- the ProSeal laryngeal mask airway should be thoroughly evaluated regarding its behavior during regurgitation of gastric fluids
- the impact of different materials on the accept–reject profile of an airway device warrants further investigation
- for better comparison of airway devices, standardized criteria should be defined which have to be addressed in clinical studies
- the cost benefit ratio for tracheal intubation versus use of a supraglottic airway should be evaluated in large scale trials

**Practice points**

- the laryngeal mask airway is the best evaluated supraglottic airway device so far
- though new airway devices are developed in increasingly numbers, it is reasonable to become proficient with only a few of them
- compared to the laryngeal mask airway, the laryngeal tube is inferior in terms of airway morbidity and technical aspects of ventilation
- the oesophageal tracheal combitube is not suitable for routine anaesthesia due to its high airway morbidity
individual patient’s laryngopharyngeal anatomy. Thus, applying fixed cuff volumes may not be recommended, may contribute largely to airway morbidity and should be replaced also in the instruction manuals by insufflating the lowest cuff volumes resulting in an acceptable airway leak pressure guided by meticulous cuff pressure monitoring. Furthermore, intracuff pressure monitoring should become routine practice with any extraglottic airway device.

REFERENCES


