LMA Flexible™

A Practical Guide

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I. Introduction

The LMA™ laryngeal mask airway (LMA™ airway) has revolutionised airway management and anaesthesia in the two decades since the first description of the device in 1983 by Dr. Archie Brain, the inventor, in the now classic paper 'The laryngeal mask – a new concept in airway management', published in the British Journal of Anaesthesia[1].

Over 2,500 publications and in excess of 200 million general anaesthetics using some form of the LMA™ airway indicate the importance and impact the LMA™ airway has had on anaesthetic practice.

The LMA Flexible™ was first described by Alexander in 1990[2] and became commercially available in 1992. The LMA Flexible™ was designed for use in surgery to the head, neck, and upper body where an LMA Classic™ airway tube would:

(i) Interfere with the surgical field
(ii) Interfere with surgical access
(iii) Be occluded
(iv) Cause displacement of the cuff during surgery

The LMA Flexible™ is therefore ideally suited for surgery such as:

- Adenotonsillectomy
- Dental
- Palatal
- Ear
- Head
- Neck
- Nasal
- Ophthalmic
- Facial lesions
- Upper body

Worldwide, the number of surgical procedures undertaken with the LMA Flexible™ is unknown, although, approximately 5% of all LMA™ airways sold are LMA Flexible™ airways. Each year approximately 4 million general anaesthetics are given in the UK and 20 million anaesthetics are given in the USA. Despite the five times greater number of general anaesthetics provided in the USA, the UK accounts for 25% of the entire LMA Flexible™ market.

Within countries, great variations also exist in LMA Flexible™ use. In the UK and Australia 15%-60% of anaesthetists use the LMA Flexible™ for adenotonsillectomies[3,4,5].

Considerable institution-to-institution and country-to-country variation exists in the use of the LMA Flexible™. Reasons for this wide variation probably relate to 5 key features:

- General LMA™ airway usage
- LMA Flexible™ training
- Recognition of correct depth of anaesthesia for LMA Flexible™ insertion
- Use of the standard insertion technique
- Familiarity of surgeons with LMA Flexible™ airways, particularly for intraoral work

The LMA Flexible™ provides a safe and effective airway for ENT, head and neck, and upper torso procedures, with significant advantages over a facemask and tracheal tube (these are discussed in Section IV).

II. History

By the late 1980's, as clinical use of the LMA Classic™ increased dramatically, letters started to appear in the literature which described kinking of the LMA Classic™ airway tube.

This led to the design and development of the LMA Flexible™, the first of the specialised LMA™ airways, by Dr. Brain. This new device contained an identical cuff to the LMA Classic™, with a longer, narrower, wire-reinforced medical grade silicone airway tube, which gives the shaft more flexibility and resistance to compression.

Dr. C. Alexander at the Royal East Sussex Hospital in the UK was the first to use this new LMA Flexible™ in 20 patients for tonsillectomies or molar extractions[2].

In 1992 the LMA Flexible™ was released to the market and by 1993 the first papers were written on:

(i) The use of the LMA Flexible™ for adenotonsillectomy (published from The Royal National Throat, Nose and Ear Hospital, London and the University of Western Ontario)[6,7]

Fig 1. Dr. Paul Bailey, Consultant Anaesthetist, The Royal National Throat, Nose and Ear Hospital London, pioneer in the use of the LMA Flexible™ for ENT procedures and Dr. Archie Brain, the inventor

(ii) Its use for molar extractions by researchers at Addenbrooks Hospital, Cambridge[8].

Since 1992 there have been over 100 publications on the LMA Flexible™.

In 2004 a disposable PVC based LMA Flexible™ was released, ideal for use where there is a risk of cross contamination.

III. Device

1. Reusable LMA Flexible™

A. Device Description

The LMA Flexible™ consists of 3 parts: the cuff, wire-reinforced airway tube or shaft, and cuff inflation line.

The reusable LMA Flexible™ has an identical cuff to the LMA Classic™ with a narrower, longer, wire-reinforced airway tube (or shaft), which gives the shaft more flexibility and resistance to compression.

The flexibility of the tube allows movement of patient anatomy or the shaft, without displacement of the cuff.

The wire-reinforced airway tube provides significant protection against tube kinking but not against biting.

The longer tube means the anaesthesia breathing circuit is attached away from the face, allowing the surgeon greater access and minimal interference with surgery.

The floppy nature of the tube will allow the shaft to be placed in any position and moved or manipulated during intraoral surgery.

The disadvantage of the flexible tube is that it does not allow force to be transmitted down the shaft and therefore many of the alternative insertion techniques commonly adopted for the LMA Classic™ will not be successful and strict adherence to the correct insertion technique is critical for optimal use of the device. Also, unlike the LMA Classic™, where the tube position in relation to patient anatomy provides information on malposition or displacement of the cuff, in the LMA Flexible™ the shaft provides no such information.

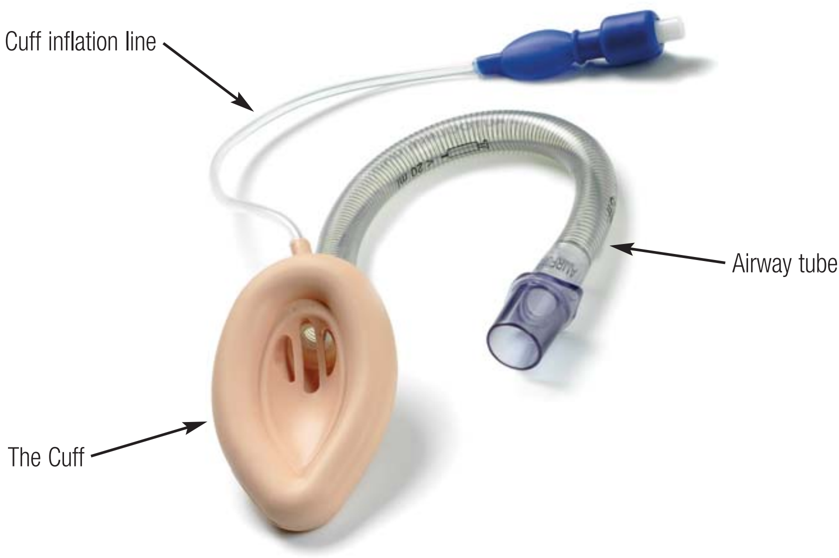


Fig. 2: Components of the reusable LMA Flexible™.

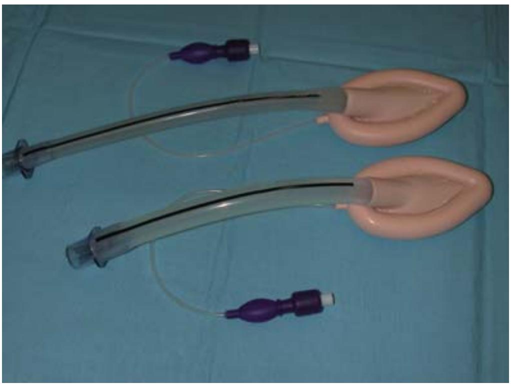
B. Gas Flow

The longer, narrower tube of the LMA Flexible™ compared to the LMA Classic™, means the resistance to gas flow is increased. The flow resistance of the LMA Flexible™ is 3-5 times greater than that of the LMA Classic™ but is similar to comparable sized endotracheal tubes[9]. The longer, narrower tube also requires a smaller fibreoptic scope than the standard LMA Classic™[10].

C. Laser Resistance

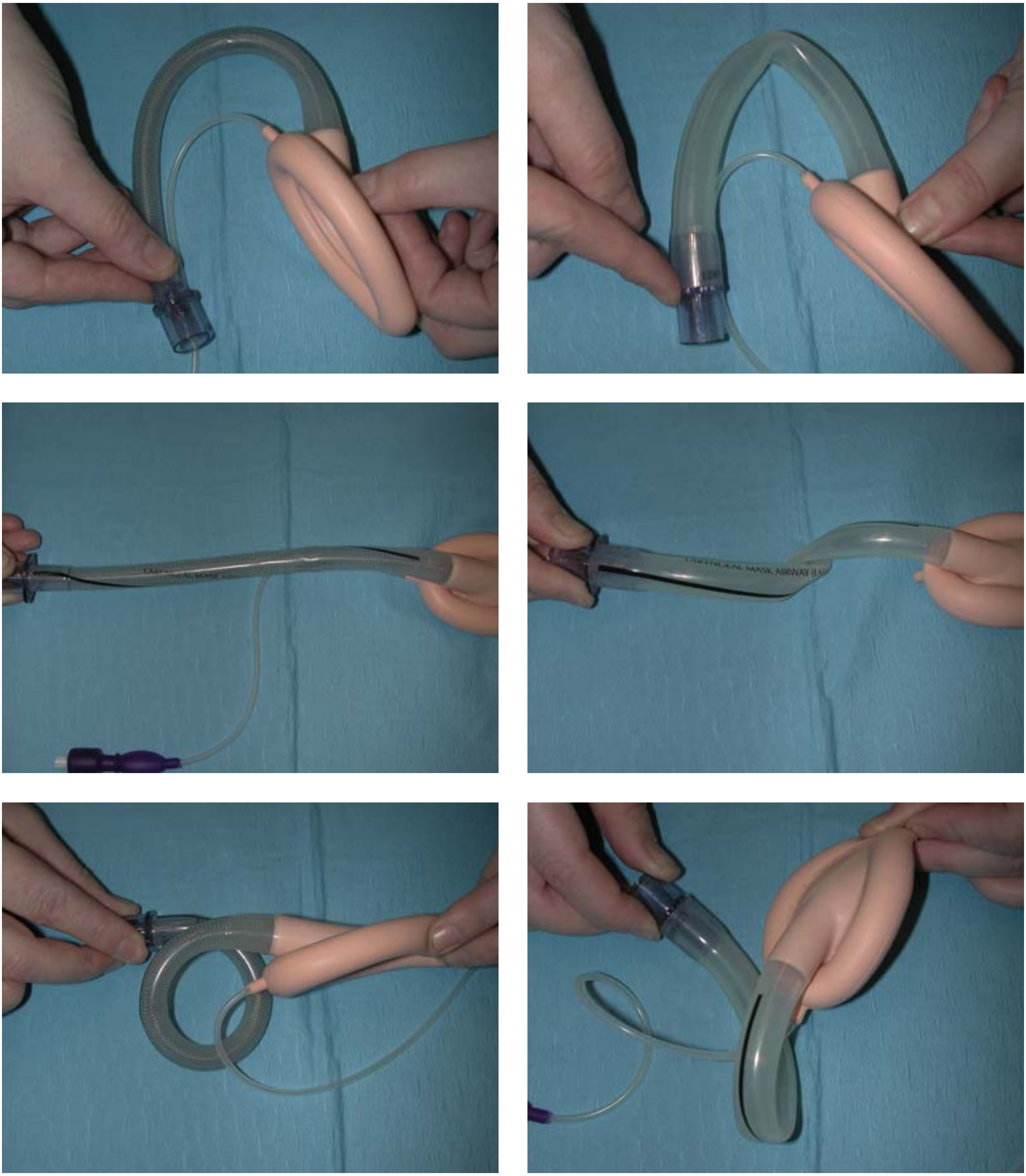
The laser resistant properties of the reusable LMA Flexible™ have been assessed[11,12,13] and it has been shown to be relatively resistant to CO_2 and KTP (potassium titanyl phosphate) laser strikes. The silicone cuff of the LMA™ airway is penetrated most easily due to its reduced thickness.

Figs. 3, 4: LMA Flexible™ and LMA Classic™. Note identical cuffs.



Figs. 5, 6: LMA Flexible™ and LMA Classic™. Note longer, narrower wire reinforced LMA Flexible™ airway tube.

LMA Flexible™ | LMA Classic™



Figs. 7-12: Flexibility of the LMA Flexible™ shaft (left) compared with the LMA Classic™ (right). The patency of the LMA Flexible™ shaft is seen in a variety of positions.

D. Gas Permeability

The gas permeability of the LMA Flexible™ cuff should be identical to the LMA Classic™ cuff as they are the same. The silicone LMA™ airway cuff is permeable to gases, particularly nitrous oxide and carbon dioxide[14]. When using nitrous oxide with an air-filled cuff, the intracuff pressure increases over a 30-minute period. Typically after a period of 1-2 hours equilibrium is reached[15,16,17].

Fig. 13: Gas permeability – Intracuff pressure monitor attached to pilot ballon.

E. Cleaning and Sterilisation

The LMA Flexible™ should be cleaned and sterilised in an identical manner to the LMA Classic™. This involves manual cleaning after removal. It is important to avoid drying of secretions on the LMA™ airway and if manual cleaning is delayed the LMA™ airway should be stored in soapy water to prevent this. This is particularly important for the LMA Flexible™ following its use for intraoral or nasal surgery where secretions and blood must not be allowed to dry.

Before sterilisation, care should be taken to adequately remove any residual air or fluid in the cuff and standard sterilisation by steam autoclaving undertaken.

The reusable LMA Flexible™ is designed to be used for 40 uses. A detailed log of the number of autoclave cycles should be kept and the LMA Flexible™ discarded after 40 uses.

1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

Fig. 14: 40 use record card.

2. LMA Flexible™ Single Use

A. Device Description

The LMA Flexible™ Single Use, introduced in 2004, has an identically designed cuff, inflation line and airway tube to the reusable LMA Flexible™. It is made of medical grade polyvinyl chloride (PVC). Although the shape of the cuff is identical, the thickness of the PVC is slightly greater than the reusable silicone cuff of the LMA Flexible™. The length of the airway tube is the same for the disposable and reusable devices but the diameter is slightly greater for the LMA Flexible™ Single Use, although this is still considerably smaller than its corresponding LMA Classic™.

B. Laser Resistance

Fig. 15: Components of the LMA Flexible™ Single Use.

PVC has minimal laser resistant properties and is explosive with a blowtorch flame occurring when used with a laser.

The LMA Flexible™ Single Use should never be used in laser surgery as it may cause a risk of an airway fire.

C. Gas Permeability

Gas permeability of the LMA Flexible™ Single Use with nitrous oxide anaesthesia and an air-filled cuff is minimal with no changes in the intra-cuff pressures for the LMA Flexible™ Single Use[18]. This is probably a reflection of the thickness of the LMA Flexible™ Single Use PVC cuff, as it is known that nitrous oxide diffuses through PVC.

D. Cleaning and Sterilisation

The LMA Flexible™ Single Use is intended as a single use device and is therefore unsuitable for cleaning and sterilisation.

IV Uses

The LMA Flexible™ has specific advantages over both a facemask and a tracheal tube. Because of its airway tube flexibility, it is particularly useful for operations on the upper chest, breasts, shoulders, neck, some facial procedures, ophthalmic, ear and nasal procedures, and with experience, intraoral procedures with a shared airway including palatal surgery, dento-alveolar procedures and adenotonsillectomy.

Since 1992, over 50,000 ENT procedures have been undertaken with the LMA Flexible™ at The Royal National Throat, Nose and Ear Hospital, London. These have included over 10,000 adenotonsillectomies, over 20,000 nasal procedures and over 20,000 ear procedures.

By 1994, two years after the release of the LMA Flexible™, 60% of all adenotonsillectomies at The Royal National, Throat, Nose and Ear Hospital were undertaken using a LMA Flexible™[3]. Currently the author estimates that in excess of 95% of all adenotonsillectomy procedures utilise the LMA Flexible™.

LMA Flexible™ compared with a facemask

A number of studies have shown the significant advantages of the LMA™ airway over facemask ventilation, and although most of these studies have compared a LMA Classic™ to the facemask, the LMA Flexible™ would be expected to behave in a very similar manner when correctly sited because the cuff of both devices is identical.

The quality of airway management with the LMA™ airway is superior to a facemask, with:

(i) better oxygenation[19,20]
(ii) improved seal with less oropharyngeal air leaks[21,22]
(iii) better monitoring of tidal gases, particularly at low-flow anaesthesia[23]
(iv) less pollution[24,25,26]
(v) Features which make facemask ventilation difficult, such as; facial burns[27], beards[28], and edentulous patients[29]

The quality of the airway with the LMA™ airway is superior to a facemask

Fig. 16: LMA Flexible™ compared with a facemask.

Fig. 17: The LMA Flexible™ is useful in patients where face mask anaesthesia may be difficult.

LMA Flexible™ compared with the Endotracheal Tube

The LMA™ airway has significant advantages over the endotracheal tube at:

- induction
- maintenance
- recovery from anaesthesia

Fig. 18: LMA Flexible™ compared with an endotracheal tube.

The vast majority of research on this subject has been undertaken with the LMA Classic™, but as the cuff of the LMA Flexible™ and LMA Classic™ is identical, physiological responses would be expected to be similar.

(i) Induction

Specific advantages of LMA™ airway insertion compared to the endotracheal tube relate to two key factors:

(i) the avoidance of laryngoscopy and tracheal intubation
(ii) the avoidance of the physiological responses to laryngoscopy

The avoidance of laryngoscopy and tracheal intubation will reduce the incidence of dental trauma, the risk of endobronchial and oesophageal intubation, as well as avoiding the use of muscle relaxants.

Physiological responses to laryngoscopy and tracheal intubation include significant increases in heart rate, blood pressure, plasma catecholamine levels and intraocular pressure.

LMA™ airway insertion has been shown to have significantly less effect on plasma catecholamine rise, heart rate rise and blood pressure rise[30,31,32,33,34] and lasts for between 2-3 minutes in normotensive patients without cardiovascular disease. These responses have also been shown to be significantly lower in patients with cardiovascular disease[32,35,36].

Induction of Anaesthesia

- Avoidance of laryngoscopy/tracheal intubation
- Avoidance of the physiological responses to laryngoscopy

As well as attenuation of cardiovascular responses, intraocular pressure changes have also been shown to be significantly reduced with LMA™ airway insertion compared to laryngoscopy and tracheal intubation[37,38,39].

(ii) Maintenance of Anaesthesia

During maintenance of anaesthesia, cardiovascular responses with increased heart rate or blood pressure are also lower with the LMA™ airway than endotracheal intubation[7,40,41]. Oxygenation during both spontaneous ventilation and positive pressure ventilation is similar for the LMA™ airway and patients with an endotracheal tube in place[42,43,44,45,46,47,48].

Maintenance of Anaesthesia

- Superior cardiovascular profile
- Tolerance at lighter levels of anaesthesia
- Avoidance of muscle relaxants

These studies suggest that whilst oxygenation with spontaneous or positive pressure ventilation is similar for both the LMA™ airway and the patient with the endotracheal tube in place, hemodynamic responses are significantly less with the LMA™ airway, with improved cardiovascular stability.

The LMA™ airway is also tolerated at much lighter levels of anaesthesia than the tracheal tube. Muscle relaxants can be avoided, allowing facial nerve and recurrent laryngeal nerve monitoring during surgery. The LMA™ airway is also useful for asthmatic patients by avoiding endotracheal instrumentation.

(iii) Recovery

One of the most significant advantages of the LMA™ airway over the endotracheal tube is the improved recovery profile. The LMA™ airway is tolerated better during emergence and can be left in place until return of protective reflexes. This is particularly important for ENT surgery and other intraoral procedures, which have one of the highest incidences of recovery airway problems.

This improved recovery profile leads to a smoother recovery with a reduced incidence of respiratory complications including; coughing, bucking, straining, airway obstruction, laryngospasm and desaturation. Oxygenation is better, with significantly fewer hypoxic patients with the LMA™ airway compared to an endotracheal tube[37,49,50,51,52,53,54,55,56,57].

Recovery

- Improved recovery profile
  - coughing
  - bucking
  - straining
  - laryngospasm
  - better oxygenation
  - airway obstruction
- Improved cardiovascular profile

As with the induction and maintenance phase, hemodynamic responses are lower with a more stable cardiovascular profile to both emergence and removal of the LMA™ airway compared to the endotracheal tube[37,49].

There are some significant advantages in utilising the LMA™ airway in preference to an endotracheal tube for induction, maintenance and recovery from anaesthesia.

V. Training

It would be unrealistic to expect an individual with no prior experience in the use of the LMA™ airway to be able to insert and use the LMA Flexible™.

Training for the successful use of the LMA Flexible™ involves a number of steps, including:

(i) Reading the relevant manuals, videos, CDs and DVDs in order to understand the device itself, the pre-use tests, correct deflation, standard insertion technique, understand where the LMA™ airway cuff sits when inflated and its relationship with the upper oesophageal sphincter, glottic opening, laryngopharynx and oropharynx
(ii) Practice the correct insertion technique in a manikin
(iii) Once the practitioner has an understanding of the device, correct insertion and the anatomical relationship of the LMA™ airway cuff and its surrounding structures, only then should the practitioner commence clinical use

Before attempting to use the LMA Flexible™, the practitioner should have clinical experience in the use of the LMA Classic™.

For the inexperienced clinician, the LMA Flexible™ is less forgiving than the LMA Classic™, principally because the correct insertion technique must be strictly adhered to because of the nature of the airway tube and the inability to transmit pressure along that shaft. The practitioner should have gained experience with the LMA Classic™ and have knowledge of:

(i) The correct depth of anaesthesia for insertion
(ii) The correct insertion technique
(iii) Be able to identify malposition of the cuff
(iv) Identify oropharyngeal leaks and an incorrect seal
(v) Have gained experience with spontaneous ventilation, assisted and positive pressure ventilation
(vi) At the end of surgery, understand when and how to remove the LMA™ airway

As well as gaining this clinical experience, the practitioner should understand which cases are suitable and not suitable for the LMA™ airway, its indications and its contraindications.

Only once the practitioner has this basic understanding, knowledge and experience with the LMA Classic™ should they proceed to LMA Flexible™ use.

A. LMA Flexible™ Training

Many individuals have significant problems using the LMA Flexible™, despite considerable experience with the LMA Classic™.

The most common reason for this is that most of these practitioners do not use the standard insertion technique and attempt to substitute their non-standard insertion techniques.

Non standard insertion techniques are successful with the LMA Classic™ but are often unsuccessful with the LMA Flexible™.

It is interesting to note that the phenomenal success of the LMA Classic™ with over 200 million general anaesthetics administered to date is, in part, because a practitioner with very little knowledge or understanding of the device can use it with high success rates despite no formal training, education or knowledge.

However, for optimal use and particularly for the LMA Flexible™ an understanding of the device and the correct insertion technique is required.

Some investment of time, education, knowledge and skills is required for optimal LMA Flexible™ use.

With the LMA Flexible™, a sensible approach to training would be to use the device initially for relatively straightforward cases of short duration, gaining experience with assessing the suitable depth of anaesthesia for insertion and gaining more experience with the insertion technique. These short procedures could include minor ear procedures, simple facial lesions, and simple upper body or neck procedures.

Following on from these basic uses, some intermediate cases involving more major ear surgery, nasal surgery, ophthalmic surgery and facial plastic cases could be undertaken. Finally, advanced uses of the LMA Flexible™ involving a shared intraoral airway should be undertaken including adenotonsillectomies, dentoalveolar surgery and palatal surgery.

It would be unrealistic to expect a trouble-free intraoperative course in a small child for intraoral work, for example, adenotonsillectomy, with an inexperienced surgeon and an inexperienced anaesthetist.

Figs 19-21: Manikin training for LMA Flexible™ insertion.

VI. Team Approach

Three groups are key to the successful use of the LMA™ airway, particularly for intraoral surgery. As well as the anaesthetist, the surgeon should have some understanding of the device and the recovery staff must know when and how to remove the LMA Flexible™.

Team Approach

- Anaesthetist
- Surgeon
- Recovery staff

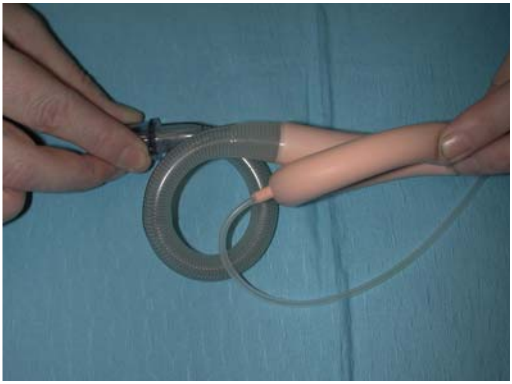


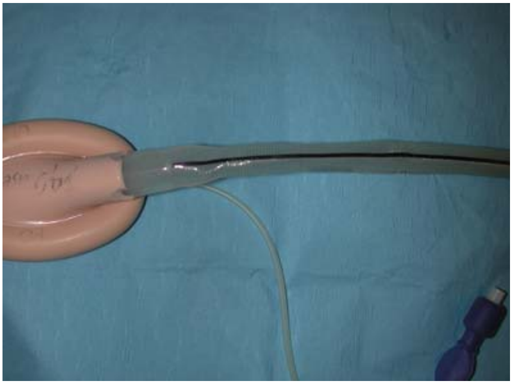
Fig. 22: Loop test.

VII. Practical aspects of Anaesthesia

A. Pre-use

1. Pre-use tests

- Wire-reinforced airway tube – loop test
- Tube patency - assessing for damage and foreign bodies, colour and bite marks
- Connector check
- Aperture bars check
- Deflation test – reinflation indicating a leak in the cuff, valve, pilot balloon or inflation line
- Inflation test – 50% over inflation to assess for any leaks
- Cuff symmetry



Figs. 23, 24: Bite marks visible at proximal and mid position of LMA Flexible™ shaft.

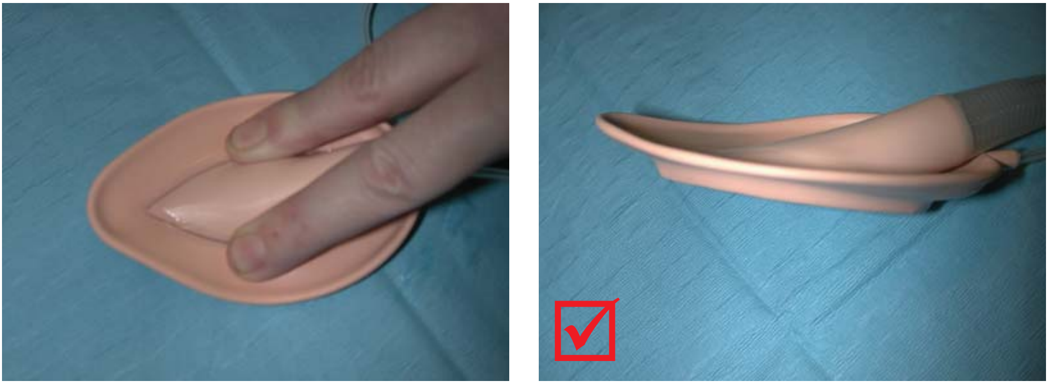
Fig. 25: Visual inspection of connector. Note smaller inner diameter of LMA Flexible™ (left) compared to LMA Classic™ (right).

Fig. 26: LMA Flexible™ with aperture bars damaged and broken.

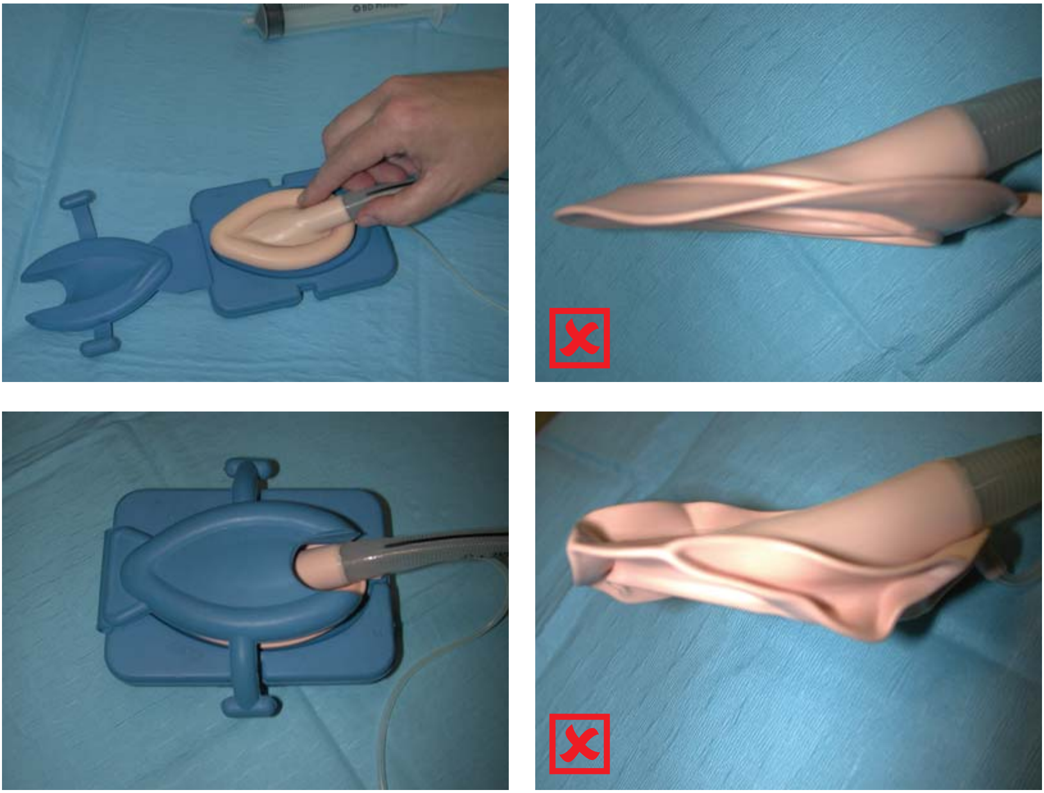
2. Cuff Preparation

- Manual

Fig. 28: Manual cuff deflation.



- Cuff deflator



Figs. 29, 30: Cuff deflator tool.

3. Lubrication

Fig. 31: Lubrication on the dorsal surface of the cuff.

Fig. 32: Incorrect placement of lubricant on the ventral surface of the cuff.

Lubrication is essential to ease placement of the LMA Flexible™ and should be placed on the dorsal surface of the cuff as this is the surface in contact with the hard palate, soft palate and oropharyngeal mucosa during insertion.

It is not necessary to place lubricant on the ventral surface of the cuff as during the standard insertion technique this surface is not usually in contact with the tissues and, further, the lubricant may migrate into the area of the aperture bar causing blockage or risk of inhalation.

Water-based lubricants are suitable but they can dry out. It is therefore more suitable to place the lubricant immediately prior to insertion of the LMA Flexible™.

Silicone-based lubricants should be avoided for the reusable LMA Flexible™ as they can damage the cuff, but they may be suitable with the LMA Flexible™ Single Use.

B. Induction of Anaesthesia

Induction of anaesthesia, either by intravenous induction agents or inhalational agents, has been studied extensively in the context of LMA™ airway insertion.

No clear consensus has been reached on the superiority of one technique (intravenous or inhalational) over the other.

This may be a reflection of the differences in:

(i) Intravenous induction agent dosage (mg/kg)
(ii) Different induction technique (bolus, target controlled)

For volatile agents:

(iii) Percentage of agent used (high volatile percentage from start, gradual increase in volatile percent) or
(iv) Technique (vital capacity, tidal breathing techniques).

For induction techniques, propofol has been shown to be superior to thiopentone, probably because of its superior depression of upper airway reflex activity[58,89,60,61,62].

The dose of propofol required for optimal insertion conditions has also been investigated. The dose required will vary depending on the clinical condition of the patient, their age, and the method of administration. Generally, children require a greater dose of induction agent and for propofol this is typically at least 4mg-kg[63,64,65]. In adults, typically doses of around 2mg-kg are required[66].

C. Insertion

1. Correct Depth of Anaesthesia for Insertion

Whatever induction technique is used, the important part is the ability to recognise and achieve the correct depth of anaesthesia.

This recognition of the correct depth of anaesthesia for LMA Flexible™ insertion is critical, with inexperienced users often attempting to insert the LMA Flexible™ in a patient who is not adequately anaesthetised, who has significant oropharyngeal tone, is not relaxed and is moving. It is under these sorts of conditions that an insertion failure occurs. The patient may bite on the anaesthetist's finger and residual stomach contents may be regurgitated with the risk of potential aspiration.

Correct Depth of Anaethesia for Insertion
• Apnoea
• Easy facemask ventilation
• Relaxed oropharyngeal tone

The clinical features suggesting a suitable depth of anaesthesia has been reached in order to introduce the LMA Flexible™ are twofold. First, a sufficient depth of anaesthesia to produce apnoea and allow easy facemask ventilation and second, a sufficient depth of anaesthesia to relax oropharyngeal tone and musculature to allow unresisted jaw manipulation or a jaw thrust manoeuvre[67].

Recognition of the correct depth of anaesthesia for LMA Flexible™ insertion is critical.

Figs. 33, 34: Unrestricted jaw manipulation.

Fig. 35: Jaw thrust manoeuvre.

2. Standard Insertion Technique

The standard insertion technique is, in the author's opinion, the best technique for LMA Flexible™ insertion as long as the correct depth of anaesthesia has been reached. The insertion technique for the LMA Flexible™ is similar to that of the LMA Classic™. The most significant difference is that pressure cannot be transmitted along the airway tube.

The patient should be positioned in a 'sniffing the morning air' position with the neck flexed on the shoulders and the head slightly extended on the neck.

The non-dominant hand should be on the back of the patient's head, whilst the dominant hand holds the LMA Flexible™, as shown in the figure, with the index finger at the base of the airway tube and cuff (like holding a pen). The cuff is flattened against the hard palate, ensuring the cuff tip is not curled over and the cuff is flattened in an oval shape. Because of the smaller diameter of the shaft, more space is available in the mouth and the cuff is ideally positioned by the finger; also there is no pressure exerted by a semi-rigid shaft as in the LMA Classic™.

Once the LMA™ airway cuff is positioned at the hard palate, the index finger is used to advance the LMA™ airway along the palatopharyngeal curve. As the LMA™ airway moves more distally, the index finger changes from its flexed position at insertion to a neutral position and finally into an extended position. As the finger changes from a neutral to an extended position, the wrist is also internally rotated, allowing the finger to pass further into the oropharynx.

Utilising this technique, anaesthetists with small fingers should still be able to correctly place the LMA Flexible™.

Fig. 36: Patient in 'sniffing morning air' position. Note position of fingers (similar to holding a pen).

Fig. 37: Index finger used to guide LMA Flexible™ along palatal curve.

Fig. 38: Note: Internal rotation of wrist and extended finger position.

Alternative insertion techniques for the LMA Flexible™ have been suggested and include techniques to temporarily stiffen the airway tube to aid insertion by introducing a stylet [68,69,70], a bougie[71], or a small endotracheal tube [72,73]. Other techniques have included introduction by modified Magills forceps[74] and Fukahara forceps[75].

No randomised trials have compared the different insertion techniques for the LMA Flexible™. In the author's opinion, the standard insertion technique with digital manipulation and feedback provides the best information for LMA Flexible™ insertion.

3. Malposition following Insertion

Malposition of the cuff varies from minor ventilatory changes (non optimal ventilation) through to complete obstruction. The most common cause for this malposition is the use of the non-standard insertion technique.

Ventilatory characteristics which may suggest malposition include:

(i) leaks
(ii) abdominal chest movements
(iii) ease of ventilation
(iv) capnography
(v) change in ventilatory characteristics on rotation of the head from one side to the other

In patients with significant tonsillar hypertrophy (Grade 3-4), there is a significant narrowing of the space between the tonsils. In these patients, as the cuff passes along the palatopharyngeal curve and approaches the tonsillar tissue, there is a tendency for the mask to rotate up to 90 degrees as it passes through the narrow space, and then return to its natural position.

Occasionally, the cuff can 'flip' through 180 degrees, so that the cuff is facing in the wrong direction, and total obstruction occurs. This situation is not common. What is more common is that the cuff does not fully rotate back to its natural position and may be partially rotated such that with the head positioned to one side ventilation is excellent but when the head is rotated to the opposite side ventilation is obstructed or clearly compromised.

Under these circumstances the LMA Flexible™ should be removed and resited.

An alternative insertion technique involving lateral rotation of the cuff to ease passage through the narrow space between the tonsils may be attempted. This may be aided by a jaw thrust type manoeuvre in which the anterior posterior space within the oropharynx is increased to aid passage of the laterally rotated cuff as it passes between the tonsils.

D. Maintenance

During maintenance of anaesthesia, the LMA Flexible™ provides an excellent airway for both spontaneous and positive pressure ventilation.

Whilst oxygenation is similar between the LMA™ airway and endotracheal tube during maintenance, cardiovascular responses are significantly reduced, with improved cardiovascular stability when the LMA airway™ is used.

This is particularly useful in patients undergoing ear, nasal and facial plastic surgery where hypotensive anaesthesia may be indicated to reduce bleeding and improve the surgical field.

The incidence of bronchospasm with the LMA™ airway is also very low, as might be expected in an airway device that does not directly irritate the tracheao-bronchial tree. A rate of 0.025% to 0.13%.[57,76]

Maintenance problems with the LMA™ airway relate to intraoral surgery where there may be:

(i) movement of the airway tube during dento-alveolar work
(ii) compression of the airway tube during adenotonsillectomy procedures by the Boyle-Davis tonsillar gag

During dental procedures, the LMA Flexible™ produces less airway obstruction and hypoxia than the LMA Classic™ or a nasal mask[77].

In adenotonsillectomy procedures, the incidence of obstruction following the application of the Boyle-Davis tonsillar gag will vary considerably, dependent on the experience of the anaesthetist and surgeon.

E. Recovery

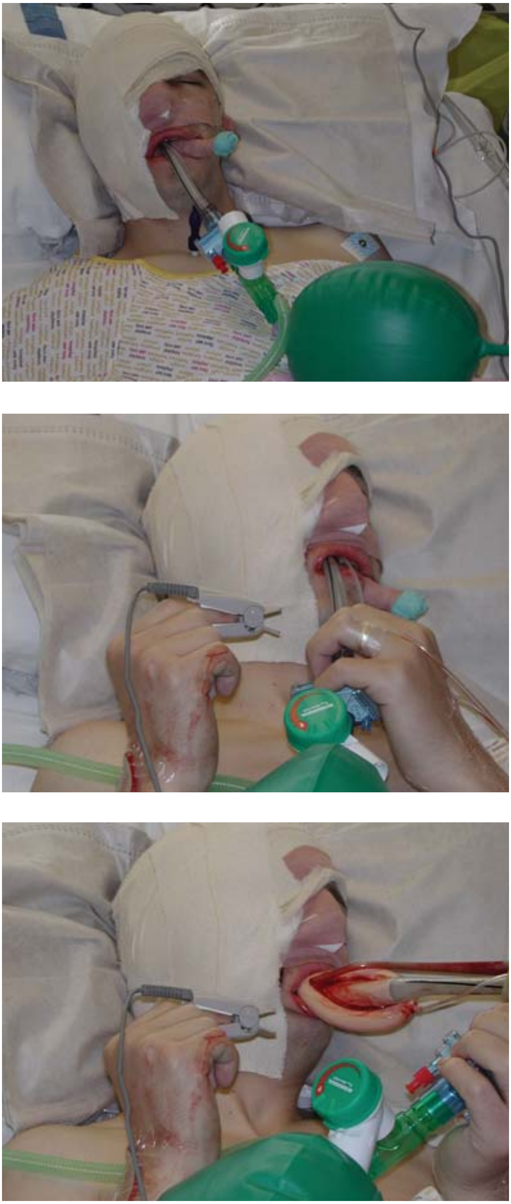
Fig. 39: Recovery following nasal surgery.

For many shared airway procedures, such as ophthalmic, nasal, ear, facial plastics, head and neck procedures, it is important that the airway and cardiovascular profile during recovery is smooth with no coughing, bucking, laryngospasm, desaturation, venous congestion, and bleeding. Many of these surgical procedures, particularly shared airway work, are known to have some of the worst airway recovery profiles of all surgical procedures.

A significant advantage of utilising the LMA Flexible™ for recovery is the improved airway and cardiovascular profile for these procedures.

For adenotonsillectomy procedures undertaken with the LMA™ airway, the airway recovery profile is superior to those undertaken with an endotracheal tube, with a lower incidence of hypoxia.[6,78]

The superior airway recovery profile is one of the main indications to use the LMA Flexible™, particularly for shared airway procedures.



Figs. 40-42: Self entubation of LMA Flexible™ following surgery

VIII. Airway Protection

With a correctly sited LMA™ airway, soiling of the tracheo-bronchial tree by contamination from blood, debris, and oropharyngeal secretions should not occur when the oropharyngeal leak pressure or seal is greater than 15cm of H_2O.

Two studies have looked at methylene blue dye[79] placed in the pharynx and barium dye[80] to look for airway soiling. In the first of these papers, 64 anaesthetised patients had methylene blue dye placed in the pharynx and subsequently had a fibreoptic scope placed to view the trachea to detect any dye. None was present. Similarly under screening, no barium dye was seen within the tracheal bronchial tree.

Airway protection from oropharyngeal material is vital for nasal surgery, dental surgery and adenotonsillectomy procedures. During nasal surgery, at emergence, aspiration of blood was much less common with the LMA™ airway compared to an endotracheal tube[53, 81].

For dentoalveolar surgery[82], aspiration of blood occurred in 6% of patients with a nasotracheal tube but there were no incidences of aspiration with the LMA Flexible™.

For adenotonsillectomy procedures, aspiration of blood was greater for patients with an uncuffed endotracheal tube compared to the LMA Flexible™[6,78] and the incidence of aspiration was similar for the LMA Flexible™ to a cuffed endotracheal tube.

For a correctly sized and positioned LMA Flexible™, the seal will provide airway protection from blood, secretions or debris above the cuff. However, the cuff will not provide protection from regurgitated material from the stomach due to gastric insufflation and distension due to a poorly sized or positioned LMA Flexible™.

There are currently no reports of aspiration with the LMA Flexible™.

IX. Clinical Uses

A. Upper Body Procedures

For upper body procedures such as upper chest, breast and shoulder surgery, the LMA Flexible™ may be suitable. The shaft can be positioned such that it will not interfere with the surgical field or drapes.

For shoulder surgery, with the head rotated away from the site of surgery, the LMA Flexible™ may be useful.

For patients placed in a lateral position for surgical access to the operative site, the LMA Flexible™ may be indicated.

Figs. 43-46: LMA Flexible™ airway tube in various positions.

B. Facial Lesions/Facial Plastics

For facial lesions, the shaft of the LMA Flexible™ can be positioned in any direction and left untaped, allowing the surgeon an undistorted surgical field. The improved cardiovascular profile compared to an endotracheal tube will aid hypotensive anaesthesia, improving the surgical field and reducing bleeding. The superior cardiovascular and airway recovery profile will reduce the incidence of congestion and bleeding.

C. Ophthalmic

For both extraocular and intraocular surgery, the LMA Flexible™ has advantages over the endotracheal tube. There is better intraocular pressure control, cardiovascular stability, and an improved airway recovery profile with less coughing during emergence. For intraocular surgery, most studies describe paralysed patients with positive pressure ventilation[38,39,51,83,84,85,86,87].

D. Neck Procedures

A variety of neck procedures can be undertaken with the LMA Flexible™ and this will be dependent on the experience of the anaesthetist, surgical requirements, the potential for displacement and minor alterations of neck anatomy.

The role of the LMA™ airway for thyroid surgery has been described[88,89,90,91].

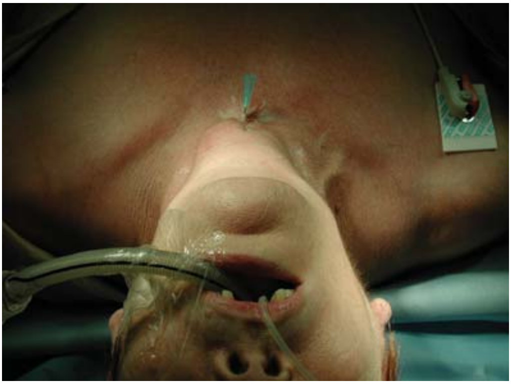
The LMA Flexible™ is suitable for thyroid surgery, resection of neck lesions and biopsy of neck lesions. The patient's head can be positioned to the side or the patient placed in a lateral position.

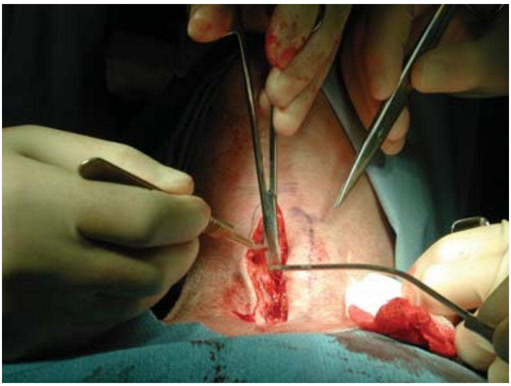
Figs. 47, 48: LMA™ Flexible airway tube positioned to expose neck.

Limitations of the LMA Flexible™ for neck surgery include:

(i) Minor alterations in neck anatomy following cuff inflation
(ii) Changes in ventilatory characteristics following surgical manipulation to the neck
(iii) Requirement for a totally `secure' airway for large tumours extending from the oropharynx or laryngopharynx through the pharyngeal wall outwards with significant neck extension

The LMA™ airway has been used successfully for major head and neck surgery lasting up to 9 hours following failed endotracheal intubation[92].





Figs. 49, 50: Anterior neck procedures using LMA Flexible™.

E. Ear Surgery

The LMA Flexible™ is ideally suited for all types of ear surgery where rotation of the head from one side to the other causes no change to the position of the cuff and therefore ventilation. After insertion of the LMA Flexible™, the head can be rotated from one side to the other to assess for any changes in ventilatory characteristics.

Fig. 51: Ear surgery.

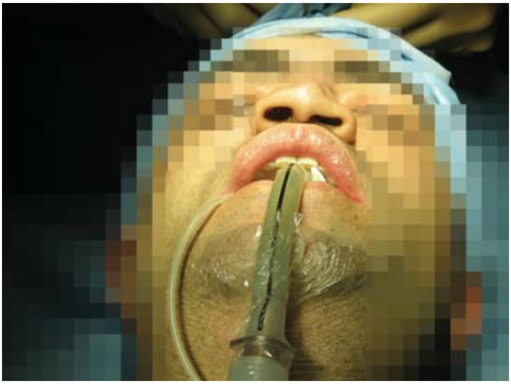
For minor ear procedures, two studies[20,93] have looked at the ventilatory characteristics of the LMA™ airway compared to a facemask. The LMA™ airway was superior.

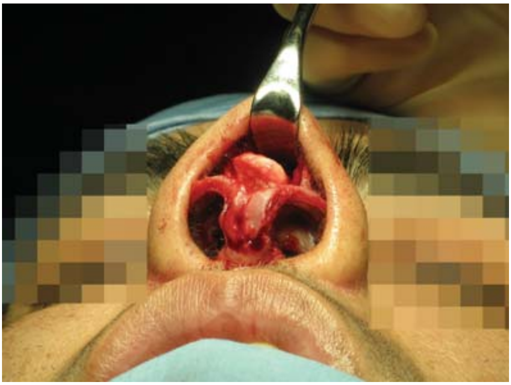
For major ear surgery, the haemodynamic stability during surgery allows a good surgical field. Ventilation without the use of neuromuscular blocking agents allows facial nerve monitoring.

The smooth, cough free emergence provides an excellent recovery profile reducing bleeding and protecting surgical grafts within the ear.

F. Nasal Surgery

The LMA Flexible™ is suitable for all types of intranasal surgery, including short procedures such as reduction of nasal fractures, antral washouts, or longer procedures such as functional endoscopic sinus surgery (FESS), nasal polypectomy, septoplasty, submucous resection and turbinate surgery.





Figs. 52, 53: Nasal surgery with LMA Flexible™

The LMA Flexible™:

(i) Protects the airway from contamination by blood, debris and secretions above the cuff
(ii) Provides airway protection with positive pressure ventilation with a seal above 15cms H_2O

Fig. 54 Advanced naso pharyngeal tumour with LMA Flexible™ in situ.

(iii) Provides haemodynamic stability during surgery to reduce bleeding
(iv) Has superior emergence characteristics compared to an endotracheal tube[53,94]

The superior haemodynamic profile during surgery reduces the likelihood of significant bleeding and improves the surgical field.

Positive pressure ventilation with control of CO_2 levels is useful for nasal procedures where controlled hypotension may be required to reduce bleeding and improve the surgical field.

Some units continue to use traditional gauze roll throat packs for nasal surgery with the LMA Flexible™. Unlike an endotracheal tube, the role of the throat pack during nasal surgery with the LMA Flexible™ is not to protect the tracheobronchial tree from airway soiling. The cuff of the LMA Flexible™ provides adequate protection against airway soiling. Its role is to absorb any topical nasal vasoconstrictor inserted through the nostrils into the nasopharynx, which may pass through into the oropharynx.

Figs. 55-57: Sinonasal procedures with LMA Flexible™.

A throat pack placed against the soft palate may also act as a barrier to reduce contamination of the oropharynx by blood, debris and secretions from the nasopharynx during surgery.

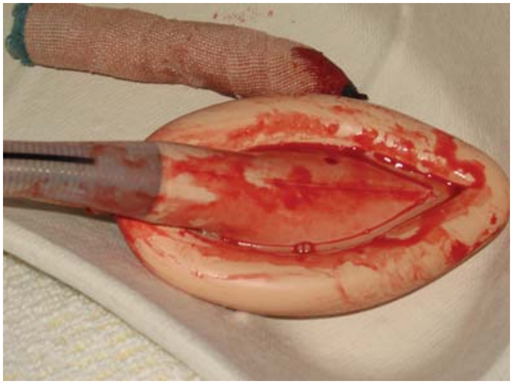


Fig. 58: LMA Flexible™ following removal. Note blood on surface.

Fig. 59: LMA Flexible™ following removal.
Note no blood within bowl.

During placement of a throat pack when the LMA Flexible™ is in place, great care must be taken to avoid displacement of the cuff. At the end of surgery care must be taken when removing the throat pack to avoid minor displacement of the cuff.

The head can be flexed to allow any clots, blood or debris in the nasopharynx to pass into the oropharynx. Laryngoscopy is then undertaken with oropharyngeal suctioning to remove any blood, secretions or nasal debris.

G. Intraoral Surgery

Using the LMA Flexible™ for intraoral surgery is an advanced use and both the anaesthetist and surgeon must be familiar with the characteristics of the device.

(i) Dental

The LMA Flexible™ has been used in dental surgery since its original description by Alexander in 1990[2].

When compared to a nasal mask, the LMA Flexible™ has a superior airway and cardiovascular profile[95], with better oxygenation, less airway obstruction and fewer arrhythmias with less tachycardia.

When compared to a nasotracheal tube for dental surgery, the LMA Flexible™ protected against contamination of the tracheobronchial tree by aspiration of blood better than the nasotracheal tube[96] and was more cost effective because of a shorter procedure time and shorter recovery time[97].

The use of the LMA Flexible™ in comparison to nasotracheal intubation avoids the requirements for muscle relaxation, nasal trauma from tube placement and increases case turnover.

H. Intraoral Surgery Palatal

Patients present for palatal surgery with mild obstructive sleep apnoea or snoring due to palatal flutter. Controlled laser burns (CO_2 laser) to the soft palate tighten and fibrose the soft palate reducing palatal flutter and local snoring.

The procedure involves the use of a Boyle-Davis tonsillar gag in the same manner as an adenotonsillectomy procedure.

The LMA Flexible™ has been shown to cause significantly fewer airway problems during insertion and recovery for palatal procedures compared to an endotracheal tube[98] in a group of patients who may be overweight, have mild obstructive sleep apnoea, have a difficult-to-maintain airway, and be difficult to intubate.

(i) Intraoral Surgery – Adenotonsillectomy

The use of the LMA Flexible™ for adenotonsillectomy procedures varies considerably within individual institutions, between institutions nationally, and internationally.

At The Royal National Throat, Nose and Ear Hospital, London, since 1992, over 10,000 adenotonsillectomy procedures have been undertaken with the LMA Flexible™, and the author estimates that over 95% of all procedures use the LMA Flexible™.

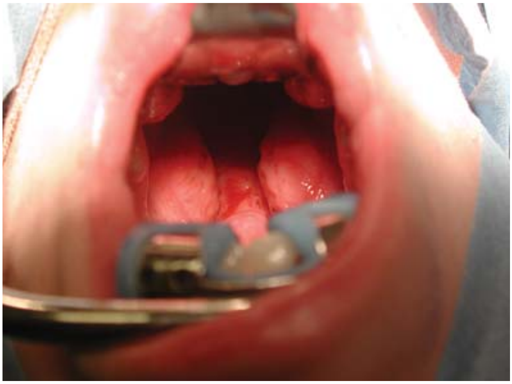


Fig. 60: Tonsillectomy with LMA Flexible™ in situ. No part of the LMA Flexible™ is visible.

The main advantage of utilising the LMA Flexible™ is the superior airway recovery profile with fewer episodes of bronchospasm, laryngospasm, bleeding and desaturation[3,6,7,78,99]. This superior recovery profile is particularly useful in children, who have a high incidence of airway recovery problems.

Another advantage is the improved protection from soiling of the tracheobronchial tree when compared to an uncuffed endotracheal tube.

Fig. 61: Careful blade placement by surgeon.

Fig. 62: Suboptimal LMA Flexible™ placement. Airway tube and mask inflation line visible.

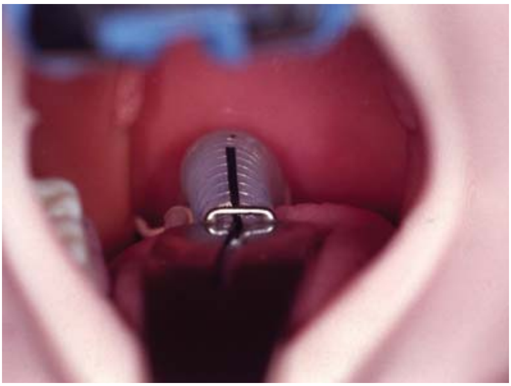


Fig. 63: Suboptimal blade choice. LMA Flexible™ airway tube visible with potential obstruction due to a smaller blade.

Fig. 64: Suboptimal blade choice/head and neck position. Note compression of shaft between blade and teeth.

Problems during maintenance of anaesthesia relate to the placement and opening up of the tonsillar gag (Boyle-Davis gag). Mechanical obstruction during the use of the tonsillar gag varies from 2-20%[3,7]. For the majority of these cases the obstruction is correctable.

For optimal use, a number of steps should be undertaken:-

1) The device:
- LMA Flexible™ pre-use tests should exclude any airway tubes with bite marks
- Correct size of LMA Flexible™
- Standard insertion technique with midline placement of airway tube and pilot tube

2) Maintenance
- Correct length of blade
- Lubrication of blade by surgeon
- Careful insertion of blade by surgeon
- Optimal head and neck positioning before opening of tonsillar gag

3) Ventilation
- Confirmation of ease of ventilation with open tonsillar gag
- Spontaneous or positive pressure ventilation
- No part of airway tube or cuff visible to surgeon
- Airway tube shielded if split blade during laser surgery

4) Removal of device
- Careful tonsillar gag removal at the end of surgery by surgeon
- Laryngoscopy to check no further bleeding
- Placement of bite block
- Discontinuation of volatile agents to allow recovery

If problems arise with partial obstruction following opening of the tonsillar gag, a number of checks can be made:

- Head and neck position
- LMA Flexible™ size. Tonsillar gag size
- Slight tension on the airway tube to maintain a midline position as the blade is introduced by the surgeon, reducing the likelihood of any part of the tube becoming kinked or trapped between the blade and the teeth in particular
- Try different blade size
- Further adjustments to head and neck position
- Change the LMA Flexible™ size

SUMMARY

Training on insertion is critical.

Surgeon/anaesthetist co-operation and understanding is an important factor in success.

Advanced procedures should only be attempted once the user is familiar with the device in basic procedures.

In summary, the use of the LMA Flexible™ for adenotonsillectomy procedures is an advanced use with a superior recovery profile, less airway soiling compared to uncuffed tubes but may require adjustments during insertion of the Boyle-Davis gag.

Table 3

Cleaning and sterilisation

1. No chemicals should be used. The LMA™ airway may absorb substances causing deterioration of materials or a mucosal reaction.
2. On removing the LMA™ airway, place in warm water containing simple soap.
3. Rinse thoroughly.
4. Wash tube and cuff, using small brush upwards from the bars to clean inside.
5. Leave the LMA™ airway to dry before autoclaving.
6. Remove all air from the cuff IMMDEDIATELY PRIOR to autoclaving
7. Place in autoclavable bag and STEAM AUTOCLAVE at 134° (+3°/-0°) Centigrade.

Table 4

Chemicals known to attack the valve

Chemicals resulting in severe attack	Chemicals resulting in slight attack
Acetic acid	Acetic acid, 3%
Brimide water, saturated	Acetone
Buffer solutions, pH 4.0	Aluminium chloride
Calcium hypochlorite	Aluminium sulphate
Chlorine	Alums
Chromic acid	Aniline
Dichloroethylene	Benzoic acid
Hydrochloric acid, 30%	Calcium bisulphate
Hydrcyanic acid	Citric acid
Hydrofluoric acid, dilute or 40%	Creosote
Hydrogen fluoride	Dimethyl formamide
Hdrogen sulpphide, wet	Ethyl acetate
Nitric acid	Hydrogen, dry
Nitrogen oxides	Lactic acid
Nitrous acid	Malic acid
Oxalic acid	Methylene chloride
Phenol	Nitrobenzene
Phosphoric acid, 25%	Oleic acid
Sodium hypochlorite	Palmitic acid
Sulphate liquors	Petroleum oils
Sulphur chloride	Picric acid
Sulphuric acid, 10%	Pyridine
Sulphurouos acid	Sodium thiosulphate
	Stearic acid
	Succinic acid
	Sulphur dioxide
	Tannic acid
	Tartaric acid
	Tedtrahydrofurane
	Tetralin
	Thiophane
	Trichloroethylene
	Vinegar

Table 5

Resistance of Polysulfone to cleaning systems

Effect on Polysulfone	Compound	High Stress [13.8 MPa (2000 psi) and over]	Low Stress [6.8 MPa (1000 psi) and under]	Unstressed Prolonged Exposure	Under 1 minute
Non-solvent	Freon TF* Ammnia Detergents, Soaps (Tide, Cascade, Alconox, Joy, Ivory Snow, SBS 50, Emerol) Freon TWD 602**	Little or no effect	No effect	No effect	No effect
Non-solvent	1% Lestoil Solution Kerosene Mineral Spirits (e.g. Varsol) Most Regular Gasolines Heptane Alcohols Naphtha CELLOSOLVE Solvents Turpentine Freon (Freon TF+ethonol)	Severe crazing or cracking	Little or no effect	No effect	No effect
Non-solvent	Carbon Tetachloride 1,1,1-Trichloroethane Freon TA (Freon TF+acetone)	Cracking	Possible crazing	—	No effect
Partial (or swelling) sovents	Esters (e.g. ethylacetate) Toluene (toluol) Xylene (xylol) Benzene (benzol) Acetone, Methyl Ethyl Ketone	Cracking and fracture	Severe crazing and cracking	Swells and softens	No effect
Good solvents	Methylene Chloride Trichloroethylene Cyclohexanone Chloroform Chlorobenzene Tetrachloroethylene 1,1,2,2-Tetrachloroethane	Cracking, Fracture and softening of the surface	Softening of the surface and probable cracking	Dissolves	Softenin g of the surface

* Trichlorotrifluoroethane

** Freon TF with water and detergent

Table 7

Description of different sizes of LMA™ airway (LMA) and LMA Flexible™ (FLMA) devices.

Mask Size	Patient Weight (kg)	ID/OD (mm)	Length (cm)	FLMA ID (mm)	FLMA Length (cm)	Max Cuff volume (ml)	Largest TT ID (mm)	FOB Size LMA (mm)	FOB Size FLMA (mm)
1	<5	5.25/8.25	8	-	-	<4	3.5	2.7	-
1.5	5-10	6.1/9.6	10	-	-	<7	4.0	3.0	-
2	10-20	7.0/11.0	11.55	5.1	15	<10	4.5	4.7	2.7
2.5	20-30	8.4/13.0	12.5	6.1	17.5	<14	5.0	5.3	4.7
3	30-50*	10.0/15.0	19	7.6	17.5	<20	6.0 cuffed	7.3	5.3
4	50-70*	10.0/15.0	19	7.6	17.5	<30	6.0 cuffed	7.3	5.3
5	>70*	11.5/16.5	20	8.7	20	<40	7.0 cuffed	8.7	7.3

* Very approximate guide. See text for gender-related option.
Key: ID/OD = Internal diameter/outside diameter. FOB = fiberoptic bronchoscope.

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Laryngeal Mask Anesthesia Principles and Practise

Second Edition, Saunders 2005

Professor JR Brimacombe

The most comprehensive work on the laryngeal mask airway, by the most widely published authority on the subject.

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