Can J Anesth/J Can Anesth (2010) 57:588–601
DOI 10.1007/s12630-010-9272-x

REVIEW ARTICLE/BRIEF REVIEW

The Fastrach™ Intubating Laryngeal Mask Airway®: an overview and update

Le masque laryngé Fastrach™ Intubating Laryngeal Mask Airway®: aperçu et mise à jour

Neal S. Gerstein, MD · Darren A. Braude, MD · Orlando Hung, MD · John C. Sanders, MBBS · Michael F. Murphy, MD

Received: 11 October 2009 / Accepted: 12 January 2010 / Published online: 29 January 2010

Abstract

Purpose *To provide an evidence-based overview and update on the use of the Fastrach™ Intubating Laryngeal Mask Airway® (FT-LMA) when used within operative and non-operative settings.*

Principal findings *The FT-LMA is available in three sizes to provide ventilation and the ability to pass an endotracheal tube (ETT) into the trachea blindly, semi-blindly, or with indirect visualization for patients over 30 kg. The Chandy maneuver is recommended routinely; the first maneuver optimizes ventilation, and the second maneuver increases success at endotracheal intubation (ETI). The manufacturer's reinforced tube or a pre-warmed or reversed standard ETT may be utilized. Insertion and ventilation are successful in almost all patients. Blind ETI is highly successful; adjuncts are generally not necessary. The FT-LMA has a proven role in the airway management of anticipated difficult operating room (OR) intubations, unanticipated OR intubations, cervical spine injuries, and limited airway access situations. Literature in the pre-hospital and emergency department settings is limited but favourable. The FT-LMA has compared favourably with fibreoptic intubation, the LMA-Classic™, the laryngeal tube, and the CobraPLA™. Initially, the more expensive LMA CTrach™ appeared to be more successful, but overall it is not. The FT-LMA airway seal pressures are excellent; serious complications are uncommon, and the FT-LMA figures prominently in most difficult airway guidelines.*

Conclusions *The FT-LMA has proven to be a useful difficult airway device both within and outside of the operating room. Effective ventilation is established in nearly all cases, and blind ETI is possible in the vast majority of cases if the optimal techniques described are used. Serious complications are uncommon.*

Orlando Hung MD: Presently collaborating with the Aircraft Medical Ltd. to build an infusion monitor device.
John C. Sanders MD: 2003-06 contributed content and lectured for a CME course on advanced use of the LMA at the University of New Mexico. All course fees went to the UNM Department of Anesthesiology. Seed money and equipment for the course were supplied by LMA N.A. Until 2007, was on the speakers' bureau for LMA N.A.. No relationship with LMA N.A. after 2007.
Michael F. Murphy MD: Member of a Medical Advisory Panel for Covidien in 2008. Shareholder of First Airway and Airway Management Education Center, both of which are for-profit educational companies.

N. S. Gerstein, MD (✉)
Department of Anesthesiology, University of New Mexico, MSC11 6120, Albuquerque, NM 87131-0001, USA
e-mail: ngerstein@gmail.com

D. A. Braude, MD
Department of Emergency Medicine, University of New Mexico, Albuquerque, NM, USA

O. Hung, MD
Departments of Anesthesia, Surgery, and Pharmacology, Dalhousie University, Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada

J. C. Sanders, MBBS
Shriners Hospital for Children, Salt Lake City, UT, USA

M. F. Murphy, MD
Department of Anesthesia, Dalhousie University, Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada

Résumé

Objectif *Fournir un aperçu fondé sur des données probantes et une mise à jour sur l'utilisation du masque laryngé Fastrach™ Intubating Laryngeal Mask Airway® (FT-LMA) tel qu'il est utilisé dans des contextes opératoire et non opératoire.*

Constatations principales *Le FT-LMA est disponible en trois tailles pour permettre la ventilation et le passage d'une sonde endotrachéale (SET) dans la trachée de façon aveugle, semi-aveugle ou avec visualisation directe chez les patients pesant plus de 30 kg. La manœuvre de Chandy est recommandée de façon routinière; la première manœuvre optimise la ventilation, et la seconde augmente le succès lors d'une intubation endotrachéale (IET). La sonde armée du fabricant ou une SET standard préchauffée ou inversée peut être utilisée. L'insertion et la ventilation réussissent chez presque tous les patients. L'IET en aveugle a un taux de réussite élevé; en règle générale, les accessoires ne sont pas nécessaires. Le FT-LMA joue un rôle éprouvé dans la prise en charge des voies aériennes lors d'intubations anticipées comme difficiles dans la salle d'opération (SOP), d'intubations imprévues en SOP, de lésions de la colonne cervicale et dans les situations où l'accès aux voies aériennes est limité. La littérature portant sur son utilisation dans des contextes pré-hospitaliers et dans le département des urgences est restreinte mais favorable. Le FT-LMA a été favorablement comparé à l'intubation par fibroscopie, au LMA-Classic™, à la sonde laryngée et au CobraPLA™. Au départ, le masque laryngé CTrach™, plus onéreux, semblait être plus efficace, mais les résultats globaux démontrent que ce n'est pas le cas. Les pressions d'étanchéité des voies aériennes du FT-LMA sont excellentes; les complications graves sont peu courantes, et le FT-LMA occupe une place de choix dans la plupart des directives pour la prise en charge des voies aériennes difficiles.*

Conclusion *Le FT-LMA s'est avéré être un dispositif de prise en charge des voies aériennes utile aussi bien en salle d'opération que dans d'autres contextes non opératoires. Une ventilation efficace est établie dans la plupart des cas, et une IET en aveugle est possible dans la grande majorité des cas si les techniques optimales décrites sont utilisées. Les complications graves sont peu répandues.*

The Fastrach™ Intubating Laryngeal Mask Airway® (FT-LMA) (Laryngeal Mask Company, Jersey, UK) was first developed by Dr. A. Brain in 1997 in response to difficulties found when attempting to insert an endotracheal tube (ETT) blindly into the trachea through the Classic™ LMA (C-LMA).[1,2] The FT-LMA is an intubating laryngeal airway intended to provide both ventilation and the consistent ability to pass an ETT blindly into the trachea. With more than a decade of clinical experience and literature, our goal is to provide an evidence-based overview and update on the use of the FT-LMA within both the operative and the non-operative settings.

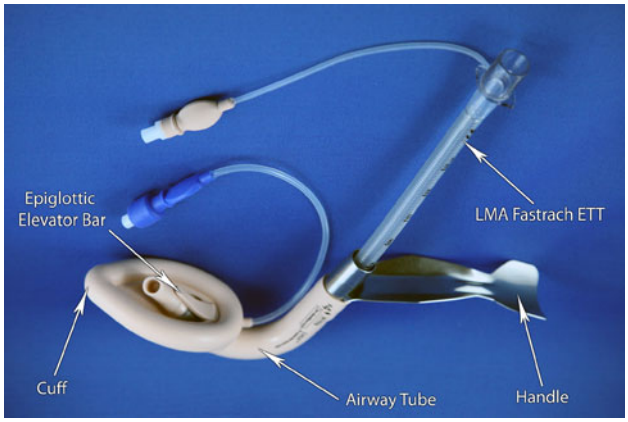

Fig. 1 The Fastrach™ Intubating Laryngeal Mask Airway® with its reusable endotracheal tube *in situ* and components labelled

Articles were identified by searching the following keywords on PubMed: "Fastrach", "Intubating LMA", and "Intubating Laryngeal Mask Airway". In addition, references from selected articles were hand searched. Since this was intended as a pragmatic clinically-based overview and update rather than a meta-analysis or comprehensive review, only those papers that addressed relevant issues are included. This update is specific to the FT-LMA; other intubating laryngeal airways, such as the LMA CTrach™ (CTrach) or the intubating laryngeal airways (Cookgas LLC, Saint Louis, MO, USA) are included only in comparison with the FT-LMA.

Overview

Compared with the C-LMA, the primary distinguishing features of the FT-LMA include: 1) an anatomically curved rigid airway tube, 2) an integrated guiding handle, 3) an epiglottic elevating bar (replacing the standard C-LMA vertical aperture bars), and 4) a guiding ramp built into the floor of the mask aperture[1] (Figure 1). Together, these features allow optimal alignment of the mask aperture with the glottic opening and provide a conduit for ETT passage. The internal diameter of the airway tube is 13 mm – the minimum that is able to accommodate an ETT with an internal diameter up to 8.0 mm. With lubrication, even 8.5 and 9.0 mm ETTs may fit, but generally they are not recommended.[A]

[A] LMA North America Inc. LMA Fastrach™ Reusable and LMA Fastrach™ Single Use Instruction Manual, 2006 edition. Available from URL: www.lmana.com/docs/LMA_Fastrach_manual.pdf (accessed December 2009).

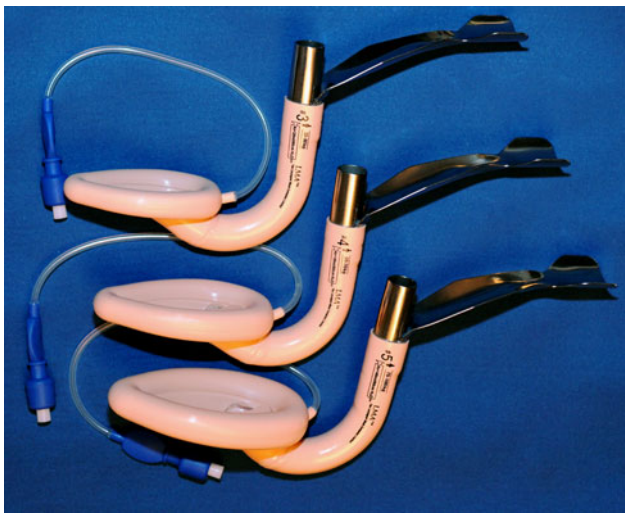

Fig. 2 The three sizes of the Fastrach™ Intubating Laryngeal Mask Airway®: Size #3 - top device, Size #4 - middle device, Size #5 - bottom device

FT-LMAs are available in sizes 3 (recommended for patients weighing 30-50 kg), 4 (50-70 kg patients), and 5 (70-100 kg patients) - similar to the standard sizing of the C-LMA (Figure 2). There are reusable and disposable versions available. Two studies (a single manikin study and a single human subject study) indicate that experienced and novice clinicians achieve equal rates of success in terms of placement, ventilation, and blind intubation with both disposable and non-disposable FT-LMAs.[3,4]

In their initial experience with 150 patients, Brain *et al.*[2] inserted the FT-LMA successfully on the first attempt in all (100%) patients. Adequate ventilation was accomplished in all patients, with minor adjustments required in four of these patients. Blind ETT insertion was successful in 149 of 150 (99.3%) patients. In a multicentre European trial, blind tracheal intubation through the FT-LMA was successful in 481 of 500 (96.2%) cases within three attempts.[5]

General insertion technique

The FT-LMA is inserted in a similar fashion as the C-LMA.[A] However, the rigid nature of the airway tube obviates the need of inserting one's fingers into the oropharynx. Insertion may be performed either with the cuff fully deflated so the cuff forms a concavity towards the pharyngeal surface, as recommended by the manufacturer, or partially inflated.[A] The issue of whether to insert the device with a partially or fully inflated cuff has not been addressed directly for the FT-LMA; however, the issue has been discussed for the C-LMA. Some investigators[6,7] have found inserting the C-LMA easier and generating less oropharyngeal trauma with a partially or fully inflated cuff. However, Brimacombe *et al.*[8] found a greater incidence of unsuccessful first time insertion (secondary to a down-folded epiglottis) when the C-LMA was inserted with an inflated cuff. A water-soluble lubricant should first be applied to the posterior (palatal) surface of the device. The patient's mouth is opened and device insertion can be facilitated by a moderate degree of mandibular advancement. The device is rotated into position while maintaining light pressure against the patient's palate and posterior pharynx until the handle meets the face or resistance is felt as the tip of the device lodges in the upper esophageal sphincter. Once properly placed, the cuff is inflated either with the volume of air dictated by the manufacturer's recommendations printed on each of the different sizes of the device or to an approximate cuff pressure of 60 cm H_2O.[A] The clinician may modify the volume of air at that time, as dictated by the adequacy of ventilation and the presence of air leakage.

The device should be gently rotated in the sagittal plane (the "first" Chandy Maneuver) (Figure 3A) while the patient is clinically assessed and until ventilation is optimized. This assures that the device aperture is aligned with the glottic opening. Clinicians should exercise caution with cricoid pressure, as this has been shown to impair ventilation with the C-LMA and may, therefore, affect ventilation with the FT-LMA as well.[9,10]

Intubation using the FT-LMA

The FT-LMA can be left *in situ* as a ventilatory device or the clinician can proceed with placement of an ETT. Successful passage of an ETT through the glottis is dependent on multiple factors, including operator technique and experience, tube lubrication, concomitantly administered drugs (i.e., opioids, muscle relaxants), type of ETT used, and the patient's anesthetic depth. While sometimes reserved for cases of difficulty, we and the manufacturer suggest routine use of the Chandy "second" maneuver (lifting the FT-LMA from the posterior pharyngeal wall using the metal handle), which prevents ETT collision with the arytenoids and minimizes the angle between the aperture of the FT-LMA and the glottis[A,11] (Figure 3B). When the FT-LMA is used to rescue a failed rapid sequence intubation (RSI), the inherent paralysis will improve intubation success through the FT-LMA. In patients who are not fully paralyzed, low-dose rocuronium 0.2 $mg \cdot kg^{-1}$ has been shown to increase successful blind intubation from 30% to 80%,[12] while other reports indicate no difference in blind intubation success between low-dose 0.2 $mg \cdot kg^{-1}$ and medium-dose 0.4 $mg \cdot kg^{-1}$ rocuronium.[13] It is our experience that administering a small dose of muscle relaxant (i.e., 0.1-0.2 $mg \cdot kg^{-1}$ rocuronium), once adequate ventilation is

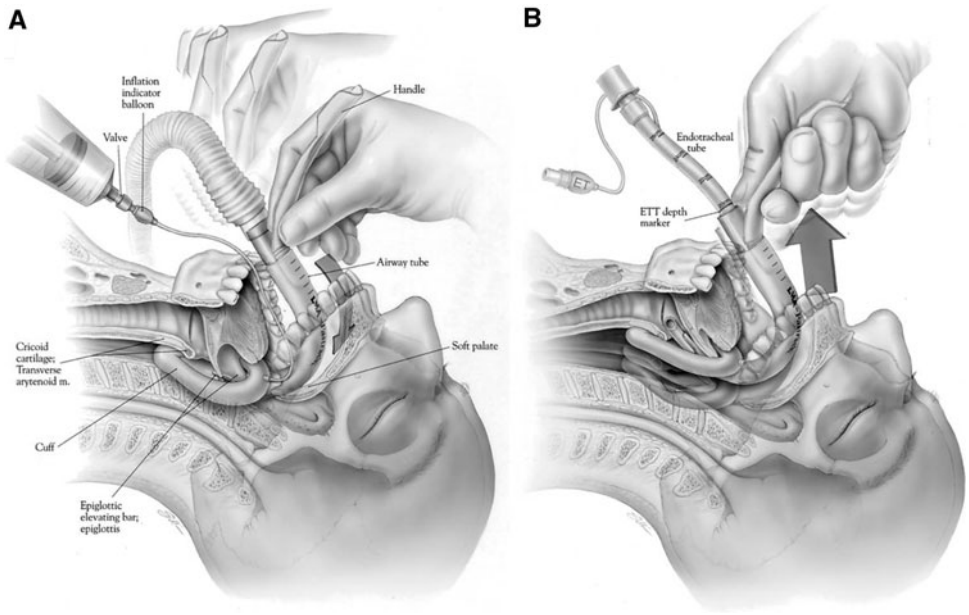

Fig. 3 (Adapted with permission from *Ferson DZ, Rosenblatt WH, Johansen MJ, Osborn I, Ovassapian A*. Use of the intubating LMA-Fastrach™ in 254 patients with difficult-to-manage airways. Anesthesiology 2001; 95: 1175-81). The Two Chandy Maneuvers. The two steps of the Chandy maneuver are performed sequentially. **A** Ventilation is optimized after the Fastrach™ Intubating Laryngeal Mask Airway® (FT-LMA) (LMA North America, Inc., San Diego, CA, USA) is fully inserted by rotating the device in the sagittal plane using the metal handle until bag ventilation is easiest or tidal volume maximal. This "first" maneuver aligns the internal aperture with the glottic opening. **B** Before blind intubation or intubation assistance with an Eschmann® Tracheal Tube Introducer (gum elastic bougie) or with an airway exchanger catheter (AEC), the FT-LMA is slightly lifted (but not tilted) away from the posterior pharyngeal wall using the metal handle. This "second" maneuver prevents the endotracheal tube (ETT) from impacting the arytenoids or vestibule of the larynx and helps guide the passage of an ETT, bougie, or AEC into the trachea[11]

confirmed via the FT-LMA, prevents vocal cord adduction in response to the stimulus of the ETT contacting the glottic opening. Alternatively, we have found that laryngeally instilled local anesthetic (i.e., 2% lidocaine 3-4 mL administered supraglottically or via a fibreoptic bronchoscope [FOB] side port) reliably relaxes the vocal cords.

If difficulty is encountered while passing the ETT despite use of the two Chandy maneuvers, troubleshooting is guided by the distance beyond the transverse 15 cm mark on the ETT (indicates when the tip of the ETT has emerged out of the distal end of the FT-LMA) at which resistance is appreciated.[A] When resistance is encountered at approximately 2 cm distal from the aperture, it is possible that the tip of the tube is impacting the vestibule wall or a down-folded epiglottis. First, the ETT should be partially retracted into the metal tube of the FT-LMA, and then the inflated FT-LMA should be rotated out of the oropharynx approximately 6 cm and then reinserted (the "up-down maneuver") to free the epiglottis. If intubation is still unsuccessful or if resistance is felt before or after 2 cm, it is possible that the wrong size FT-LMA is being used. Application of cricoid pressure can impair optimal placement of the FT-LMA and can impair passage of a blindly inserted or FOB inserted ETT.[9,14] Reducing or removing cricoid pressure may be warranted in this context to allow proper FT-LMA or ETT insertion.

Endotracheal tube selection

The ETT designed for use with the FT-LMA is a straight soft wire-reinforced reusable silicone tube with a distal segment that terminates in a conical Tuohy-like tip.[15] Due to its blunt tip, this tube is well-suited for blind insertion through the FT-LMA. It is important to maintain the orientation of the external black longitudinal line of the ETT with the patient's nose to insure the bevelled tip is appropriately oriented at the glottic opening. Brain *et al.* quote a $> 95\%$ success rate with blind insertion of this tube.[2] There are two drawbacks of the reusable silicone tube - its cost of about $70 US (LMA North America, Inc., San Diego, CA, USA, October 2009) and the compliance characteristics of its cuff (high pressure, low volume). The use of a standard polyvinylchloride (PVC) ETT is feasible, but the success rates are lower with blind insertion because of the left-sided bevel and the propensity for arytenoid cartilages or false or true vocal cords to obstruct insertion. Kanazi *et al.*[15] demonstrated a low first attempt success rate of 48% using a standard ETT that increased to only

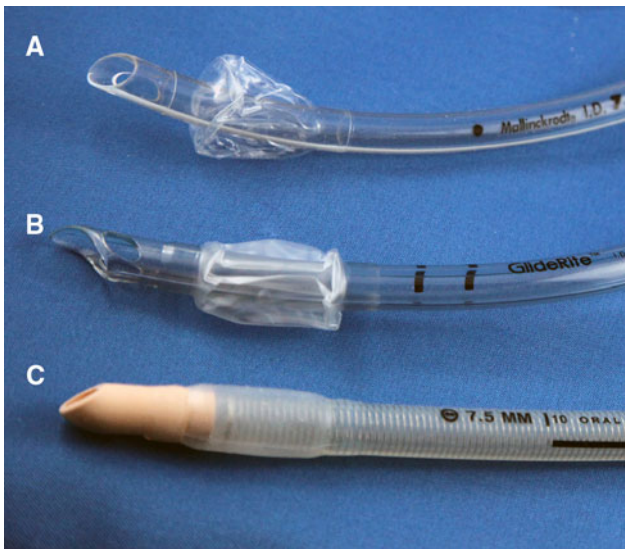

Fig. 4 Comparison of endotracheal tube (ETT) types. **A** conventional polyvinylchloride (PVC) ETT (note: left facing bevel). **B** Parker ETT (note: posterior opening bevel). **C** reusable silicone-tipped ETT (manufacturer's ETT)

57% with clockwise or counterclockwise manipulation. However, they also compared the use of the relatively inexpensive Parker Flex-Tip ETT (Parker Medical, Highlands Ranch, CO, USA) with a posterior opening bevel and achieved a success rate similar to that of a PVC ETT after the first attempt (54% *vs* 48%, respectively), which increased to 86% after manipulation[15] (Figure 4). In the setting of blind intubation through the FT-LMA, Kundra *et al.*[16] compared the use of the silicone wire-reinforced tracheal tube *vs* a standard PVC ETT as well as a latex armoured tube (LAT). They demonstrated that a pre-warmed standard PVC ETT was as successful in blind insertion through the FT-LMA as the silicone wire-reinforced ETT; the LAT was inferior and resulted in a greater number of esophageal intubations. Ye *et al.*[17] described a high success rate (91.5%) of using standard PVC ETTs in Mallampati 3 or 4 patients by reversing the insertion orientation of the ETT (the curve of the ETT reversed from the curve of the airway tube of the FT-LMA). Reversing the insertion decreases the angle by which the ETT exits the FT-LMA (Figure 5).

Another potential issue arises with the use of the manufacturer's recommended wire-reinforced ETTs. These tubes (like all reinforced tubes) are prone to permanently kink if a patient bites down on them, which can lead to near total or total tube occlusion and the subsequent inability for ventilation.[18] This is particularly important if the clinician is planning to keep the patient ventilated for a prolonged period, e.g., in the intensive care unit. This issue can be obviated by placing a bite block or changing to a non-reinforced tube.

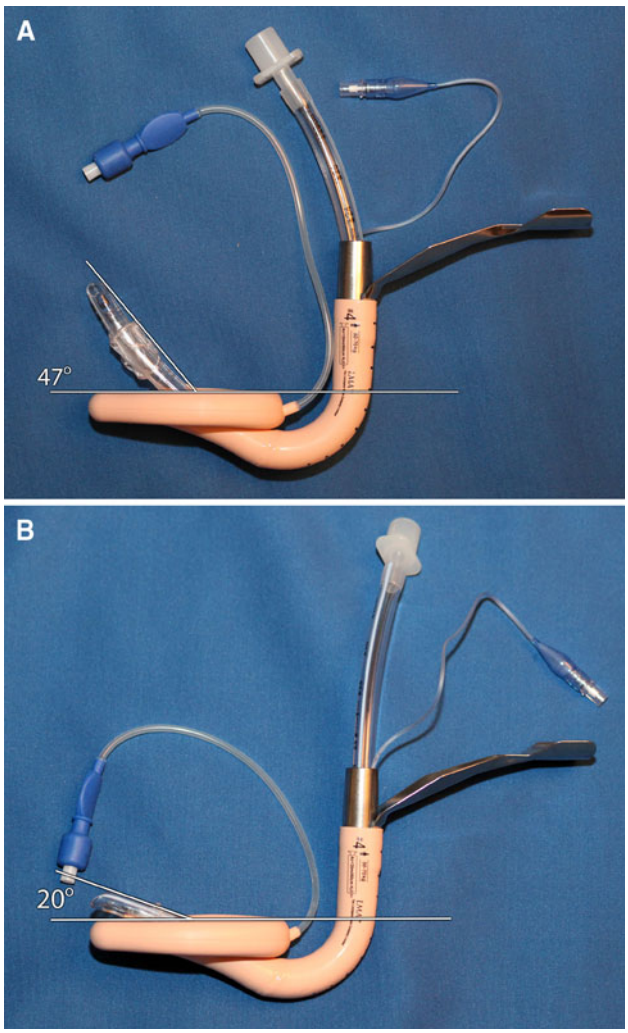

Fig. 5 Demonstration of the impact of reversed insertion of an endotracheal tube (ETT) through the Fastrach™ Intubating Laryngeal Mask Airway® (FT-LMA): **A** Normal (curvature anterior) insertion of a standard ETT. **B** Reversed (curvature posterior) insertion of a standard ETT

There are various options for dealing with the issue of cuff compliance of the silicone reusable ETT. First, if the reusable ETT is intended for short duration use, then the cuff pressure should be acceptable as long as it is minimized. If prolonged intubation is anticipated, then a standard PVC or Parker Flex-Tip ETT could be placed via the FT-LMA. A third option would be to place the reusable ETT first, then to insert an airway exchanger catheter (AEC) through this tube, followed by extracting the FT-LMA and the reusable ETT but leaving the AEC as a conduit for the placement of a standard PVC ETT. If prolonged ventilation is necessitated, an additional option is to use the newer single-use FT-LMA tracheal tube (LMA North America Inc., San Diego, CA, USA). In 2007, Pêan *et al.* described their *in-vitro* testing of this newer tube and demonstrated that its cuff had low pressure and high

compliance characteristics similar to a standard PVC ETT.[19]

FT-LMA removal

If possible, the FT-LMA should be removed following intubation to prevent pharyngeal edema or pressure-induced injuries to oropharyngeal soft tissue.[A] It is essential that the 15 mm ETT connector be removed prior to extraction of the FT-LMA from the oropharynx; hence, ease of removal of this connector must be insured prior to ETT insertion. Once an ETT has been inserted, removal of the FT-LMA involves stabilizing the ETT with a semi-rigid obturator rod that keeps the ETT stationary in the oropharynx while the FT-LMA is removed. This device can be misplaced, accidentally discarded, or unavailable at the time FT-LMA removal is desired. Korula *et al.*[20] described an alternative by using a downsized ETT (e.g., 5.0 mm internal diameter cuffed ETT) inserted into the distal end of the *in situ* ETT. Alternatively, the clinician can also use the Magill forceps. This technique involves removing the ETT connector, inserting and grasping the ETT with the forceps, stabilizing the ETT while the FT-LMA is extracted, and re-grasping the distal section of ETT while the FT-LMA is fully removed. Another possibility is use of a tube-exchanger or Eschmann® Tracheal Tube Introducer (gum elastic bougie). However, for shorter cases, for use by non-anesthesiologists, or in the case of a very difficult airway, the FT-LMA may be left *in-situ* with the cuff completely or partially deflated. The small risk of pressure-related mucosal injury may be offset by the risk of displacing the ETT during removal. The ETT connector should be separated from the reusable ETT prior to autoclaving, since the autoclaving process tends to weld the two together so they are very difficult to separate for placement without damaging the ETT (Table 1).

Table 1 Fastrach™ LMA Placement Technique Summary*

INSERTION TECHNIQUE
1) Select device of appropriate size
2) Deflate the cuff
3) Apply water-soluble lubricant to posterior surface
4) Insure proper head and neck position
a. neutral, single pillow, minimal extension
5) Rotate device into place until resistance or handle meets face
6) Inflate cuff as per manufacturer's recommendation
7) Rotate device gently in the sagittal plane until ventilation is optimized
BLIND INTUBATION TECHNIQUE
1) Optimize ventilation to direct aperture at the glottis (1st Chandy maneuver)
2) Consider low-dose muscle relaxant if patient not paralyzed
3) Lift device vertically (2nd Chandy maneuver)
4) Pass well-lubricated wire-reinforced ETT with black line facing patient's nose
5) Once tube advances, freely inflate cuff and confirm placement with ETCO2
6) Remove ILMA as discussed in text
a. Manufacturer recommends fully deflating cuff
TROUBLESHOOTING
Tube meets resistance - general
1) Tube not lubricated or too big for device
2) Reduce cricoid pressure
3) Change device size
Tube meets resistance at 2 cm beyond the 15 cm transverse line on the ETT
1) Impacting device vestibule: rotate ETT
2) Down-folded epiglottis: up-down maneuver
Tube passes freely into esophagus
1) Repeat Chandy maneuvers
2) Change device size

* LMA Fastrach™ Reusable and LMA Fastrach™ Single Use Instruction Manual, 2006 Edition, LMA North America, Inc. www.lmana.com

Techniques to facilitate FT-LMA intubation

Although tracheal intubation can be performed blindly through the FT-LMA, the success rate varies from 70% to 99%.[2,21] Several airway devices and techniques have been suggested to facilitate intubation through the FT-LMA.

Use of the airway exchanger catheter

Two case reports describe intubation through the FT-LMA with an AEC. Hsin *et al.*[22] describe the successful use of the FT-LMA and an AEC for ventilation and intubation in a patient with severe ankylosing spondylitis (a frequent cause of known difficult intubation secondary to limited neck extension and temperomandibular joint athropathy) who refused awake fibreoptic intubation. Following induction of anesthesia and insertion of an FT-LMA, the AEC was inserted blindly and connected to a capnogram for confirmation of tracheal position. An ETT was then inserted using the AEC as a guide. A recent case report by Kim *et al.*[23] described the use of a #3 FT-LMA as a rescue device after failed intubation in an 11-yr-old patient weighing 40 kg and 134 cm tall with a known difficult airway. After successful placement of the FT-LMA, a 3 mm diameter AEC was inserted, and tracheal position was confirmed by capnography. The FT-LMA was removed and a 6.0 armoured ETT was inserted over the AEC.

Use of a lightwand

Tracheal intubation has been reported employing a light-guided technique with a flexible lightwand (Trachlight™) together with the FT-LMA.[24,25] No differences were exhibited in terms of the time required to place the FT-LMA or the ETT, hemodynamic changes, or postoperative complications; however, Fan *et al.*[25] showed that there were significantly more attempts and failures in the blind intubation group (FT-LMA alone) compared with the Trachlight™ group in patients with no history of a difficult intubation (76% for the blind *vs* 95% for the Trachlight). Using a flexible lightwand, Dimitriou *et al.* also demonstrated that lightwand-guided intubation through the FT-LMA has a first-time and overall success rate of 84% and 98%, respectively, in 44 patients with an unanticipated failed laryngoscopic intubation.[26] Recently, Wong *et al.*[27] reported the successful use of the light-guided FT-LMA intubation technique in a patient with a difficult airway secondary to the Hallermann-Streiff syndrome. In an out-of-hospital tracheal intubation by an emergency physician, Dimitriou *et al.* have shown that a flexible lightwand-guided tracheal intubation through the FT-LMA had a high success rate with no failure in 37 patients.[28]

Flexible fibreoptic bronchoscope-guided tracheal intubation

In a comparative study, Joo *et al.* showed that the first attempt success and overall success rate for FOB assisted intubation through the FT-LMA were 93.3% and 96.7%, respectively, compared with 86.7% and 96.7%, respectively, for the blind insertion technique.[29] In a comparative study, Pandit *et al.* found that the FOB-assisted tracheal intubation had a higher success rate (95%) through the FT-LMA than through the C-LMA (80%),[30] although the time to intubation was longer with the FOB-assisted technique compared with the blind technique (74 sec *vs* 49 sec, respectively). Unfortunately, the success rate of FOB-assisted intubation through the FT-LMA is less predictable following a failed blind technique in patients with a difficult airway. While Ferson *et al.* reported a 100% success rate of FOB-assisted intubation through the FT-LMA (seven of the seven patients),[11] Joo *et al.* reported a success rate of only 50% (five of the ten patients).[31]

Miscellaneous techniques

In a letter to the editor, Agro *et al.* reported the use of a flexible fibreoptic device, the Shikani Flexible Seeing Stylet™, (Clarus Medical, Minneapolis, MN, USA) to facilitate the Fastrach intubation.[32] Although tracheal intubation was successful in 12 of the 13 patients (92.3%) when the dedicated ETT was used with the FT-LMA, it was less effective, i.e., one of the six patients (16.7%), when a standard PVC ETT was used. The investigators commented that the major limitation of the Shikani Flexible Seeing Stylet™ was its inability to control the direction of the tip of the device. They concluded that the Shikani Flexible Seeing Stylet™ is more useful with a FT-LMA ETT rather than a standard ETT.

Using the Patil Intubation Guide (Anesthesia Associates Inc., San Marcos, CA, USA), a whistle diaphragm to detect breath sounds, Osborn successfully intubated through the FT-LMA under topical anesthesia in a patient with a recent cervical spine fusion.[33] In 2005, a case series was published describing the use of the airway whistle with the FT-LMA in four patients with known difficult airways (the status of two patients was post neck radiation for neck cancers, and two patients were morbidly obese [body mass indexes (BMI) of 49.1 $kg \cdot m^{-2}$ and 72.8 $kg \cdot m^{-2}$]).[34] The FT-LMA was inserted awake in each case, and placement was optimized using the Chandy maneuvers based on the loudest whistling that was produced during inspiration and exhalation. In three of the four patients (in the fourth patient no whistle was used for ETT placement), the clinicians proceeded with intubation that too was guided by use of the airway whistle. They describe the sound volume from the whistle progressively increasing as the ETT was inserted and ultimately reaching a peak volume once the ETT cuff was inflated.

Others have suggested the use of an aspiration test from a 50 mL "catheter tip" syringe and capnography to assist tracheal intubation through the FT-LMA.[35] However, this technique is for confirmation of ETT placement through the FT-LMA more than for facilitating the tracheal intubation using the FT-LMA.

Indications for placement

Anticipated difficult intubation in the operating room

One of the primary indications for the use of the FT-LMA is the need to secure a known difficult airway. Fukutome *et al.*[36] was one of the first groups to describe the use of the FT-LMA in the context of the difficult airway. They used the device in 31 adult patients in whom tracheal intubation was known or suspected to be difficult. In 30 (97%) of the patients, the FT-LMA was successfully inserted and allowed for adequate ventilation. In the remaining one patient, insertion of the device was not possible. Tracheal intubation through the device was successful in 28 of 30 patients (93%).[36]

In 2001, Ferson *et al.* published a retrospective review of the anesthetic and medical records of patients with known or suspected difficult airways (including patients with Cormack-Lehane grade 4 views, patients with immobilized cervical spines, patients with airways distorted by tumours, surgery, or radiation therapy, and patients wearing stereotactic frames) in whom the FT-LMA was used electively or emergently.[11] All providers in their review had significant prior experience with the use of the C-LMA. Insertion of the FT-LMA was accomplished in three attempts or fewer in all patients, with overall success rates for blind and FOB-guided intubations of 96.5% and 100%, respectively. Additionally, their group reported no pharyngeal, laryngeal, or esophageal complications associated with the use of the FT-LMA.

Asai described a patient with restricted mouth opening (an interincisor distance of 2 cm) and facial features consistent with a likely difficult airway (thyromental distance of 3.5 cm).[37] Due to the inability of the practitioners to use their fingers to insert a standard LMA, a FT-LMA was chosen and placed without incident on the first attempt. Combes *et al.* compared insertion of the FT-LMA and blind intubation through the FT-LMA between obese patients (mean BMI 42 $kg{\cdot}m^{-2}$) and lean patients (mean BMI 23 $kg{\cdot}m^{-2}$) undergoing elective surgeries.[38] They found no difference in intubation success between the groups; actually, obese patients required significantly fewer adjustments (i.e., fewer Chandy maneuvers) for optimal placement. Moreover, they demonstrated that the trend of the FT-LMA was toward simpler airway management in obese patients, with lower overall difficult airway management scores, as measured by a visual analogue scale (VAS) (difficulty of airway management measured on a 100 mm VAS by the physician who managed the airway), and a shorter duration of airway management.

Additionally, the FT-LMA has been inserted into awake patients and has been used for awake intubations in known difficult airway scenarios.[39-41] Hence, the FT-LMA can be utilized when awake techniques are necessitated or when access to FOB is limited and an awake technique is necessary.

Unanticipated difficult intubation in the operating room

In the setting of the unanticipated difficult airway, particularly the "cannot intubate, cannot ventilate" scenario, Combes *et al.* demonstrated the efficacy of a basic algorithm that included the FT-LMA.[42] Over an 18-month interval, they had 100 (0.9%) cases of unexpected difficult airways encountered among 11,257 patients; impossible ventilation never occurred. Thirteen patients were managed with blind intubation through the FT-LMA, and two patients were ventilated with the FT-LMA (80 patients were managed with bougie-assisted tracheal intubation, and the other five were not included in the study due to algorithm deviation or being awakened). They concluded that either the FT-LMA or a gum elastic bougie were sufficient to manage most cases of an unanticipated difficult airway.

A number of case reports dating back to 1998 have demonstrated the ability of the FT-LMA to facilitate ventilation and intubation when direct laryngoscopy (DL) has failed, including with the use of a bougie.[43-45] In a similar context, the previously discussed case report by Asai centred around the use of the FT-LMA to rescue the failed insertion of a C-LMA.[37]

Additionally, the FT-LMA has been shown to be useful in the pregnant patient, a population with a known potentially difficult airway[46-48] and considered to have unpredictable gastric emptying and fasting states.[49] In a 2004 case report, use of the FT-LMA is described in a failed intubation scenario when a pregnant patient's airway needed to be secured with an ETT.[50] In a 2004 survey of available airway equipment in Irish obstetrical units, only 50% of the difficult airway carts were stocked with the FT-LMA. However, the authors concluded that because of Irish obstetric anesthesiologists' familiarity with the C-LMA, obstetric anesthesiologists should consider the FT-LMA to be "the best available option as an alternative intubating device" and difficult obstetric airway management training could be "improved by training inexperienced anesthesiologists in the use of the intubating laryngeal mask".[51]

Suspected or confirmed cervical spine injury

FT-LMA use has increased in popularity for use in patients with potential or known cervical spine (c-spine) injuries where the primary goal is minimizing c-spine movement during intubation. A 1998 American anesthesiologist survey involving management techniques in difficult airway scenarios demonstrated that 1/199 would consider using an C-LMA in a patient with an unstable c-spine.[52] This result contrasts to a similarly constructed 2002 Canadian anesthesiologist survey that showed 3/100 respondents managing a c-spine injury with the FT-LMA.[53] In a recent survey of 115 European anesthesiologists' and emergency medicine physicians' airway management practices for c-spine injuries, nearly half of the respondents were familiar with the use of the FT-LMA *vs* less than a quarter with the FOB.[54] In this same survey, DL and awake nasal intubation with the FOB were the two most preferred intubation methods, followed by the FT-LMA and the C-LMA.[54]

Early concern about the use of the FT-LMA in unstable c-spine patients was raised by Keller *et al.*[55] Using cadavers with a simulated C3 injury and microchip sensors implanted into the pharyngeal surface of C2-C3, they

measured the pressures exerted against the cervical vertebra by the C-LMA and the FT-LMA during insertion, tracheal intubation, and other typical maneuvers. They also evaluated the effect of these pressures on c-spine movement. They found that maximal cervical pressures were higher for the FT-LMA than for the C-LMA over various cuff inflation ranges, and both the C-LMA and FT-LMA exert transient pressures of > 220 cm H_2O against the cervical vertebra during insertion, with resultant posterior displacement of cervical vertebra.[55] However, follow-up commentary by Todd *et al.* pointed out many flaws of the Keller study (cadaver use, rare site of injury, not a truly unstable c-spine, statistical analysis issues) and questioned the validity of Keller's results.[56] Moreover, Todd *et al.* stressed that the "gold standard" of securing the airway in the setting of an unstable c-spine with FOB techniques is frequently impractical, and likely the FT-LMA has an important place in this scenario.

In the 2001 retrospective review by Ferson *et al.*[11] a subgroup of 70 patients with known unstable c-spines was specifically examined. The FT-LMA was used in 70 patients with unstable c-spines who were immobilized in rigid collars that remained in place during FT-LMA insertion. Blind intubation was successful on the first attempt in 63 cases (92.6%); in five cases (7.4%) two attempts were needed, and FOB assistance was electively used in the remaining two cases. They reported no new neurologic deficit related to airway management with the FT-LMA. Komatsu *et al.*[57] prospectively compared blind intubation with the FT-LMA in 50 patients wearing rigid Philadelphia cervical collars (but without significant c-spine instability) with a control group not wearing collars and with no c-spine pathology. They found FT-LMA insertion times were significantly longer in the collar group (30 sec *vs* 22 sec); there were significantly more insertion attempts, and adequacy of ventilation was significantly worse in the collar group. However, the overall intubation success rate was equal in both groups (96% in the collar group and 98% in the control group). The other measured variables related to insertion and intubation (intubation time, total intubation time, number of intubation attempts, and types of adjustments applied) were similar in both groups. There were no major complications in either group.

In a recent study by Gercek *et al.*[58] three common methods of intubation in patients with c-spine injuries (DL, FT-LMA, and FOB – all with manual in-line immobilization) were compared using *in vivo*, real-time, three-dimensional ultrasonography in healthy patients undergoing elective surgery. They demonstrated that manual in-line stabilization reduced the cervical spine range of motion to a limited extent during different intubation procedures. The least diminution (or conversely the greatest c-spine movement) occurred with DL (overall flexion / extension range of 17.57°) *vs* significantly less c-spine movement with FT-LMA use (overall flexion / extension range of 4.60°) and FOB use (overall flexion / extension range of 3.61° - oral, 5.88° - nasal). Furthermore, the total time required for intubation from shortest to longest was 16.5 ± 9.76 sec for the FT-LMA, 27.25 ± 8.56 sec for DL, 52.91 ± 56.27 sec for oral FOB, and 82.32 ± 54.06 sec for nasal FOB.[58]

Another factor in the context of the c-spine injured patient is the possibility of significant airway distortion secondary to bleeding and edema caused by the neck injury. Combes *et al.*[59] reported a patient with a C2-C3 dislocation and a massive anterior neck hematoma. Intubation attempts by DL and bougie assistance were both unsuccessful. The FT-LMA allowed for adequate ventilation and ultimately FOB-assisted intubation.

Poor access for direct laryngoscopy

Other possible indications for use of the FT-LMA include the inability to perform conventional DL because of any atypical patient location (i.e., in the field without access to stand behind a patient) or in a patient with injuries that preclude placing a patient supine. Agrawal *et al.*[60] describe using the FT-LMA to secure the airway of a woman with extensive back and pelvic injuries in which anesthesia had to be induced for surgery while in the prone position. Biswas *et al.*[61] described a case series of 82 adults with normal airways presenting for elective cholecystectomy who were blindly intubated with an FT-LMA while either in the right or left lateral decubitus position. The FT-LMA was placed in all patients on the first attempt; ventilation through the FT-LMA was feasible 97.5% of the time after the first attempt at insertion, and 100% could be ventilated after FT-LMA adjustments. There was only a single failed intubation (in the left side down) while all other patients were intubated on the second attempt.

Use by inexperienced providers and non-anesthesiologists

Multiple studies support the FT-LMA as an airway device for inexperienced providers.[62-64] Using cadavers, Choyce *et al.* demonstrated that non-experienced medical students had significantly faster and greater success at ventilation with the use of FT-LMA compared with a C-LMA.[63] Moreover, 67% of these same untrained medical students were able to successfully intubate the trachea through the FT-LMA. In a study by Levitan *et al.*,[65] 111 medical and non-medical personnel with and without prior intubation training were given a < 60-sec demonstration on the use of the FT-LMA. Ninety-seven percent of this study's participants demonstrated success with blind intubation via the FT-LMA.

In two studies, Timmermann *et al.*[66,67] compared conventional bag mask ventilation and DL with FT-LMA ventilation and intubation by medical staff with minimal airway management experience. In both studies, the providers were more successful and faster with FT-LMA-guided ventilation and intubation than with conventional techniques. Also, the FT-LMA-guided intubations were successful in patients in whom DL had failed. These results suggest that the FT-LMA may be a superior device for maintaining ventilation and placement of an ETT in an emergency situation by individuals unskilled in intubation. Moreover, these data suggest that the training of airway management for Emergency Medical Service (EMS) personnel should include the use of the FT-LMA for ventilation and intubation.

A recent prospective case series of FT-LMA insertions completed from August 2003 to December 2005 evaluated the ability of flight nurses and paramedics to successfully use the FT-LMA as a primary airway device.[68] These Helicopter Emergency Medical Service (HEMS) providers attempted placement of four FT-LMAs on-scene, five FT-LMAs in an emergency department, and four FT-LMAs in the helicopter. The FT-LMA was successfully placed in ten of the 13 patients (77%). Two of the three unsuccessful FT-LMA insertions occurred in the emergency department, while one of the unsuccessful insertions occurred in the helicopter. Otherwise, three of the four placements in the helicopter and all on-scene placements were successful. There was a 91% success rate of blind intubation in the ten patients who successfully received the FT-LMA. Follow up revealed one case of pulmonary aspiration.

In their review of the FT-LMA in EMS, Dries *et al.* stated that the success rate of blind insertion of an ETT through the FT-LMA is double that of a conventional LMA.[69] Timmerman *et al.*[70] prospectively examined the use of the FT-LMA by experienced emergency medicine physicians for the management of out-of-hospital difficult airways. Out of 146 patients, 135 were intubated via a laryngoscopy technique. The FT-LMA was successfully used in the remaining 11 patients, i.e., in eight patients after failed oral intubation and in three patients without a prior attempt at intubation. Their group found that all patients with difficult airways could be successfully ventilated with the FT-LMA.

An additional use in the EMS setting is the administration of medications that are absorbed through the tracheal mucosa. Liao *et al.*[71] describe the placement of an intra-tracheal catheter placed in a blind fashion through the FT-LMA airway tube. In scenarios where intravenous access, intraosseous infusion, or endotracheal intubation are not feasible or are delaying appropriate resuscitation, this might be a useful resource for drug administration.

Comparison to other devices

Ventilation

In a recent cadaver study by Bercker *et al.*,[72] the FT-LMA was superior to the Laryngeal Tube™ (LT), Laryngeal Tube Suction II™, and the ProSeal™ LMA (PLMA) in terms of providing laryngeal seals when the esophagus was pressurized and, the authors inferred, theoretically reducing the risk of aspiration. In their study, the FT-LMA withstood up to 115 cm H_2O of esophageal pressure *vs* 48 cm H_2O for the C-LMA and 71 cm H_2O for the PLMA. No clear conclusion can be drawn from these findings regarding the prevention of aspiration. Certainly, the incorporated esophageal drain tube in the PLMA is advantageous in reducing the likelihood of gastric contents collecting in the oropharynx and then leaking into the airway to cause aspiration. However, it is uncertain how a higher leak pressure that measures the leakage of gas from the airway into the pharynx correlates with leakage of gastric contents from the pharynx or esophagus into the airway and with the frequency of resultant aspiration.

Kurola *et al.*[73] compared insertion success and ventilation adequacy between the FT-LMA, the LT, and the CobraPLA when used by paramedical students in a controlled setting designed to mimic a patient in cardiac arrest. Their study was performed in apneic patients under general anesthesia without the use of a muscle relaxant. The FT-LMA was inserted successfully by 24 of 32 (75%) students on the first attempt *vs* 14 of 32 (44%) students for the LT and seven of 32 (22%) students for the CobraPLA. The time needed for successful insertion on the first attempt and the ventilatory parameters were similar in all three groups. Also, as described in the section on use by inexperienced providers, Choyce *et al.* demonstrated that non-experienced clinicians had faster and greater success at ventilation with the use of FT-LMA compared with the C-LMA.[63]

In the setting of a potential c-spine injury and the use of manual in-line stabilization, Komatsu *et al.*[74] compared the FT-LMA with the LT in terms of ventilation quality. The FT-LMA was superior to the LT with respect to ease of insertion (placement success at first attempt, 42/51 patients *vs* 16/51 patients, respectively; $P < 0.0001$) and time required for insertion (20 sec *vs* 28 sec, respectively; $P = 0.0009$). The best achieved tidal volume for a preset inspiratory pressure was less for the LT *vs* the FT-LMA (440 mL *vs* 630 mL, respectively; $P = 0.013$). The two devices were similar with respect to the minimum airway pressure at which gas leak occurred and the incidence of gastric insufflation. Additionally, Asai *et al.*[75] performed a randomized crossover comparison of the C-LMA and the FT-LMA in terms of ease of placement (assessed by a

10 cm VAS score) and the adequacy of ventilation (assessed by no audible leak and appropriate chest excursion during inspiration) during manual in-line stabilization of 25 American Society of Anesthesiologists (ASA) I and II patients with no known upper airway pathology undergoing general anesthesia with muscle relaxant use. All 25 FT-LMA patients were adequately ventilated *vs* 22 C-LMA patients. Also, placement of the FT-LMA was significantly easier than placement of the C-LMA (0.8 cm *vs* 2.3 cm, respectively; $P < 0.001$; 95% confidence interval [CI] for median difference 8-31 mm) and placement of the FT-LMA was faster than placement of the C-LMA (9.9 sec *vs* 14.4 sec, respectively; $P < 0.001$; 95% CI for mean difference 3.2-6.2 sec).

Intubation

Langeron *et al.*[76] compared FT-LMA to FOB intubation in 100 patients with at least one difficult intubation criterion (Mallampati class III or IV, thyromental distance < 65 mm, interincisor distance < 35 mm). The rate of successful tracheal intubation with FT-LMA was comparable with FOB. The number of attempts and the time to successfully secure the airway were not significantly different between groups. Adverse events (oxygen desaturation, soft tissue trauma / bleeding, and bronchospasm) occurred significantly more frequently in the FOB group than in the FT-LMA group. As discussed in the *Intubation Techniques* section, Pandit *et al.*[30] compared FOB intubation through a C-LMA with FOB intubation through the FT-LMA and with blind intubation through the FT-LMA. Mean total intubation times were significantly shorter with the blind technique through the FT-LMA compared with the C-LMA/FOB and the FT-LMA/FOB techniques (49 sec *vs* 75 sec *vs* 74 sec, respectively). Though not significantly different, successful intubation on the first attempt was least successful with the blind technique through the FT-LMA compared with C-LMA/FOB and FT-LMA/FOB (15/20 [75%] *vs* 16/20 [80%] *vs* 19/20 [95%], respectively).

In a manikin study, Sreevathsa *et al.*[77] compared the time required to intubate the trachea using FOB-guided intubation through an FT-LMA *vs* the CTrach. They found that the time was significantly shorter with the CTrach compared with the FT-LMA, with a mean time for FT-LMA and CTrach 84 sec *vs* 53 sec, respectively ($P < 0.001$). They speculated that the CTrach's continuous video display facilitates appropriate alignment of the ETT with the larynx. In a more recent comparison of intubation between the CTrach *vs* the FT-LMA (blind intubation) in 271 patients undergoing elective surgery, the CTrach demonstrated superior ability to view the glottis and a higher first-attempt success rate of tracheal intubation but a similar intubation rate by the third attempt (success rates within three attempts: CTrach 100% *vs* FT-LMA 96.4%; $P = 0.06$). However, more time was required with the CTrach.[78]

Nileshwar *et al.* found only a non-significant trend toward higher overall intubation success with the Bullard laryngoscope when they compared its use *vs* blind intubation with the FT-LMA in a simulated setting of an unstable c-spine in 62 patients undergoing general anesthesia with the placement of manual in-line stabilization.[79] Asai *et al.*[80] compared the ease of intubation (measured by a 100 mm VAS) by DL with a gum elastic bougie *vs* intubation via the FT-LMA using a FOB during manual in-line stabilization of 40 ASA I and II patients with no known upper airway pathology undergoing general anesthesia with muscle relaxant use. The success rate of intubation in the FT-LMA/FOB group was significantly higher than in the DL/bougie group (17/20 *vs* 9/20, respectively; $P < 0.01$). Intubation with the FT-LMA/FOB was significantly easier than intubation with DL/bougie ($P < 0.001$; 95% CI 18-68 mm for difference in VAS). Total intubation time was significantly shorter in the FT-LMA/FOB (95% CI 8-50 sec for difference). Ultimately, another interesting result from their investigation was that the tracheae of seven of the 11 patients that could not be intubated by DL/bougie were intubated successfully with the FT-LMA.

Complications and limitations

Multiple reports describe esophageal intubation as a potential complication of blind insertion of an ETT through the FT-LMA.[30,36,57,79,81] Since the bowl of the FT-LMA may include the esophagus and initial FT-LMA ventilation may be adequate, Dimitriou *et al.*[81] suggest that, clinicians need increased assurance of tracheal placement (i.e., capnography, bilateral breath sounds) when the trachea is intubated blindly. A case of an esophageal perforation has also been reported after five blind intubation attempts were made through the FT-LMA.[82]

Kihara *et al.*[83] compared the FT-LMA with the C-LMA in ASA I and II female patients and found that use of the FT-LMA resulted in significantly more minor complications, such as sore mouth and difficulty swallowing. Minimizing excessive force during blind intubation may prevent injury to the larynx or avoid oropharyngeal pain after FT-LMA removal. Dental damage (the loss of two lower incisors in an elderly male with known poor dentition) has been reported. This episode of dental damage occurred during anesthesia emergence when a patient vigorously bit down on the rigid airway tube of the FT-LMA that was left *in-situ* through the duration of the operative procedure.[84]

Similar to other single cuff laryngeal mask airways, the FT-LMA also has the limitation of not reliably protecting the lungs from regurgitated stomach contents.[85] Interestingly, Brimacombe *et al.*[86] described the overall aspiration rate of a C-LMA as 0.02%, which is comparable to elective ETT use. However, C-LMA use was in low-risk patients, while an ETT was used in patients with all levels of aspiration risk; notwithstanding, an ETT should be considered the preferred airway device in the context of aspiration risk. However, the FT-LMA is generally used as a tool to place an ETT and not as the primary airway maintenance device in the same manner as the C-LMA. We have no data on whether aspiration risk is higher when using an FT-LMA to place an ETT than when an ETT is placed using other methods. Keller *et al.*[87] reported a case of aspiration associated with the elective use of the FT-LMA in a patient with an asymptomatic hiatal hernia. In their case, no exceptional events took place prior to the regurgitation episode, i.e., difficult insertion or an inability to ventilate with low peak pressure. This case highlights the potential for regurgitation and aspiration in a full-stomach scenario.

In one of their early papers, Brain *et al.* state that the FT-LMA has a maximum external dimension of 2 cm.[1] However, in a case report by Preis *et al.*, they describe difficulty placing the FT-LMA in a patient with an interincisor distance of 24.5 mm.[88] They found differential amounts of silicone on the FT-LMA's airway tube and varying angles at the junction of the airway tube and mask; both issues led to a maximum FT-LMA dimension > 2 cm. They caution that FT-LMA use may not always be suitable when the interincisor distance approaches 2 cm.

Guidelines

The FT-LMA figures prominently in the American Society of Anesthesiologists (ASA) and the Difficult Airway Society (DAS) guidelines for managing the anticipated and unanticipated difficult airway.[89,B] The ASA Difficult Airway Algorithm is divided into two sections labelled "A" and "B".[89] The section labelled "B" is meant to address the "failed airway'. Where "if face mask ventilation is not adequate" is noted midway through the ASA algorithm, clinicians are prompted to attempt LMA placement. While the algorithm does not recommend an FT-LMA specifically, the forgoing discussion supports the use of this device over the C-LMA.

The DAS recommends the use of the C-LMA or the FT-LMA:[B]

- as Plan B for the unanticipated difficult intubation of an adult patient during routine induction of anesthesia;
- for the failed airway during rapid sequence induction of anesthesia in the non-obstetric adult patient; and
- for a failed intubation with increasing hypoxemia and difficult ventilation in the paralyzed anesthetized patient (as rescue techniques for the "can't intubate, can't ventilate" situation).

[B] Difficult Airway Society: Difficult Airway Society guidelines Flow-chart 2004.

Summary

The FT-LMA has proven to be a useful difficult airway device both within and outside of the OR. Effective ventilation is rapidly and successfully established in nearly all cases, and blind intubation is possible in the vast majority of cases if optimal technique is used. As well, adjuncts, such as FOB or lightwand, may be used occasionally. Serious complications are uncommon and typically limited to oropharyngeal trauma. The FT-LMA may be more advantageous than ETT placement by DL in many ways, e.g., less training needed for placement, a rapid learning curve, maintenance of the neutral position of the neck and head, and the ability to insert with limited mouth opening, neck soft-tissue compliance, or atypical patient positions. In summary, the FT-LMA can be used on its own for ventilation or to facilitate ETT placement; it is effective in a multitude of difficult airway scenarios.

Conflict of interest disclosures No funding, in any capacity, was utilized for the purposes of composing this review paper.

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