

THE LARYNGEAL MASK AIRWAY

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Few advances in anaesthesia have had such a dramatic impact as the introduction of the classic Laryngeal Mask Airway (cLMA) to anaesthesia in 1988. This was the first really effective alternative to facemask or tracheal intubation for airway maintenance during anaesthesia. The cLMA rapidly became the standard alternative to tracheal intubation and is the first of the modern supraglottic airway devices (SADs) [also referred to by some as extraglottic airway devices: EADs]. Many anaesthetists, though not all, initially restricted the LMA to anaesthesia for minor extremity surgery with spontaneous breathing, but it is interesting to note that in the Dr Archie Brain first publication on the cLMA reported its use in 21 patients, of whom 16 underwent gynaecological laparoscopy with controlled ventilation. Since then the indications for the LMA have evolved rapidly and there is now a far more liberal attitude to indications for laryngeal mask use. It is estimated that over 200 million anaesthetics have now been administered using a cLMA.

The LMA has continued to develop since 1988 and seven alternative laryngeal masks have been developed and marketed. This practical review summarises the role of the various devices. The 'family' of LMAs now includes the standard or classic LMA (cLMA), the flexible/reinforced LMA (fLMA), the Intubating LMA (ILMA) and the ProSeal LMA (PLMA). Single-use versions of the cLMA, fLMA and ILMA are now available (although largely unevaluated).

In modern anaesthesia the LMA family has a role in routine anaesthesia, planned difficult airway management and in rescue of the obstructed or 'lost' airway.

The Classic Laryngeal Mask Airway (cLMA)

The cLMA was developed by Dr Archie Brain (figure 1) from 1981-1988 and released in 1988. During development over 100 prototypes were tested in more than 6000 patients. Its introduction was revolutionary: despite considerable scepticism at the time of its introduction, within a year every single hospital in the United Kingdom had purchased the cLMA.

The cLMA consists of a transparent silicone tube with a small oval-shaped silicone mask at the distal end. The mask has an anterior cuff, with pilot balloon and its posterior surface is semi-rigid to prevent folding. Across the distal end of the airway tube are two flexible bars that prevent the tongue impeding insertion, and the epiglottis

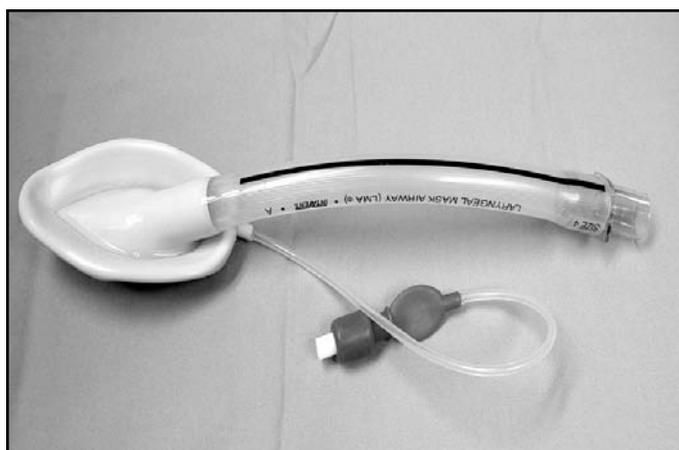
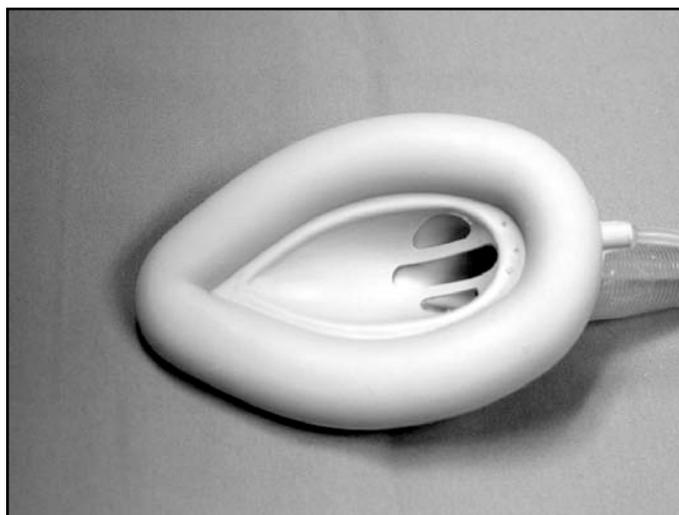


Figure 1a,b and c: Classic LMA

causing obstruction after placement. The lateral cuff lies against the pyriform fossa and the upper cuff lifts the base of the tongue. The mask is held in a stable position by the hypopharyngeal constrictor muscles laterally and cricopharyngeus inferiorly. When correctly placed the LMA lies with the airway orifice facing anteriorly over the glottis, the tip at the origin of the oesophagus and the cuff encircling the laryngeal inlet (figure 2). The cLMA cuff forms a low pressure seal allowing controlled or spontaneous ventilation. Correct positioning relies on getting the tip of the mask to the upper oesophageal sphincter, behind the cricoid cartilage.

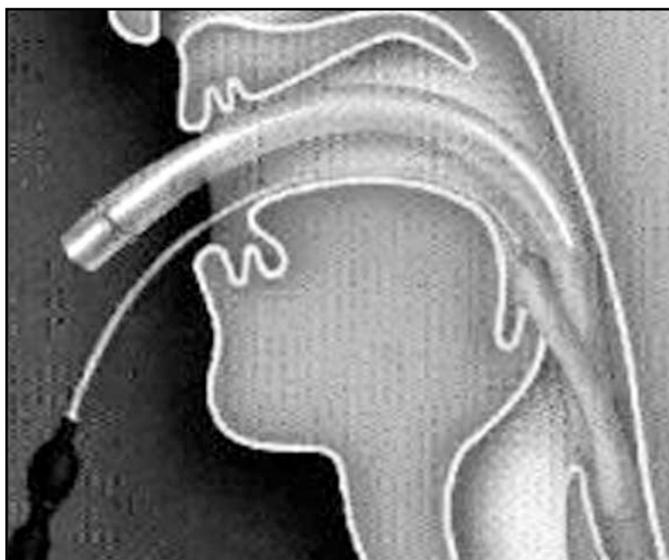


Figure 2

Size selection, pre-use checks and cleaning

The cLMA is supplied in 7 sizes from 1-6 suitable for practically all size patients (table 1). Size selection is generally based on weight for children and in adults the default should be a size 4 for women and a size 5 for men. If one size does not 'fit', it is often worth trying a different size based on clinical judgement. As an approximate rule,

LMA sizes	
Weight	Size
<5kg	1
5-10kg	1.5
10 - 20kg	2
20 - 30kg	2.5
30 - 50kg	3
Adult female	2 - 4
Adult male	4 - 5

where patient size suggests one of two mask sizes might be used (eg a patient of 20kg or 30kg) mask performance is frequently better with the larger mask. Mask insertion may be slightly more difficult but airway seal and performance is often superior.

The cLMA is designed for repeated use. The manufacturers guarantee it will perform well up to 40 times based on research showing alterations in the characteristics of the silicone used in its construction. However some hospitals use the cLMA for up to 100 uses without problem, although the manufacturers do not support this practice.

Checking the laryngeal mask carefully before use is vital. This includes:

- A full visual inspection to ensure the cuff, connector and tubing appear normal
- Exclude foreign bodies within the tube lumen
- Deflate the cuff fully and observe - if there is a leak in the cuff, it will start to re-inflate
- Gentle inflation to ensure pilot cuff and valve function
- Gentle folding over of the tube to detect damage and weakening of the airway tube.

After use the cLMA must be decontaminated (washed and dried) to remove any visible debris (including brushing the interior of the airway tube) then sterilised in accordance with local practice. The cLMA is designed to be autoclaved. There have been concerns that routine cleaning does not remove all protein deposits from laryngeal masks, but there is no evidence to date that this represents an important infection risk. Supplementary cleaning for 20 minutes with potassium permanganate 2mg/L eliminates approximately 90% of protein deposits from cLMAs, although this is not routine in most hospitals. Once cleaned the cLMA should be stored in a sterile fashion.

Routine use

A major advantage of the cLMA, over many other SADs, is that it is readily inserted, even in inexperienced hands, and routinely allows 'hands free' airway maintenance during anaesthesia. In one study of over 11,000 patients the cLMA provided a safe and secure airway in 98.5% of cases. There are a number of advantages for the cLMA including better oxygenation compared to facemask anaesthesia and reduced haemodynamic instability, anaesthetic requirements and sore throat compared to tracheal tube anaesthesia.

Case selection

Despite its versatility the cLMA requires careful case selection to ensure patient safety.

The cLMA is most suited to peripheral and minor surgery in healthy patients who are breathing spontaneously. This is a good place to start and learn. With experience the strengths and limitations of the cLMA are learnt. Obese patients, and those with a history of gastro-oesophageal reflux are less suitable.

Insertion

A greater depth of anaesthesia is needed for insertion of a cLMA than for a guedel airway but less than that needed for tracheal intubation. Depth of anaesthesia is crucial to success as movement during insertion often leads to an imperfectly positioned mask.

Before insertion the patient should be unresponsive with a relaxed jaw and should not respond to jaw thrust. However, insertion of the cLMA does not need use of muscle relaxants. Propofol is the most suitable induction agent as it profoundly suppresses airway reflexes and enables cLMA insertion without coughing or movement. If propofol is not available, insertion after thiopentone induction is aided by deepening anaesthesia with volatile agents or topical local anaesthesia to the oropharynx. Whichever induction agent is used, giving a rapid onset opioid (eg fentanyl or alfentanil) prior to induction improves mask insertion. If necessary the cLMA can be inserted under topical anaesthesia.

Insertion is carried out with the patient in the laryngoscopy position ('sniffing the morning air') and may be made easier by an assistant performing jaw thrust during insertion. The cLMA cuff should be fully deflated and the posterior surface well lubricated with a water-based lubricant before insertion. The anaesthetist stands behind the supine patient with one hand stabilising the patients head and neck and the other holding the cLMA. This is best done by placing a hand under the patients occiput and slightly extending the upper cervical spine. The cLMA is held like a pencil at the junction of mask and tube. The route the cLMA should follow mimics the route of a bolus of food during insertion. The cLMA is advanced

posteriorly (as if towards the occiput) along the hard palate and is allowed to follow the postero-superior aspects of the airway. When the cLMA 'stops' during insertion, the tip has reached cricopharyngeus (the upper oesophageal sphincter) and should be correctly positioned. Insertion should take place in one smooth movement to ensure this 'end point' is identified. In the authors' experience meticulous attention to insertion technique is rewarded by improved mask performance and reduced complications. For children and when the standard insertion technique fails partial inflation of the cuff, or initial insertion with the LMA rotated, akin to insertion of a Guedel airway, may help insertion.

The cuff should be inflated prior to connection to the anaesthetic breathing circuit. Five simple tests assist in confirming correct positioning of the cLMA:

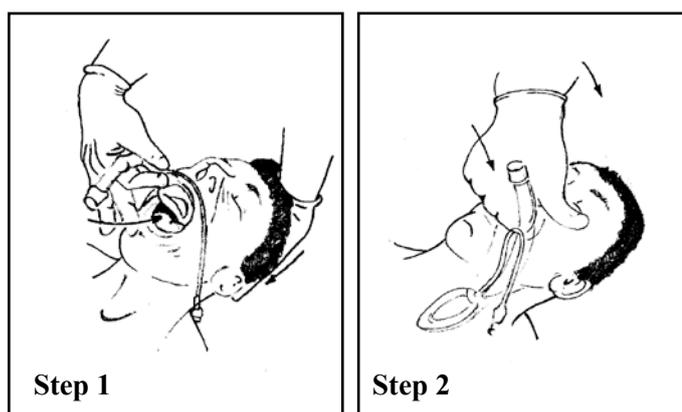
1. A definite end point is noted during insertion.
2. The cLMA rises slightly out of the mouth as the cuff is inflated.
3. The anterior neck bulges slightly as the cuff is inflated.
4. The black line on the back of the cLMA remains in the midline.
5. The LMA cuff is not visible in the mouth.

The amount of air 'recommended' for cuff inflation by the manufacturer varies with cLMA size (Table 2). It is important to note that the recommended volumes are maximum volumes. Usually no more than half this volume is required. The volume required is that to achieve a low pressure seal with the airway. The pressure in the cuff should not be above 60 cmH₂O. This pressure can be detected at the pilot balloon with an anaeroid barometer and with experience is easily estimated clinically. Over-inflation may increase the risk of pharyngolaryngeal complications, including nerve injuries (glossopharyngeal, hypoglossal, lingual and recurrent laryngeal) and occasionally causes airway obstruction.

Once the cLMA is inserted, head and /or neck movement make little difference to the position of the cLMA though may cause changes in the intra-cuff pressure and airway seal. Nitrous oxide if used will diffuse into the cLMA cuff until the intracuff partial pressure equilibrates with the anaesthetic gas mixture. This leads to increases pressure in the cuff in the first 30 minutes of nitrous administration. Excessive cuff pressures can be avoided by intermittently palpating the pilot cuff.

After insertion patency of the airway should be tested by gentle hand ventilation. Remember the cLMA cuff produces a low-pressure seal around the larynx and airway

Figure 3a and b



pressures above this seal will cause anaesthetic gases to leak from the airway. Gentle, slow hand ventilation should produce chest rise without airway noise or audible air leak followed by unobstructed exhalation (the anaesthetic reservoir bag rapidly refills). Oxygen saturation should remain stable and the capnograph trace should be square waved. A sloped capnography trace indicates airway obstruction - check for airway noise and raised airway pressure. Similarly if the reservoir bag does not refill normally this indicates either a large leak (does not refill at all) or partial airway obstruction (slow refilling). Where a self-inflating bag is used this useful clinical sign is lost. If there is a large gas leak or airway obstruction the cLMA should be removed and reinserted.

The cLMA should be secured with tape or tied in such a manner that it is prevented from migrating outwards. When the anaesthetic circuit is attached, ensure that its weight is prevented from pulling on the cLMA as this will lead to displacement.

A bite block is recommended, and a roll of gauze between the lateral teeth is effective.

This helps secure the device particularly in edentulous patients and prevents biting down during recovery from anaesthesia leading to airway obstruction, dental damage and damage to the cLMA.

When controlled ventilation is used peak airway pressures in slim adults and most children is usually no more than 10-14cmH₂O. Pressures above 20 cmH₂O should be avoided, as not only does gas leak out of the cLMA, but this exceeds oesophageal sphincter pressure. At low airway pressures gas leak is out of the mouth but at higher pressures gas enters the oesophagus and stomach increasing the risk of regurgitation and aspiration later in the case.

For small children and infants spontaneous breathing through the cLMA for prolonged periods is probably not advisable. The cLMA increases airways resistance and access to the airway for clearance of secretions is not as good as via a tracheal tube. Fortunately controlled ventilation in this group is often easy as children generally have lungs with high compliance and the airway seal with a cLMA is generally slightly higher in children than in adults.

During the maintenance phase of anaesthesia the cLMA usually provides a clear airway and adjustment of position is rarely necessary. However occasionally misplacement can occur, particularly if anaesthesia becomes light or the patient moves. The anaesthetic circuit reservoir bag should be visible and full monitoring with appropriate alarms should be used throughout anaesthesia to ensure this infrequent event is detected should it occur. If the patient's position needs to be altered it is wise to disconnect

the airway during movement. When the repositioning is complete, reattach the anaesthetic circuit and recheck the airway.

At the end of surgery the cLMA should be left in place until the patient has woken up and is able to open his/her mouth to command, at which time protective airway reflexes have normally recovered. Suction of the pharynx and turning the patient at this time are generally unnecessary and may lead to stimulation and increase airway complications such as laryngospasm. When the patient can open their mouth the cLMA can be removed: most secretions will come out at this time and any additional secretions or blood can be suctioned out at the time of removal if the patient cannot clear them. In children the timing of removal is less clear: some studies suggest a higher rate of complications when the cLMA is removed awake, and some when it is removed 'deep'. Certainly removing it in a 'light' patient who is not fully awake increases problems and should be avoided. If the cLMA is removed deep, watch out for airway obstruction and hypoxia. If removed awake be ready for coughing and laryngospasm.

Avoiding regurgitation and aspiration

The cLMA does not offer protection against pulmonary aspiration of regurgitated stomach contents and it is unwise to use the cLMA in any patient in whom there is an increased risk of regurgitation. This includes the following patients: non-starved patients, emergencies, those with symptomatic hiatus hernia or gastro-oesophageal reflux and the grossly obese. Few patients have 'no risk' of aspiration and it is rational to divide patients into those with low, moderate or high risk of aspiration. The cLMA is a device to use only in those with a low risk of aspiration. The cLMA forms a low pressure seal with the airway and if excessively high pressures are applied to the cLMA during controlled ventilation, increasing volumes leak from the mask into the oesophagus and thence into the stomach increasing the risk of regurgitation.

The risk of serious lung injury, when aspiration occurs, is reduced by neutralising stomach contents (H₂ blockers, proton pump inhibitors and antacids all do this) but the best way to avoid this problem is by careful selection of cases, and avoiding use of the cLMA in patients at obvious increased risk of regurgitation / aspiration.

Good practice with the cLMA is as follows:

- select cases carefully
- insert the cLMA at an adequate depth of anaesthesia
- optimise correct placement by using the recommended insertion technique and checks of correct positioning
- avoid high airway pressures both when 'bagging' the patient before the cLMA is inserted

- after insertion use slow low pressure ventilation
- secure the cLMA to prevent misplacement during use
- unless necessary return to spontaneous breathing as soon as possible
- avoid movement of the cLMA during surgery unless unavoidable
- allow the patient to recover until able to open the mouth to command before removing the cLMA

Clinical application and areas of controversy

The cLMA has now been used in a much wider range of clinical settings than when first introduced. Although there remains considerable debate over what is appropriate or safe use of the cLMA even amongst experienced users, in many countries it is now used for up to two thirds of all anaesthetics. For some it has replaced tracheal intubation where this was previously thought to have been the mandatory 'gold standard' eg the paralysed patient, during laparoscopic surgery or advanced life support. However it is important to note that success in cases such as these is dependant on careful case selection, avoiding use when there are contraindications, and employing meticulous technique. It is unwise to use the cLMA for complex and unusual cases until considerable experience is gained with more routine and straightforward cases. Assessing the risk of aspiration is vital for the suitability of the cLMA in situations where intubation would normally be used.

Despite widespread use of the cLMA during controlled ventilation, there remains considerable debate as to the appropriateness of the technique where aspiration is thought to be a risk. There is a potential for the cLMA to disrupt the integrity of the upper oesophageal sphincter and it is also thought possible that an LMA may also reduce lower oesophageal sphincter competence (due to its presence stimulating swallowing reflexes). Laparoscopic procedures are particularly controversial with concerns over increased risk of aspiration from raised intra-abdominal pressure, lithotomy position and increased airway pressures. Despite these concerns there is evidence that the cLMA is widely used both for controlled ventilation, and during gynaecological laparoscopy, with a low incidence of complications. However it is likely that the Proseal LMA (see below) is a better choice for all cases where controlled ventilation is required and the anaesthetist believes a laryngeal mask is indicated.

Post-operative sequelae

These are usually minor. Sore throat is variously reported in 5% to 30% but is almost always minor, transient and less of a problem than after tracheal intubation. Blood is visible on the cLMA in up to 20%, but detectable in microscopic amounts in up to 80%. Rarer complications include nerve

injury due to prolonged mucosal compression leading to neuropraxia. Hypoglossal, glossopharyngeal, lingual and recurrent laryngeal nerve palsies have been reported.

Difficult airway

The cLMA is also an important tool in the management of the difficult airway and as an aid to endotracheal intubation. Much of the published literature on its use in management of the difficult airway is anecdotal and has not been subjected to robust controlled trials.

The cLMA has three roles in management of the difficult airway:

1. Use in patients in whom tracheal intubation is difficult or impossible (ie avoidance of tracheal intubation)
2. Rescue of the airway when ventilation and or tracheal intubation fail.
3. As a conduit for assisting tracheal intubation and allowing oxygenation during attempts.

When considered as an alternative to tracheal intubation it is important to note that physical features that predict difficulty with laryngoscopy and intubation do not predict difficulty with cLMA placement. Importantly however mouth opening is critical. If mouth opening is less than 2.5cm cLMA insertion is very difficult and if below 2.0 cm it is impossible.

The cLMA will rescue an obstructed airway in more than 90% of cases. This is particularly so when the obstruction is supraglottic. For this reason it can be argued that a cLMA should always be available (and the anaesthetist familiar with it!) wherever anaesthesia is provided. When cricoid pressure is applied this obliterates the space that the tip of the cLMA must enter when correctly placed. So when the cLMA is inserted (indeed for all laryngeal masks) it is important to reduce or release cricoid pressure during insertion. Once the device has been placed cricoid pressure can be resumed.

The bowl of the cLMA lies over the glottic in more than 90% of cases making it a suitable device for attempting to instrument the trachea when conventional methods fail. Narrow endotracheal tubes (ET) and bougies have been reported for this use. Importantly the cLMA allows oxygen and ventilation to continue uninterrupted during these attempts. Relatively long and narrow tubes are needed, particularly if an attempt is then made to remove the cLMA (table 2). There is a danger of the tube catching on the bars of the mask as it passes and if the tube is too short it may not reach the trachea, or the tracheal tube cuff may sit at or outside the glottis. The glottis in an adult is usually approximately 3cm beyond the bars of the cLMA so an endotracheal tube must be advanced approximately

6-7cm beyond this to ensure the tube tip and cuff are inserted far enough.

Blind techniques with an endotracheal tube or bougie may be successful but fail far more often than they succeed. Where available fiberoptic-guided techniques increase success rates to close to 100%. A specifically designed semi rigid tube of 80 cm length and with internal and external diameters of 4.6mm and 7.0mm respectively (the Aintree Intubating Catheter, AIC), solves many of the problems associated with cLMA-guided tracheal intubation in adults. The AIC is mounted on a fibrescope and then placed in the trachea. It is long enough to allow removal of both fibrescope and cLMA before railroading an ET (>7.0mm id) over it. There is increasing experience and published data with the AIC demonstrating a high level of success. Where this is not available narrow bore

uncut tracheal tubes may be used instead. It is worth remembering that the tracheal tube will need to extend a considerable distance beyond the cLMA grilles in order to reach and pass through the vocal cords. The length of tube needs to be even longer if it is cuffed, in order to avoid inflation of the cuff within or above the vocal cords.

Developments of the cLMA

The inventor of the cLMA has produced three different laryngeal masks since the cLMA. These are the flexible LMA (fLMA), Intubating LMA (ILMA), and the ProSeal LMA (PLMA). In addition single-use versions of the cLMA (the LMA-Unique (LMA-u), flexible LMA and ILMA have been recently developed. The most recent innovation is an ILMA with built in fiberoptics allowing intubation under direct vision, the C-trach.

Table 2 Ability to pass an endotracheal tube through a variety of laryngeal masks

cLMA size 1	3.5 id	distance to bars	108mm
size 1.5	4.5 id		135mm
size 2	5.0 id		140mm
size 2 1/2	6.0 id		170mm
size 3	6.5 id		200mm
size 4	6.5 id		205mm
size 5	7.0 id		230mm
fLMA (not recommended for this technique)			
size 2	3.5 id*	distance to bars	140mm **
size 2 1/2	3.5 id*		205mm**
size 3	5.5 id		237mm
size 4	5.5 id		237mm
size 5	6.0 id		284mm
PLMA size 3	6.0 id	distance to bowl	190mm
size 4	6.5 id		190mm
size 5	6.5 id		195mm
ILMA	7.0-8.0 mm special ILMA tubes	distance to epiglottic elevator	160mm

Notes

1. These are the sizes that can be passed through the LMA without force when well lubricated.
 2. These figures can only be regarded as a guide as different manufacturers ETs have different external diameter for same ID.
 3. This data relates to Portex blue line ETs for which external diameter ranges from 1.3- 2.6mm greater than internal diameter.
 4. This data only applies to cLMAs made by Intavent Orthofix or the LMA company.
 5. If using a cuffed ETT use a size 0.5 mm less.
 6. *A tube larger than this cannot pass the proximal end of the LMA, at the site of the 15mm connector
 7. **This is longer than an uncut ETT of this size, so not suitable for this technique
- The cLMA varies in price but costs approximately US \$120.

The flexible laryngeal mask airway (fLMA)

The mask of the fLMA is identical to that of the cLMA but the airway tube is wire-reinforced. This ensures that movement of the proximal end of the tube is less likely to be transmitted to the mask end and increases flexibility allowing it to be positioned away from the surgical field without dislodging the mask. The fLMA is particularly useful in head and neck, maxillofacial and ENT surgery where the flexible nature of the airway stem allows the anaesthetic circuit to be moved out of the surgical field while still allowing surgical access. The fLMA provides good protection of the larynx from secretions and blood above the device and has become popular for nasal and intraoral surgery, including tonsillectomy.

The fLMA has a longer and narrower airway tube than the cLMA (table 2). This increases the resistance of the tube and work of breathing through it: however this is not a problem in practice as the resistance is still comparable to a tracheal tube. The fLMA is not MRI compatible because of the metal in the reinforced airway tube.

The fLMA is supplied in sizes 2-5. Insertion of the fLMA can be more difficult than the cLMA due to the flexibility of the airway tube: the mask can rotate 180° on its axial plane (leaving the mask orifice facing backwards) without this being detected at the circuit end. Good insertion technique is likely to reduce this and a number of techniques are described to assist insertion, including guiding the fLMA into place by opening the airway with a laryngoscope. A specific insertion device the 'Flexiguide' that is inserted into the fLMA and grips it from inside has been shown to aid insertion.

The long narrow airway tube makes the fLMA the least suitable laryngeal mask for accessing the trachea when this is required. As a result the fLMA has only a limited role in the management of the difficult airway.

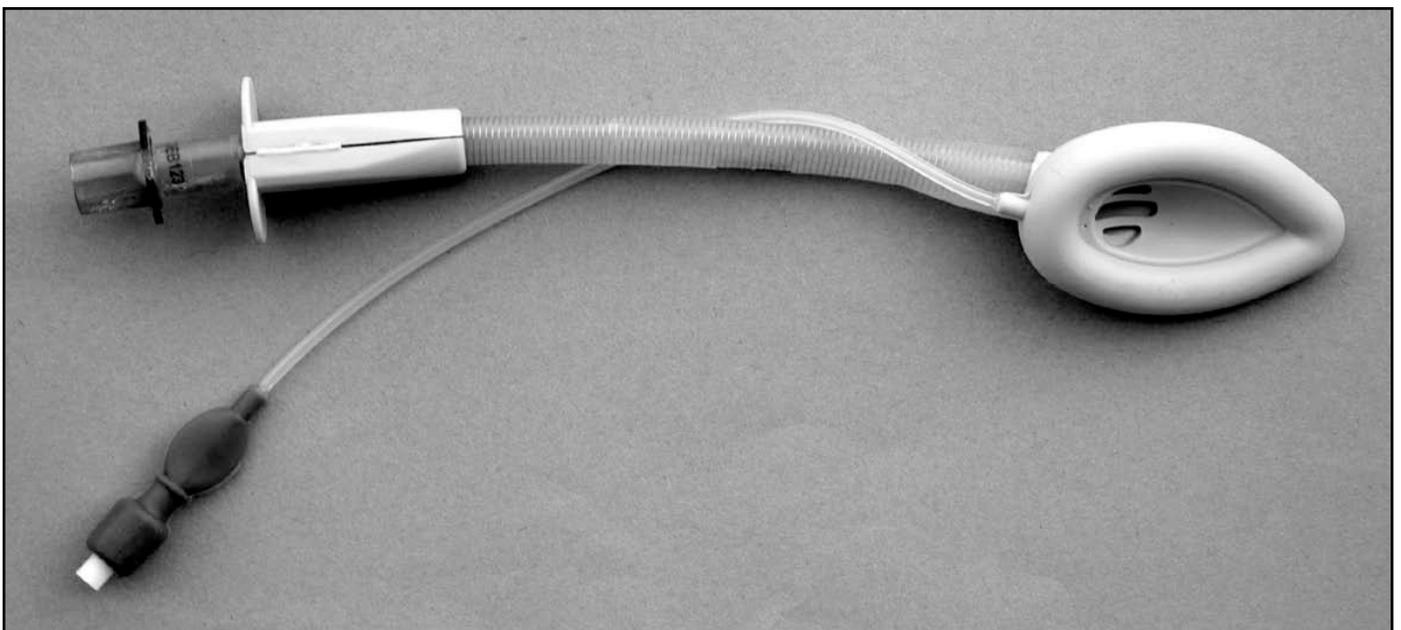
The fLMA costs approximately 30% more than the cLMA and is recommended to be used 40 times.

The Intubating Laryngeal mask airway (ILMA)

The ILMA (or Fastrach) is a laryngeal mask designed specifically to enable tracheal intubation. Although it is possible to intubate via a cLMA the long narrow airway tube creates some difficulties. The airway tube of the ILMA is rigid, shorter and of a wider diameter than the cLMA. At the proximal end of the ILMA airway tube there is a metal handle, which assists insertion and is critical for aiding intubation. This allows insertion and manipulation of the device without the operator having to place their fingers in the patient's mouth. At the mask end the bars of the mask are replaced by an 'epiglottic elevator', a semi rigid bar attached to the mask at only one end. Unlike other laryngeal masks the ILMA is designed for insertion with the patient's head and neck in the neutral position.

The ILMA is produced in sizes 3-5, and is supplied with a re-useable silicone bullet-tipped tracheal tube; the ILMA tube. The ILMA tubes range in size from 6.0-8.0 mm id, with all sizes of tubes passing through all ILMAs. The ILMA is inserted by holding the handle and then advancing the tip of the mask into the airway in a smooth arc in the curve of the mask (and airway) until it stops.

Figure 4: Flexible LMA



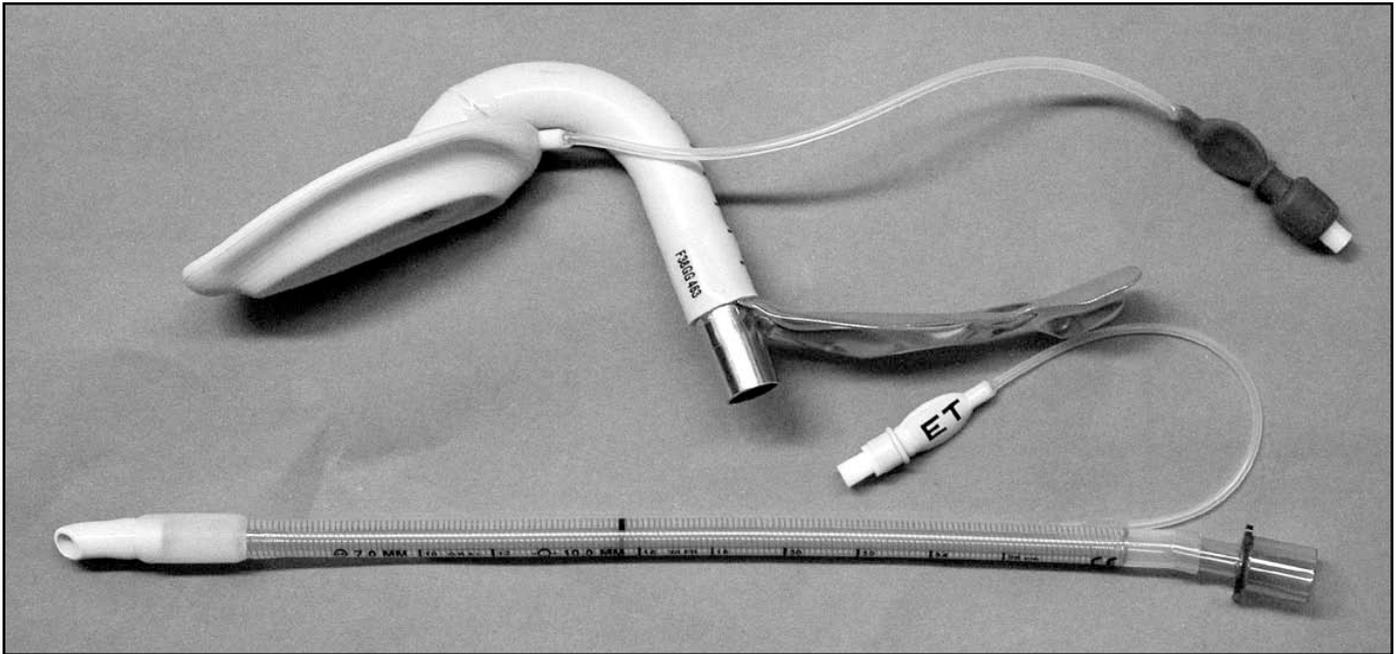


Figure 5: ILMA and ILMA tracheal tube

When blind intubation is to be attempted the anaesthetic circuit is attached and hand ventilation started while manoeuvring the ILMA handle to find the position where ventilation of the lungs is easiest (lowest resistance, highest compliance). In this position the ILMA orifice is most likely to lie opposite the larynx. Helpful movements include partial withdrawal or deeper insertion, lifting the mask to press against the larynx (named the Chandy manoeuvre after its originator), and an out/in manoeuvre to overcome epiglottic downfolding. Once correctly positioned the ILMA tube is gently advanced through the ILMA. Tube markings assist correct positioning. As the tube tip passed through the distal end of the airway tube it pushes the epiglottic elevator bar outwards, which lifts the epiglottis out of the path of the tracheal tube (TT). The ILMA tube is then rotated and advanced gently. Resistance usually indicates failure to intubate the trachea. As this is a 'blind intubation technique' it is important to use only gentle force and to confirm successful intubation (with a capnograph or Wee oesophageal detector) and exclude bronchial intubation. Fiberoptic and light-guided techniques increase intubation success with the ILMA.

The ILMA should not be used for those patients with contraindications to laryngeal mask use. When advancing the TT, resistance to passage should never be overcome by force. A soft tipped TT is recommended. The ILMA should not be used in patients with upper oesophageal pathology. Fatal oesophageal perforation has been reported when these precautions were not followed.

After intubation it is recommended to remove the ILMA for all but the shortest procedures, as the rigid airway tube

exerts high pressures on the surrounding mucosa. Removal of the ILMA is achieved by using a 'tube stabiliser' (or the hub of a 5ml syringe) to stabilise the ILMA tube while the ILMA is withdrawn over it. Sore throat and hoarseness, though usually mild, are more frequent after use of the ILMA than the cLMA.

The ILMA has an important role in management of both anticipated and unexpected difficult intubation. It is suitable for managing patients with cervical spine injury and may be used during cardiopulmonary resuscitation. The ILMA achieves an airway seal between that of the cLMA and the PLMA.

Several studies have evaluated the success rates of intubation with the ILMA. First attempt blind intubation success may be as high as 75% but in pooled studies is 66% and second attempt 22%. Overall success is approximately 95% when studies including patients with easy and difficult airways are included. Intubation success is increased to approaching 100% when a fiberoptic or light-guided technique is used. In the largest series of difficult airways, of almost 300 patients, overall success was 97%, increasing to 100% when fiberoptic guidance was used. If this is combined with four other studies then for patients with known or predicted difficult airways the overall intubation success rate is 92%, with 62% intubated at the first attempt.

Haemodynamic responses to intubation via the ILMA are similar to conventional intubation with a laryngoscope. However despite this success it is unlikely that the ILMA will enter mainstream practice for routine tracheal intubation.

There is evidence that individuals who are naive to both devices achieve greater success with ILMA than cLMA insertion. There is probably a learning curve of approximately 20 intubations though this may improve by training using a Manikin.

In addition to its role in difficult intubation, the ILMA is popular in some areas for assisting intubation in patients with cervical trauma. The patient can be left in the neutral position during ILMA insertion. It is usually necessary to take off the hard collar and stabilise the head with manual in line stabilisation (MILS) during insertion. Cricoid pressure also impedes ILMA placement and needs to be reduced or removed during insertion. Once the ILMA is inserted, cricoid pressure may be reapplied without altering function. Insertion of the ILMA and intubation through it cause minimal movement of the cervical spine.

Finally the ability to insert the ILMA from behind, in front or from the side of the patient and with the patient supine, lateral or even prone means that the ILMA is a suitable airway for insertion during extraction of patients who are entrapped.

The ILMA is an expensive device costing approximately \$500 and may be reused up to 40 times. A single use ILMA has recently been marketed but its performance is unevaluated. The most recent development of the ILMA is one with an integrated camera in the bowl communicating with a video screen close to the handle. For those with up to \$7000 this will allow the ILMA to provide intubation under direct vision without need for a fibroscope.

The ProSeal Laryngeal mask airway (PLMA)

The PLMA was introduced in 2000. It is designed with three improvements in mind:

1. Improved performance during controlled ventilation
2. Improved safety regarding aspiration
3. An ability to diagnose misplacement of the device tip.

The PLMA has a softer, larger deeper bowl than the cLMA. The mask cuff extends over the back of the device pushing it forward when inflated. There is a drainage tube passing from the tip of the mask, through the bowl to run parallel to the airway tube attached to it by an integral bite block.

When correctly positioned the drain tube of the PLMA lies at the top of the oesophagus encircled by cricopharyngeus and the bowl lies over the airway. These tubes therefore allow continuous passage to or from the gastrointestinal or respiratory tract, respectively, to the outside world. Further the gastrointestinal and respiratory tracts are functionally separated. As such, unlike the other laryngeal masks, which are simple airway tubes, the PLMA can be considered as a form of 'artificial larynx'.

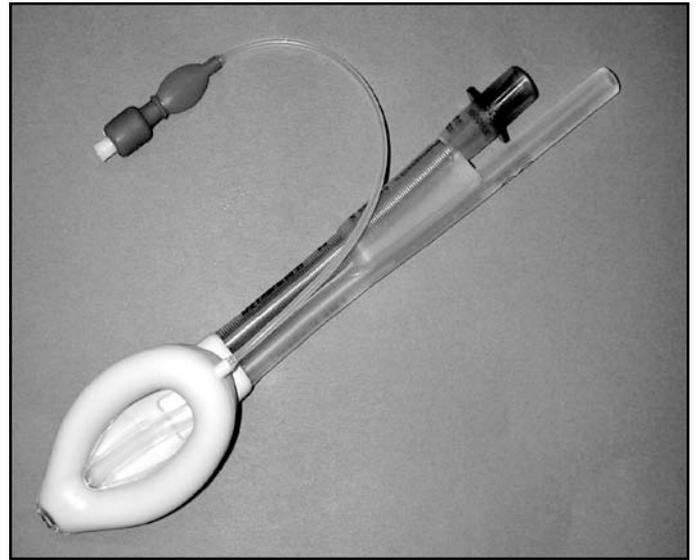


Figure 6: PLMA

The PLMA may be manually inserted (like the cLMA) or by attaching a metal introducer (rather like the ILMA insertion technique). Finally when insertion is difficult it may be railroaded via the drain tube over a bougie placed in the oesophagus. The latter technique is the most invasive but appears to be the most successful and least likely to lead to misplacement (there is a tendency for the PLMA to fold over during insertion if insertion technique is not meticulous). It is perhaps the technique of choice when first time insertion success is critical, such as when managing a difficult airway. The drainage tube allows reliable insertion of an orogastric tube. In fact inability to pass a gastric tube via the PLMA drain tube nearly always means the PLMA is misplaced with the posterior of the mask folded backwards.

A series of post insertion tests are recommended to confirm correct positioning of the device:

1. When correctly positioned the PLMA should allow leak-free ventilation with square wave capnography and airway pressures below 20 cmH₂O. Gel placed on, and occluding, the proximal drain tube should not be displaced when a pressure of 20 cmH₂O is applied to the airway; this tests separation of the gastrointestinal and respiratory tracts and fails most often when the PLMA is not pushed in far enough, allowing gas to pass directly from the airway tube up the drain tube.
2. Usually no more than one third of the bite block should be visible as this also suggests incomplete insertion.
3. Pressing on the chest should not displace the drain tube gel; if it does it suggests the drain tube tip has entered the glottis, though airway obstruction is likely to coexist.
4. Pressure at the suprasternal notch should lead to the drain tube gel bulging outwards. This tests that the drain tube is

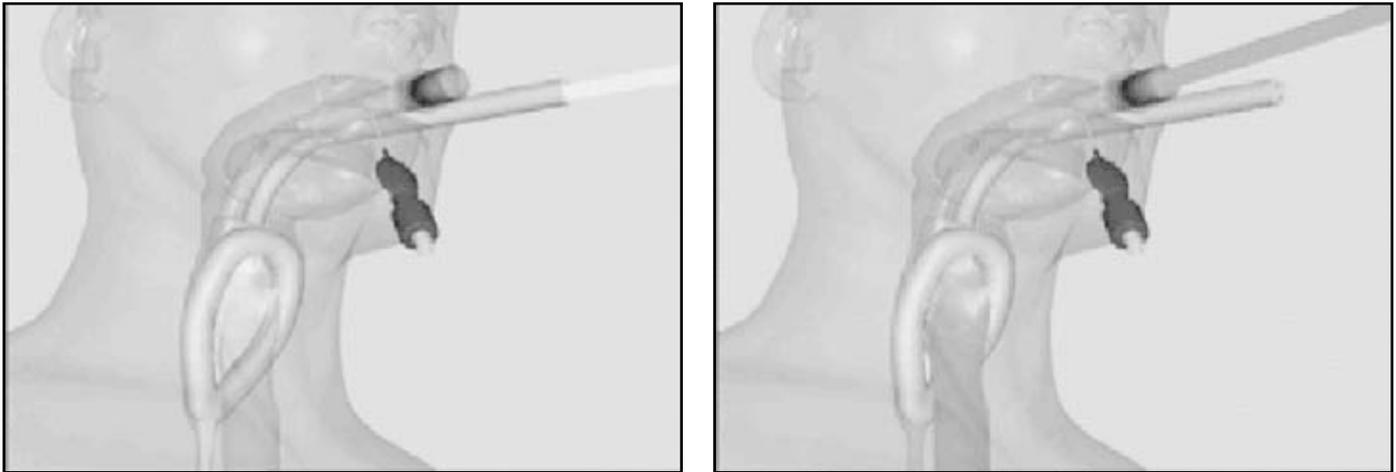


Figure 7a and b: PLMA positioning and GI vs RS route. Thanks to Intavent for illustrations.

not bent over; suprasternal notch pressure is transmitted to the oesophagus and then to the drain tube, unless the tip is folded over. If in doubt attempting to pass an orogastric tube to the tip of the drain tube, or beyond, will identify whether it is folded over. In practice these short tests can be carried out in a matter of seconds to confirm correct positioning and function of the PLMA, with further attention only necessary if a test is not 'passed'.

Importantly the drain tube allows confirmation of correct placement, or diagnosis of the type of misplacement of the PLMA: a feature not possible with other laryngeal masks.

Changes to that mask shape and size added to the posterior cuff increase the average airway seal by >50% to above 30 cmH₂O.

There is good theoretical and performance evidence to support the view that compared to the cLMA the PLMA reduces gas leak, gastric inflation and increases protection from regurgitated gastric contents. However this is entirely dependant on correct positioning of the device.

So do these modifications make the PLMA a superior device? On the positive side there is increased seal pressure (allowing a wider range of patients to be ventilated) and increased safety against aspiration. The PLMA also exerts less pressure against the mucosa than either cLMA or ILMA for a given insufflation pressure so reducing the potential for mucosal trauma and damage. These advantages must be balanced against slightly greater difficulty in insertion of the PLMA. When combining a large number of studies, first time insertion success with the PLMA was 85% and with the cLMA was 93%. In addition when the PLMA is used during spontaneous ventilation there are reports of minor complications including partial airway obstruction and oesophageal breathing via the drain tube, leading to oesophageal distention and even the possibility of gastric

distension. These complications are generally overcome by using controlled ventilation, or passing an orogastric tube.

The PLMA is the most recently introduced laryngeal mask. It has advantages over others when controlled ventilation is used. Whether its advantages in terms of safety extend to other clinical circumstances is as yet unproven. It is possible that it will become the standard laryngeal mask in time because of increased safety, but this will require more research and is far from certain.

The PLMA has no grill or elevator bar across the airway opening to the mask. This offers the possibility of an unimpeded view and access to the larynx when managing the difficult airway. In these circumstances improved ventilatory performance and reduced risk of aspiration are also likely to be benefits. The vocal cords appear to be visible through the PLMA as frequently as through the cLMA. The airway tube of the PLMA is shorter and slightly narrower than that of the same size cLMA and similar problems exist for direct tracheal access. There is as yet little written on the use of the PLMA for management of the difficult airway but one area of interest is for airway rescue after failed rapid sequence induction where its characteristics appear very suitable. Several reports have been published, and the PLMA appears in the UK Difficult Airway Society Guidelines for this situation as one of the options.

The PLMA cost approximately 10% more than a cLMA and is recommended for up to 40 uses.

Single-use laryngeal masks

Several laryngeal masks are now available in single use versions. A PVC single use cLMA was introduced in 1998, the fLMA followed in 2003 and the ILMA in 2004. The cLMA came 'off patent' in 2003 and there are now at least six manufacturers who make similar devices based closely

on its design. All of these except one are made of PVC rather than silicone. The move towards single use devices accelerated following the recognition that prion diseases (causing variant Creutzfeldt Jacob or 'mad cow' disease) were potentially transmissible despite current disinfection and sterilising techniques. The extent of this risk is at present unproven and unquantified, but is considered exceptionally low. In addition to clinical considerations a change from reusable to single-use devices has impacts on cost, storage and environmental factors. Evidence for the effectiveness or safety of single-use laryngeal masks is so far limited, and it is too early to say whether they will perform less well, as well, or better than the cLMA. It is difficult to recommend, on the basis of evidence, whether a change to single use laryngeal masks is sensible at this time, and if so which device to chose.

Summary

The family of laryngeal masks have revolutionised airway management in anaesthesia in many parts of the developed

world. In many countries the cLMA is now 'the standard' airway for anaesthesia, with other devices including the endotracheal tube only being used when there is a specific indication. In addition the laryngeal masks have important roles in difficult airway management, in which they may be used as an alternative to tracheal intubation, may rescue the lost airway and may aid alternative intubation techniques. Each laryngeal mask has strengths and limitations. It is only by understanding these, selecting (or excluding) patients and mask type carefully and by meticulous attention to technique that the role of the laryngeal mask may be extended safely to the benefit of both patient and anaesthetist.

Further reading

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 3. Cook TM, Lee G, Nolan J. The ProSeal™ Laryngeal Mask Airway: A review of the literature. *Can J Anaesth* 2005; 52: 739-60.
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