The laryngeal mask airway and the emergency airway

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The laryngeal mask airway (LMA) is an important new tool for managing the emergency airway. In a variety of emergency situations, the LMA may be considered instead of the face mask or the endotracheal tube. Furthermore, the LMA can be used as an aid to intubation and as a bridge to more secure means to control the airway. The primary risk with the LMA is aspiration of gastric contents. Anesthetists should be familiar with its advantages, risks, indications, and uses.

Key words: Difficult airway, emergency airway, laryngeal mask airway.

Two of the most important responsibilities of the anesthetist to the patient are maintenance of the airway and ventilation. Unfortunately, both of these may be difficult in the emergency situation. This article explores the role of the laryngeal mask airway (LMA) in the patient with (1) the "emergency airway," a situation in which a "normal" airway must be controlled immediately, or (2) the "difficult" airway which requires more vigilance in the operating room.

The difficult airway has been defined as difficulty with mask ventilation, tracheal intubation, or both, requiring more than three intubation attempts and taking more than 10 minutes. Studies suggest that the difficult airway is present in 1% to 3% of patients, many of which are not predictable beforehand. In closed claim studies, the majority of difficult intubation complications were not linked to obvious deficiencies in care or monitoring. It is more difficult to estimate how often it is necessary to control the airway immediately as airway control may be needed in so many different situations. Emergency airway control may be needed in the operating room. In addition, the anesthetist may be responsible for airway control in other areas of the hospital besides the operating room. Emergency control of the airway may be needed during cardiopulmonary, neonatal, obstetrical, and pediatric emergencies or resuscitation.

The anesthetist may not encounter the emergency airway frequently but must be competent in dealing with this difficult situation. The anesthetist should have a plan ready and be skilled in the delivery of this plan. The American Society of Anesthesiologists (ASA) has published a difficult airway algorithm (Figure 1). Included in this algorithm is the LMA.

The LMA was designed by Archie Brain, MD, LMSSA, FFARCSI, in England in the early 1980s as an intermediate airway device between a face mask and an endotracheal tube (ETT). It became available for use in the United Kingdom in 1988 and was approved by the U.S. Food and Drug Administration in August 1991. Since its introduction, the LMA has gained increasing use and respect as an airway adjunct capable of supplying an adequate airway and ventilation rapidly and with minimal trauma. More recently, it has become popular as an emergency airway, as well as an aid to intubation.

Advantages of the LMA with the emergency airway

The LMA has many demonstrable advantages for the anesthetist faced with difficult airway problems.

- Fast insertion. A study by Reinhart and Simmons with nonphysician emergency personnel trained in endotracheal intubation found the mean
Figure 1
American Society of Anesthesiologists difficult airway algorithm

1. Assess the likelihood and clinical impact of basic management problems:
   A. Difficult Intubation
   B. Difficult Ventilation
   C. Difficulty with Patient Cooperation or Consent

2. Consider the relative merits and feasibility of basic management choices:
   A. Non-Surgical Technique for Initial Approach to Intubation vs. Surgical Technique for Initial Approach to Intubation
   B. Awake Intubation vs. Intubation Attempts After Induction of General Anesthesia
   C. Preservation of Spontaneous Ventilation vs. Ablation of Spontaneous Ventilation

3. Develop primary and alternative strategies:

   A. AWAKE INTUBATION
      Airway Approached by Non-Surgical Intubation
        的成功* 失败
         " Cancel Case " 考虑可行性的其他选项(a) " 外科气道"
      Airway Secured by Surgical Access
         成功* 失败

   B. INTUBATION ATTEMPTS AFTER INDUCTION OF GENERAL ANESTHESIA
      初次通气尝试 成功* 失败
      继续尝试无果" 往后考虑的必要性:"
      1. 返回自主呼吸。
      2. 唤醒患者。
      3. 请求帮助。

   NON-EMERGENCY PATHWAY
   患者麻醉后,通气失败,自主呼吸适当
   采取其他方式通气(b)
   成功* 失败
   Curative Surgical Airway (f)

   EMERGENCY PATHWAY
   患者麻醉后,通气失败,自主呼吸不适当
   请求帮助
   采取其他方式通气(b)
   成功* 失败
   Curative Surgical Airway (f)

   * CONFIRM INTUBATION WITH EXHALED CO2
   (a) Other options include (but are not limited to): surgery under local anesthesia, intubation under local anesthesia infiltration or regional nerve blockade, or intubation attempts after induction of general anesthesia.
   (b) Alternative approaches to difficult intubation include (but are not limited to): use of different laryngoscope blades, awake intubation, blind oral or nasal intubation, fiberoptic intubation, intubating stylet or tube changer, lightwand, retrograde intubation, and surgical airway access.

time to ventilate successfully with the LMA was 38.9 seconds, compared with the endotracheal tube at 206.1 seconds. Use of the LMA has proved to be quickly and easily learned. Studies with anesthesia and nonanesthesia personnel have demonstrated rapid learning and competent technique.

- **Position of patient.** Although originally recommended for use only in the supine position and in the “sniffing position,” case reports and studies have been published recounting the use of the LMA in other positions, particularly in the prone and in the neutral head position. Brimacombe and Berry and Pennant et al have investigated the use of the LMA for the patient with the potentially unstable neck.

- **ETT insertion aid.** The size of the LMA permits the passage of a small ETT through its lumen, allowing for securing of the airway with an ETT. The ETT cuff protects against the main risk of the LMA, the risk of aspiration (discussed later), by isolating the lower airway from the esophagus. The ETT cuff also allows for higher ventilatory pressures in the patient with reduced compliance. The size of the ETT that can be placed through the LMA is limited by the size of the LMA (Table I). This may limit the size of the ETT to one smaller than is optimal for adequate ventilation. The new size 5 LMA was developed, in part, as a response to this problem. The size 5 LMA allows the placement of a 7½ mm ETT, a size adequate for most adults.

- **Fiberoptic bronchoscope aid.** The LMA has been used increasingly with the fiberoptic bronchoscope. The LMA can act as a guide for the bronchoscope, reducing the likelihood of secretions blocking the view and making its use quicker and easier. The large size of the LMA lumen allows for better ventilation around the bronchoscope compared with an ETT.

- **“Anterior” airways.** It is generally accepted that patients with anterior displacement of the larynx may be more difficult to intubate. Dr. Brain believes that the LMA is actually easier to pass in these patients as this anatomy directs the mask to

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### Table I

**Sizes and attributes of laryngeal mask airway (LMA) devices**

<table>
<thead>
<tr>
<th>Mask size</th>
<th>Patient weight (kg)</th>
<th>Internal Diameter (ID, mm)</th>
<th>Cuff volume (mL)</th>
<th>Largest ETT (ID, mm)</th>
<th>FOB size (mm)</th>
<th>Type of FOB that will pass through</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 6.5</td>
<td>5.25</td>
<td>2-5</td>
<td>3.5</td>
<td>2.7</td>
<td>Olympus® PF-27M ENF-P2 BF-N20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pentax® FB-10H FI-10P</td>
</tr>
<tr>
<td>2</td>
<td>6.5-20</td>
<td>7.0</td>
<td>7-10</td>
<td>4.5</td>
<td>3.5</td>
<td>Olympus® ENF-P3 BF-3020 Pentax®</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FNL-15S</td>
</tr>
<tr>
<td>2½</td>
<td>20-30</td>
<td>8.4</td>
<td>14</td>
<td>5.0</td>
<td>4.0</td>
<td>Olympus® LF-1</td>
</tr>
<tr>
<td>3</td>
<td>30-70</td>
<td>10</td>
<td>15-20</td>
<td>6.0 cuffed</td>
<td>5.0</td>
<td>Olympus® BF-2TR BF-P20D Pentax®</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FB-19H FB-19H3</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 70</td>
<td>12</td>
<td>25-30</td>
<td>6.5 cuffed</td>
<td>5.0</td>
<td>Many brands</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 90</td>
<td>11.5</td>
<td>35-40</td>
<td>7.0 cuffed</td>
<td>6.5</td>
<td></td>
</tr>
</tbody>
</table>

**ETT—Endotracheal tube**  
**FOB—Fiberoptic bronchoscope**  
(Based on information from:  
the proper location. Others have questioned this, but it is accepted that the LMA is at least no more difficult to insert in a patient with an anterior larynx than in the one with typical anatomy.

**Awake insertions.** Because the LMA can be inserted without laryngoscopy and does not pass through the glottis, there is less sympathetic stimulation than with the insertion of an ETT. The Wilkins study showed less sympathetic response and less anesthesia required after insertion compared with the ETT. Because of this, some have found awake insertions well tolerated by the patient if adequate local anesthetic and sedation are used. It is generally recommended that one use the same type and amount of local anesthetic as for any awake intubation.

**Pediatrics.** The LMA has been used increasingly in neonates, infants, and children for scheduled surgery and emergency airway control. The LMA has been used alone and as a aid to fiberoptic intubation in the pediatric difficult airway.

**Positive pressure ventilation.** The LMA can be used with positive-pressure ventilation in the patient with normal airway resistance and pulmonary compliance. When ventilation pressures are greater than 15 to 20 cm water, gastroesophageal insufflation of air may lead to gastric distension, which could increase the aspiration risk and increase the work of breathing.

**Risks associated with the LMA and the emergency airway**

Despite its advantages, the LMA is not without risks.

**Aspiration.** The risk of greatest concern with the use of the LMA is aspiration of gastric contents. Cases have been reported of aspiration with severe aspiration pneumonitis, but no deaths have been attributed to the use of the LMA to date. The meta-analysis of published literature by Brimacombe and Berry estimates the incidence of aspiration with the LMA is similar to that with the face mask and the ETT during routine surgery, approximately 2.10,000. The bowl of the LMA is designed to exclude the esophageal opening from the laryngeal opening with a low pressure seal. However, an uncontrolled study showed the upper esophageal opening included in the bowl of the LMA mask with the laryngeal opening in 6% to 9% of the cases. In this situation, gastric distension with air may produce increased risk of regurgitation, and the bowl may channel vomitus into the trachea, theoretically making aspiration more likely.

If the LMA is used with patients at risk for aspiration, the current recommendation is to apply cricoid pressure continuously for LMA insertion and continue cricoid pressure until the airway is protected. However, studies and reports show that cricoid pressure can make the insertion of the LMA more difficult. A randomized, blinded study mimicking failed intubation indicated that the application of cricoid pressure during LMA insertion resulted in a 90% success rate. Other studies have shown lower rates of success with insertion. A study on cadavers suggested that the presence of a correctly placed LMA does not interfere with the effectiveness of cricoid pressure.

Brimacombe et al have developed an algorithm for the use of the LMA during failed intubation in the patient with a full stomach. They first recommend the use of the face mask with cricoid pressure as the best and safest technique. If this fails, insertion of the LMA with cricoid pressure should be attempted. If this fails, cricoid pressure may be transiently released to insert the LMA. Finally, ventilation by face mask with no cricoid pressure can be done while preparing for cricothyrotomy. Although the new information and recommended techniques are encouraging, the risk of aspiration is at least as much as with a mask or ETT insertion and cannot be ignored.

In contrast to the agreed upon risk of aspiration of gastric contents, most studies demonstrate that secretions from the mouth and nasopharynx are reliably excluded from the trachea by the LMA mask, therefore isolating the mouth and nose from the trachea.

**Failure rate.** Although use of the LMA is easily learned, there is a learning curve. Recent studies have shown a failure rate to place on the first try from 1% to 5%, although original studies showed a higher failure rate. Inadequate anesthesia may contribute to placement failure. Certain anatomy, including a restricted mouth opening, macroglossia, and a steep angle to the posterior pharyngeal wall may also contribute to failure. Numerous different techniques have been improvised to increase insertion success in these situations. These include the following:

1. Rotating the LMA 180 degrees and inserting like a Guedel airway.
2. Inserting the LMA with the cuff partially or completely inflated.
3. Using jaw thrust while inserting.
4. Using a laryngoscope to elevate the tongue.
5. Using a stylette to hold the curve of the LMA.
6. Pressing the lip of the LMA cuff anteriorly rather than the recommended dorsal curve. It is recommended that the standard insertion technique be used on the first attempt before attempting alternative techniques. The LMA cannot be inserted in patients whose mouths do not open more than 1.5 cm.

- **Ventilation difficulties.** Patients with increased airway resistance and decreased pulmonary compliance may require ventilatory pressures higher than the 15 to 20 cm water provided with the LMA. The use of the LMA in these patients may result in hypoventilation and hypoxemia.

- **Limited in situ time.** There have been reports of mucosal ischemia and damage with the use of the LMA believed to be due to the LMA cuff. The pressure within the cuff of the LMA has been shown to rise as high as 142 mmHg during nitrous oxide use. This same study also demonstrated that with nitrous oxide, the pressure within the cuff will increase at a rate of 30 mmHg over 30 minutes, necessitating frequent checking of the balloon when nitrous oxide is used. The current recommendation is to inflate the cuff only enough to form a seal. There are no recommendations for the length of time it is safe to leave an LMA in place. This can be problematic during long surgeries or when an ETT is inserted through the LMA in an emergency situation, as it can be difficult to remove the LMA when the ETT is in place.

- **Airway stimulation.** Laryngospasm is not prevented by the LMA. Supraglottic stimulation by the LMA may cause laryngospasm in the lightly anesthetized patient, usually during insertion or removal. Bronchospasm due to airway stimulation by the LMA has also been reported, usually in patients with a history of irritable airway. The degree of stimulation related to insertion of the LMA is approximately the same as that for an oropharyngeal airway. This can be attenuated by an adequate depth of anesthesia, either general or local. In one study, topical lidocaine 2% decreased the incidence of coughing on emergence in children from 36.4% to 10.5%. Another study demonstrated that a successful superior laryngeal nerve block reduced the incidence of coughing and/or laryngospasm.

**Possible uses of the LMA with the emergency airway**

- **Failed intubation in the operating room.** Many cases have been reported of the LMA providing an adequate airway after failed intubation attempts and in situations in which the patient could not be ventilated or intubated. Because of the ease of insertion and high success rate, the American Society of Anesthesiologists algorithm (Figure 1) recommends that the LMA should be tried early in this scenario. If this does not control the airway quickly, other techniques should be tried. Having an LMA available with emergency airway equipment is recommended. Some recommend that the LMA should be available wherever anesthesia is administered.

After airway and ventilation have been controlled with the LMA, several options can be considered. The patient may be allowed to awaken. The LMA may be used alone for airway management. If there are reasons to further control the airway immediately, an ETT may be passed through the LMA.

It is possible with the LMA in place to pass an ETT by several techniques. Blind ETT placement through the LMA is considered to have a 75% to 90% success rate, but this success rate can be decreased with airway trauma and cricoid pressure. Fiberoptic bronchoscopy through the LMA is the recommended technique, with a nearly 100% success rate. Using the fiberoptic bronchoscope, an ETT may be placed through the LMA under direct vision. Alternatively, a bougie or tube exchanger may be passed, the LMA and fiberoptic scope removed, and an ETT passed over the tube exchanger. The tube exchanger allows for the removal of the LMA and the placement of a larger ETT.

If intubation is done through the LMA, the problem of what to do with the LMA must be considered. It is difficult to remove the LMA while leaving the ETT in place, as the LMA removal may displace the ETT. The LMA could be left in place with the cuff deflated. There are no clear recommendations on how long it is safe to leave an LMA in place. Several techniques have been suggested for removal of the LMA in this situation. It may be cut away, or the anesthetist may insert a bougie or jet stylet down the ETT to remove the LMA and ETT, then pass a new ETT using the bougie. The split LMA is manufactured to deal with this problem but is not yet available in the United States.

If ETT placement is impossible or contraindicated, emergency transtracheal jet ventilation, cricothyrotomy, or tracheostomy may be necessary.

- **Planned fiberoptic intubation of the known difficult airway.** Increasingly, there are reports of the LMA being used for planned fiberoptic intubations, as it makes the use of the fiberoptic scope easier and offers better control of the airway during the procedure. After topical anesthesia of the airway is achieved, the LMA may be inserted while the patient is awake. One must weigh the risks of hypoxemia. The use of the LMA in these patients may result in hypoventilation and hypoxemia.
aspiration even in the awake patient, as sedation and/or topical anesthetic may compromise the patient's ability to protect his or her own airway.

- The “unstable neck.” Studies have shown that the insertion of the LMA is possible with the patient's head in the neutral position. There are case reports of patients with limited neck movement in which the airway was secured with the LMA after failure with standard techniques. Aspiration risk must be considered. Insertion technique is basically the same, with a 95% success rate in the neutral head position on the first attempt compared with 100% in the “sniffing position.” If problems are encountered using the standard insertion technique, an alternative insertion technique, such as one of those mentioned previously, may be needed.

- Obstetric emergencies. There are case reports in which the LMA was used to provide an airway in obstetric emergencies when control of the airway was lost. The emergency need for airway control must be weighed against the risk of aspiration, since obstetrical patients are considered to have full stomachs even if they are fasting. If conventional airway management control has been unsuccessful, placement of the LMA with cricoid pressure can be attempted. The airway may then be further secured with an ETT as previously described.

- Failed sedation or regional anesthesia. In cases of failed sedation or regional anesthesia in which a general anesthetic is required, an LMA may be an option for airway control. The speed of insertion and rapid control of the airway is advantageous in these situations and may be easier than using a mask or ETT placement in positions other than supine. Proper depth of anesthesia must be assured before insertion, and the aspiration risk must be considered. Placement of an ETT through the LMA may be done if the airway must be further secured.

- Unintentional or failed extubation. In the operating room, the anesthetist does not extubate patients until the patients can be expected to maintain their own airways. The incidence of unplanned reintubation is low, with a Canadian Study showing a reintubation rate of 0.09%. However, when it does happen, it can be an emergency, as in the postanesthesia care unit with a hypoxemic patient or in the operating room when unexpected movement of the patient's head has caused extubation. This situation may also arise with a patient with a difficult airway, such as the patient with a known difficult airway or following otolaryngologic or neck surgery in which trauma or hematoma has caused airway compromise. Many cases of failed extubations can be easily solved by reintubation with laryngoscope and ETT. However, in the cases of a traumatized or known difficult airway or in which hypoxemia is significant and seconds may count, the LMA may secure the airway and allow for ventilation more quickly and with less trauma. The airway can then be secured further under more controlled conditions if this is necessary.

- Pediatrics. A number of reports in the literature describe the use of the LMA in the pediatric population, including the pediatric difficult airway. The placement of the LMA is considered somewhat more difficult in children compared with adults due to anatomic differences. These differences include overall smaller size, the larger relative size of the tongue, and steeper curve to the posterior pharyngeal wall. A first attempt insertion rate is cited between 67% and 92%. Insertion with the cuff partially inflated resulted in a greater first attempt success rate and a shorter insertion time. The LMA can be used alone or as a method to bridge to other techniques to secure the airway. The LMA can be used with fiberoptic intubation in the pediatric population as well.

- Neonatal resuscitation. In comparison with bag or mask ventilation, the LMA provides better ventilation in neonatal resuscitation. Recent reports describe using the size 1 LMA on neonates as small as 1,000 g. In cases of meconium aspiration, high ventilation pressures, or the need to give drugs via the airway, the safest option is securing the airway with a bag. One should be skilled in adult LMA insertions before attempting insertion in neonates and children.

- Emergency tracheostomies and endoscopically guided percutaneous tracheostomies. The LMA has been used for airway control during emergency tracheostomies and for the newer endoscopically guided percutaneous tracheostomies. In the latter, the LMA allows for better visualization through the bronchoscope. In both situations, the larger LMA lumen may allow for better ventilation during the procedure. In addition, it avoids the problem of ETT cuff damage during the tracheostomy insertion. There is a risk of aspiration.

- Cardiopulmonary resuscitation. The LMA is becoming increasingly popular in Europe in place of the face mask during cardiopulmonary arrest situations. Studies have demonstrated better venti-
lation with the LMA than with the face mask. As in the failed intubation scenario, the LMA may give rapid control of the airway and ventilation. There is the risk of aspiration.

Summary
The role of the LMA in emergency airway scenarios is still evolving. Because of its ease of insertion, its ability to provide ventilation quickly, and its ability to facilitate intubation and other emergency airway techniques, the LMA is a valuable part of the emergency airway algorithm. Anesthetists should be familiar with this addition to the airway management devices.

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