Review Article

The laryngeal mask airway: its features, effects and role

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The laryngeal mask airway was designed as a new concept in airway management and has been gaining a firm position in anaesthetic practice. Numerous articles and letters about the device have been published in the last decade, but few large controlled trials have been performed. Despite widespread use, the definitive role of the laryngeal mask has yet to be established. In some situations, such as after failed tracheal intubation or in anaesthesia for patients undergoing laparoscopic or oral surgery, its use is controversial. There are a number of unresolved issues, for example the effect of the laryngeal mask on regurgitation and whether or not cricoid pressure prevents placement of the mask. We review the techniques of insertion, details of misplacement, and complications associated with the use of the laryngeal mask. We discuss the features and physiological effects of the device, including the changes in intra-cuff pressure during anaesthesia and effects on blood pressure, heart rate and intra-ocular pressure. We then attempt to clarify the role of the laryngeal mask in airway management during anaesthesia, based on the current knowledge, by discussing the advantages and disadvantages as well as the indications and contraindications of its use. Lastly we describe the use of the laryngeal mask in circumstances other than airway maintenance during anaesthesia: fibreoptic bronchoscopy, tracheal intubation through the mask and its use in cardiopulmonary resuscitation.

Le masque laryngé représente un nouvel instrument de contrôle des voies aériennes maintenant solidement établi en anesthésie. De nombreux articles et lettres ont été publiés au cours de la dernière décennie mais peu d'essais cliniques contrôlés ont été réalisés. Malgré son utilisation répandue, on n'a pas encore réussi à attribuer un rôle définitif au masque laryngé. Dans certaines situations, comme après l'intubation ratée ou pour les laparoscopies et la chirurgie buccale, son utilisation est contestée. On dénombre un certain nombre de questions non résolues, par exemple l'effet du masque laryngé sur la régurgitation ou son insertion pendant la pression cricoïdienne. Nous réexaminons les techniques d'introduction, les vices d'insertion et les complications associées à son usage. Nous discutons ses caractéristiques et les répercussions physiologiques de son utilisation, incluant les changements de la pression interne du manchon et ses effets sur la pression artérielle, la fréquence cardiaque et la pression intra-oculaire. Nous tentons ensuite d'élucider le rôle du masque laryngé dans le contrôle des voies aériennes pendant l'anesthésie sur la base des connaissances actuelles par la discussion de ses avantages et désavantages ainsi que ses indications et contre-indications. Pour finir, nous décrivons son utilisation pour d'autres motifs que le maintien des voies aériennes pendant l'anesthésie: la bronchoscopie fibroptique, l'intubation de la trachée à travers le masque et son utilisation en réanimation cardiorespiratoire.

Key words
ANAESTHETIC TECHNIQUES: intubation;
COMPLICATIONS: aspiration, difficult intubation;
EQUIPMENT: fibreoptic bronchoscope, laryngeal mask airway;
HEART: cardiopulmonary resuscitation;
INTUBATION, TRACHEAL: technique.

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Contents

The laryngeal mask airway was designed by Brain as a new concept in airway management. Several oropharyngeal airways have been developed,[1] some of which provide an air-tight seal, usually by forming a plug in the upper pharynx.[2-4] The beauty of the laryngeal mask is that it forms an airtight seal by enclosing the larynx rather than plugging the pharynx, and avoids airway obstruction in the oropharynx.

Brain considered that the connection between the anatomical airway and the conventional artificial airway was less than ideal, and tried to produce an airway which directly faced the larynx. He examined the shape of the pharynx by making plaster-of-Paris casts from cadavers. He invented the laryngeal mask in 1981 based on this cast model of the hypopharynx. In the same year, he used a prototype in a patient for the first time. The details of the development of this invention are well described by the inventor.[5] Since the device was made available to clinicians in 1988, its use has spread rapidly and it is gaining a firm place in anaesthetic practice.

There have been numerous studies and reports and a major review has been published.[6] Despite these facts, the device is often misused and controversies exist surrounding its use under certain circumstances. This confusion is likely to persist until more comprehensive studies have been carried out and accurate information is available in review articles and text books. We consider that it is appropriate to describe the features of the device and then review the current role of the laryngeal mask based on the present state of knowledge.

Device

The laryngeal mask is designed to form a seal around the larynx with the distal part of the mask conforming to the hypopharynx (laryngeal part of the pharynx) (Figure 1) and the walls of the long axis of the mask facing towards the pyriform fossae.[5] Brain confirmed in cadavers that the mask of prototypes was long enough to encircle the larynx, because the length between the tip of the mask and the upper border of the mask aperture was always longer than that between the upper border of the thyroid cartilage and the lower border of the cricoid cartilage.[5]

A tube is attached to the back of the mask at an angle of about 30°. This angle was chosen because it was found to be the optimal angle for tracheal intubation through the laryngeal mask.[5] The mask consists of a cuff which is inflatable through a pilot tube and balloon, through which the cuff pressure can be monitored. When the cuff is correctly deflated, it should form a "wafer-thin leading edge" facing away from the mask aperture.[5] There are two vertical bars at the the distal end of the tube which are designed to prevent the epiglottis from falling into the aperture of the tube.[5] When the black line on the tube is in the midline, facing cephalad, the

FIGURE 1 Plaster-of-Paris cast of the pharynx superimposed on a laryngeal mask, which shows how the tip of the mask was designed to fit into the hypopharynx. The arrow indicates the level of the upper oesophageal sphincter. (Modified and reproduced with permission from Dr. A.I.J. Brain).

cuff of the mask faces the larynx. The device is made of silicone and incorporates a polysulfone connector and a polypropylene valve.

The device is currently available in five sizes in Canada (Table I). The size #5 is available in the United Kingdom (UK), and is used for large adults. The smaller sizes of the laryngeal mask are scaled-down versions of the adult sizes. Some anaesthetists argue that these smaller masks are not anatomically compatible because, compared with adults, the larynx is positioned higher and more anteriorly in small children.[7] However, the design of the mask is based on the shape of the hypopharynx rather than the larynx. Brain examined the shape of the hypopharynx in cadavers of infants and concluded that scaled-down models of adult masks are consistent with the anatomy of children.[5]

There are two modified versions: the reinforced laryngeal mask and the so-called ST-laryngeal mask. The reinforced laryngeal mask has been designed to facilitate use of the device for head, neck and oral surgery and consists of a flexometallic tube connected to a standard laryngeal mask (Figure 2). The diameter of the tube in this version is smaller than the standard one to facilitate surgical access (Table I). The reinforced laryngeal mask is available in sizes #2 to 4. The ST-laryngeal mask has a tube which is 2 cm shorter than a standard mask. Only size #3 is available in the UK.

TABLE I Specifications of the laryngeal mask

Size #	*Patient's weight (kg)*	*Cuff volume (ml)*	*Length (cm) (standard/ reinforced)*	*Internal diameter (mm) (standard/ reinforced)*
1	<6.5	Up to 4	8.6/-	5.3/-
2	6.5–20	Up to 10	12.0/13.0	7.0/5.1
2½	20–30	Up to 14	13.5/16.5	8.4/6.1
3	>30	Up to 20	17.5/21.0	10.0/7.6
4	Adult	Up to 30	17.5/21.0	10.0/7.6
5*	Large adult	Up to 40	20.0/-	11.5/-

*Size #5 is available in the UK.

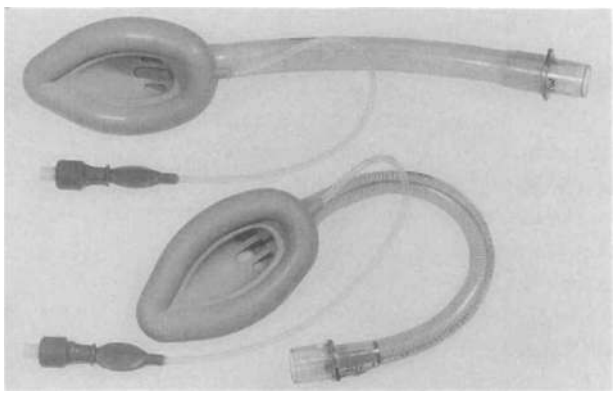

FIGURE 2 The standard and reinforced laryngeal masks. The flexometallic tube of the reinforced mask can bend through greater than 180° without kinking.

Techniques

Preparation

CLEANING

The laryngeal mask should be cleaned and sterilized before each use. It should be washed immediately after it is removed from the patient; it can be immersed in an 8.4% solution of bicarbonate to dissolve secretions before cleaning with warm water. After cleaning, the device should be sterilized in an autoclave using a maximum

temperature of 134 ± 4°C. The cuff must be completely deflated before autoclaving. The cuff will be damaged if it is not fully deflated or is autoclaved at too high a temperature.[8] Formaldehyde, glutaraldehyde, ethylene oxide or iodine-containing preparations should not be used, since these may damage the device. Prolonged immersion in chlorhexidine and ultrasound cleaning equipment should also be avoided.

PRE-USE CHECKING

The device can be re-used up to 40 times according to the manufacturer's recommendations* but it must be checked before each use. The exterior of the tube should be examined to ensure that it is free from cracks or abrasions and the interior should be inspected to ensure that there are no foreign bodies. The valve should be tested and replaced if the cuff reinflates spontaneously after complete deflation. Replacement valves are available from the manufacturer. The device should be discarded if it is damaged, or if the tube is discoloured or kinks when it is flexed to 180°. It should also be discarded if there is herniation or thinning of the wall when the cuff is inflated with a volume of air 50% greater than the maximum volume recommended.[9] The following volumes should therefore be used for testing the cuffs: size 1: 6 ml, size 2: 15 ml, size 2½: 21 ml, size 3: 30 ml, size 4: 45 ml.

Induction agents

The laryngeal mask can be placed with or without using muscle relaxants, but anaesthesia should be deep enough to obtund the airway reflexes. Induction of anaesthesia with propofol or inhalational anaesthetic agents can produce suitable conditions.

Propofol depresses pharyngeal and laryngeal reactivity more than thiopentone.[10,11] Brown *et al.* showed that gagging occurred less frequently during placement of the laryngeal mask after administration of propofol (2.5 $mg \cdot kg^{-1}$) than after thiopentone (4 $mg \cdot kg^{-1}$).[12] Between 2.5 and 3.0 $mg \cdot kg^{-1}$ propofol are required to obtain adequate conditions for placement in adults.[13,14] The required dose of propofol in children may be relatively higher than that in adults, because the dose of propofol required to tolerate a face-mask is high in children (estimated ED_{90} was 4 to 5 $mg \cdot kg^{-1}$).[15] This has not been confirmed.

Thiopentone or etomidate can be used for induction of anaesthesia provided that anaesthesia is deepened with an inhalational anaesthetic agent before placement.

*The Intavent laryngeal mask. Important information on this reusable product, June 1993. Colgate Medical Limited, Shirley Avenue, Windsor, Berkshire SL4 5LH.

The laryngeal mask can also be inserted in awake patients under topical anaesthesia (see "Other applications").

Placement

THE STANDARD TECHNIQUE

The original technique shown in the manual and video has been modified by the inventor in 1992. The full details of the technique for placement can be found in the new Instruction Manual.[9]

1 The cuff must be fully and correctly deflated before placement. This imparts rigidity to the tip of the cuff. The deflated cuff should be free from wrinkles and its rim should face away from the mask aperture. This can be achieved by pressing the hollow side down onto a clean flat surface during inflation, with two fingers pressing down on a point just short of the tip.
2 A lubricant is applied only to the posterior surface of the cuff just before placement. This prevents the cuff tip from rolling over on contact with the palate. Application of lubricant to the anterior surface of the mask is not necessary, and lubricant may block the aperture or be inhaled, causing airway obstruction or coughing.
3 Before placement, the patient's neck is flexed and the head extended ("sniffing position") by pushing the head from behind with the non-dominant hand. An assistant should open the mouth by pulling the lower jaw downwards. With experience, the operator can open the mouth with the third finger of the dominant hand.
4 The device is held between the thumb and the index finger, as close as possible to the junction of the tube and mask. The aperture of the mask faces the patient's chin.
5 The tip of the cuff is placed against the inner surface of the patient's upper incisor teeth. It is important that at this point the tube should be parallel to the floor rather than vertical (see "Misplacement"). The mask is then pressed upwards against the hard palate and advanced into the oral cavity, maintaining upward pressure (Figure 3).
6 The device is advanced using the index finger located at the junction of the tube and the mask. It is essential that the tip of the cuff does not roll over while advancing the laryngeal mask.
7 A change of direction will be felt as the cuff tip follows the posterior pharyngeal wall downwards. The laryngeal mask is pushed as far as possible into the hypopharynx by the index finger. When the mask is fully advanced, resistance will be felt.
8 The tube is then held by the non-dominant hand to

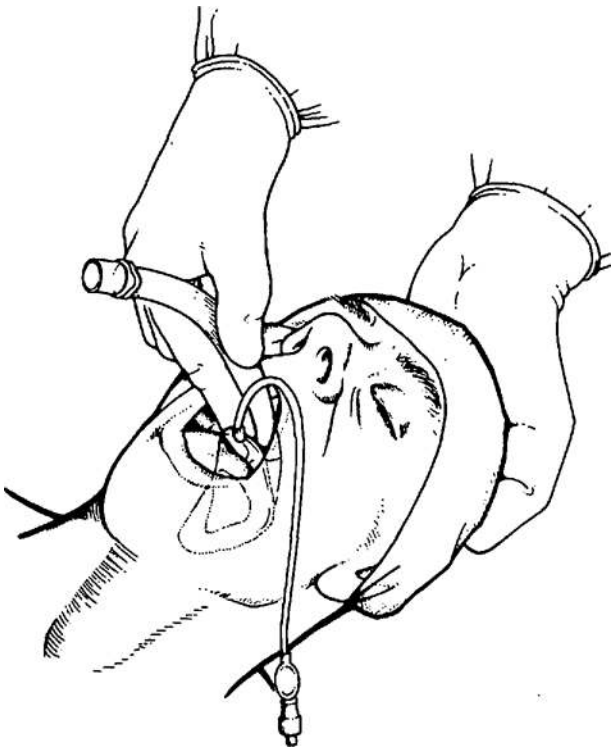

FIGURE 3 Placement of the laryngeal mask. The index finger should be positioned as close as possible to the junction of the tube and the mask, and upward pressure maintained on the hard palate during placement.

prevent the mask from moving out of position as the index finger is withdrawn.

9 With experience, the index finger can advance the mask fully into position. However, if it is considered that the mask is not fully advanced into the hypopharynx, the laryngeal mask is pressed downwards by the non-dominant hand for complete location.

10 The cuff is inflated with an appropriate volume of air (Table I). Note that the figures given in Table I represent *maximum* inflation volumes. The tube usually moves out of the mouth slightly (mean distance of 0.7 cm),[16] and the tissues overlying both the thyroid and cricoid cartilage bulge slightly when the cuff is inflated. The tube should not be held or connected to the breathing system during inflation. The tip of the mask is likely to be positioned too deeply if the tube is held during inflation (see "Misplacement").

11 The laryngeal mask is connected to the breathing system and adequacy of ventilation is assessed. When adequate ventilation is not obtained, the mask is removed and placement reattempted. The cuff should be prepared between each attempt as initially described.

12 A bite-block is inserted, and the laryngeal mask and the bite-block are fixed. Brain recommends using a wad of gauze as a bite-block.[9]

MODIFIED TECHNIQUES

Several other methods of placement have been suggested. These include a lateral approach,[17] rotation,[18,19] a partially inflated cuff,[20] jaw thrust[17] or use of the laryngoscope.[21] However, none has proved to be better than the standard technique (see "Misplacement").[22] When the cuff is partially inflated, folding of the cuff tip may be less likely to occur,[20] but the partially inflated cuff is more likely to press down the epiglottis.[22] Rotating the laryngeal mask during placement is as effective as the standard technique[22] and can be tried if difficulty is encountered.

PLACEMENT OF THE REINFORCED LARYNGEAL MASK

The technique of placement of the reinforced laryngeal mask is the same as that for the standard mask: the device is held between the thumb and index finger at the junction of the tube and mask and positioned by the index finger. However, before experience has been gained it may be difficult to drive the mask fully into position using the index finger. If a tracheal tube is used as a stylet, final positioning can be achieved by pushing the device as in the standard technique.[23] The use of a rigid stylet to prevent twisting of the reinforced laryngeal mask has been suggested,[24] but this is unnecessary if the junction of the tube and the mask is held during placement.

FIXATION

A bite-block should normally be used while the laryngeal mask is in place, because biting may damage the tube or cause airway obstruction.[25] Brain recommends using a roll of gauze (at least 3 cm width) as a bite-block, taping it firmly to the tube and fixing both to the face. These procedures prevent biting of the tube and dislodgement of both the laryngeal mask and the bite-block. Bending of the tube against its natural curvature may kink or dislodge the laryngeal mask. Unnecessary traction from breathing systems should be avoided. Methods of securing the laryngeal mask with a flexible catheter mount[26] or two swivel connectors[27] have been described. The reinforced laryngeal mask can be taped directly to the chin, and is less likely to kink or become dislodged. Although the reinforced tube is designed for maximum flexibility without kinking, it will not withstand biting or strong compressive forces.

Maintenance of anaesthesia

Both spontaneous breathing and intermittent positive-pressure ventilation (IPPV) can be achieved through the laryngeal mask. Although patients can tolerate the pres-

ence of the mask under light anaesthesia,[28] anaesthesia should be maintained deep enough to suppress airway reflexes. When the patient breathes spontaneously under light anaesthesia, laryngospasm[29] or distension of the stomach from repeated swallowing[30] may occur. The latter may predispose the patient to regurgitation, vomiting and pulmonary aspiration. There are reports of vomiting and pulmonary aspiration that occurred while the laryngeal mask was used in patients who were inadequately anaesthetized.[31,32]

During IPPV, airway pressures should always be monitored and maintained as low as possible, since the incidence of gastric insufflation increases with increasing airway pressure.[33] When wheezing is heard, it is usually caused either by adduction of the vocal cords because of inadequate muscle relaxation or by the tip of the mask being against the glottis. Administration of muscle relaxants rather than addition of the air to the cuff usually relieves the problem in the former case.

A low-flow or closed circuit anaesthesia technique can be used with the laryngeal mask, because the mask provides an air-tight seal when airway pressures are less than about 2.0 kPa.[34,35]

Removal of the laryngeal mask

The laryngeal mask should be removed only after the patient's protective reflexes have returned, and the patient responds to the command to open their mouth. Patients should not be stimulated until they spontaneously recover from anaesthesia. When patients are transferred from the operating table, anaesthesia should be maintained deep enough to prevent reflex responses to the stimulus of being moved. It is not usually necessary to remove the secretions from the upper pharynx by suction, since they do not enter the larynx provided that the cuff is not deflated until just before removal.[36,37] The bite-block must be left in place until the mask is removed. During transfer and in the recovery room, no manual airway support is required, and supplementary oxygen can be given using a T-piece connector.[38,39]

Some anaesthetists suggest removal of the laryngeal mask during emergence from anaesthesia.[40] However, this suggestion is based on a risk of complications resulting from misuse of the device. Removal of the mask during light anaesthesia may induce laryngospasm, coughing or gagging.[41] When the trachea is intubated, the incidence of pulmonary aspiration is as high during tracheal extubation as during intubation; this is usually associated with gagging.[42] Thus, it seems logical to remove the laryngeal mask after airway reflexes have returned. Usually the presence of the laryngeal mask itself does not induce such complications. The patient can cough effectively and coughing is not an indication for removal. Even when laryngospasm occurs while the laryngeal mask is in place, it should be left in position and anaesthesia deepened to relieve the spasm; removal of the mask may worsen the situation by increasing the stimuli to the airway.[43] It may be acceptable to remove the mask under deep anaesthesia,[44] but the advantages of the device will obviously be lost.

Anatomical position

When the mask is placed correctly, the distal part of the mask occupies the hypopharynx, and the tip rests on the upper oesophageal sphincter,[43] at the level of the 6th or 7th cervical vertebrae[43,45] (Figure 4). The hypopharynx extends to the lower border of the cricoid cartilage, where it becomes the oesophagus. Thus, the distal part of the mask lies posterior to the cricoid cartilage and the tip of the mask lies at the level of the cricoid cartilage. The sides of the mask face into the pyriform fossae, and the proximal edge of the mask is under the base of the tongue, below the level of the tonsils.[9,46] When the tube is fixed properly, the curve of the tube should follow that of the palate.

Goudsouzian *et al.* examined the position of the mask in children using magnetic resonance imaging (MRI) or computed tomography (CT) and showed that the proximal edge of the mask was consistently located at the level of the 1st and 2nd cervical vertebrae, whereas the position of the mask tip varied from the level of the 4th cervical to 1st thoracic vertebrae.[47]

The epiglottis is either positioned in the aperture of the mask or compressed by the upper part of the mask.[5] Examination with a fibreoptic bronchoscope or radiography showed that the epiglottis was positioned in the aperture of the mask in 15% to 66% of adults, children and infants.[7,47-50]

The mean distance between the grill of the laryngeal mask and the vocal cords is 3.1 cm in women and 3.6 cm in men.[16]

When the cuff of the mask is inflated, the thyroid, arytenoid and cricoid cartilages are pressed anteriorly, and the tissues overlying the larynx bulge slightly.[48,51]

Physiological effects

Cuff pressure

When the cuff of the mask is inflated with the recommended *maximum* volume of air, the calculated pressure transmitted to the pharyngeal mucosa is much higher than capillary perfusion pressure.[52] There is, therefore, a theoretical risk of ischaemia of the pharyngeal mucosa when the mask is inflated with the maximum volume.

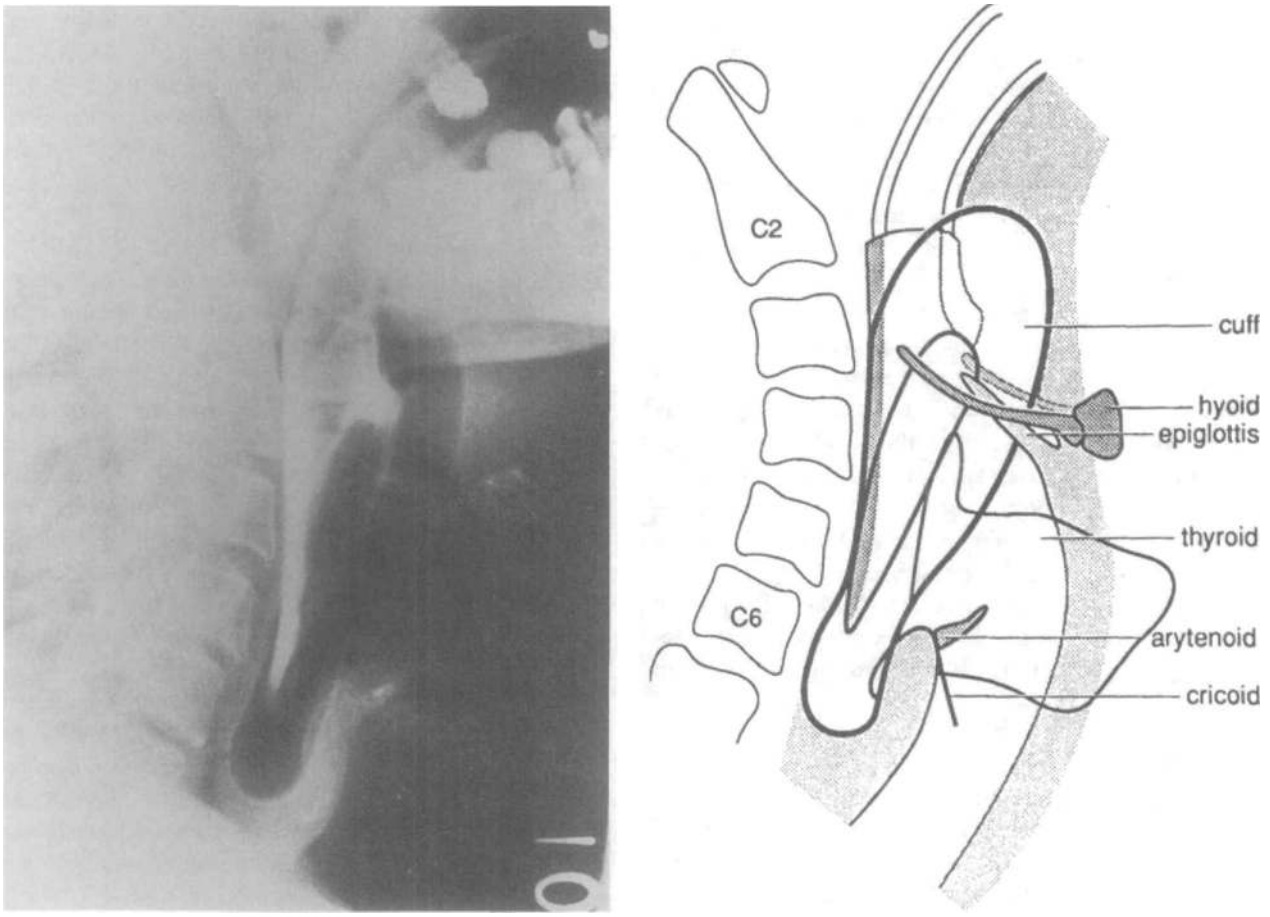

FIGURE 4 The correct position of the laryngeal mask. The distal part of the mask occupies the hypopharynx, posterior to the cricoid cartilage. The entire larynx is moved forward and the arytenoids are rotated in relation to the cricoid cartilage. As a result, the tissues overlying the thyroid and cricoid cartilages bulge. The arytenoids are markedly calcified in this patient. (Reproduced with permission from Dr. P.R. Nandi *et al.*[48] and the publisher).

Nitrous oxide and carbon dioxide diffuse into the cuff of the laryngeal mask faster than nitrogen and oxygen diffuse out. This results in an increase in cuff volume and intra-cuff pressure when nitrous oxide is used.[53] Lumb *et al.* showed that intra-cuff pressure increased from 80 to 110 mmHg, with a mean increase in volume of 5.1 ml for a size 4 laryngeal mask.[53] Others have shown increases in cuff volume ranging from 9 to 20% depending on the size of the mask used.[52,54] However, despite these increases in cuff volume and pressure, the pressure exerted upon the pharyngeal mucosa did not increase, but either remained constant or decreased. This may be because under general anaesthesia the muscles of the pharynx relax when the mask is in place.[52]

The morbidity resulting from this high transmitted pressure on the pharyngeal mucosa is unknown. The manufacturer recommends monitoring the intra-cuff pressure, and reducing excessive pressure to avoid complications. This can be achieved by using a pressure relief valve or by deflating the cuff.[53]

Dead space

The laryngeal mask bypasses part of the anatomical dead space. Dead space is, in theory, less than when the facemask is used, but more than when the trachea is intubated.

Airway resistance

Tracheal intubation results in an increase in resistance to ventilation as a result of narrowing of the diameter of the airway and reflex airway constriction.[55] The laryngeal mask should cause a relatively smaller increase in airway resistance, because the diameter of the tube of the laryngeal mask is much larger than that of the

tracheal tube and the trachea is not directly stimulated.[56] Bhatt *et al.* showed in an *in vitro* study that the resistance during constant flow and additional inspiratory work imposed by the laryngeal mask is considerably less than that imposed by a tracheal tube.[57] Ferguson *et al.*, however, reported that in awake volunteers airway resistance increased after placement of the laryngeal mask,[58] and this increase was similar to the previously reported change in airway resistance after tracheal intubation.[55] The diameter of the tube of the reinforced laryngeal mask is less than that of the standard one. As a result, the resistance of the size #4 reinforced laryngeal mask is between that of the 8 mm and 9 mm RAE performed tracheal tubes. The resistance of the size #2 reinforced laryngeal mask is between that of the RAE 5 mm and 6 mm tubes.[59]

Haemodynamics

Blood pressure and heart rate increase after placement of the laryngeal mask. The increases are similar to those after insertion of a Guedel airway and less than those after tracheal intubation.[60–64] The duration of change in heart rate is shorter than that after tracheal intubation.[61,65]

Haemodynamic changes after removal of the laryngeal mask may also be less than those after tracheal extubation, but this has not been proved. There was no difference in the changes in blood pressure between removal of the laryngeal mask and tracheal extubation, although systolic blood pressure tended to be higher after tracheal extubation.[62,65] The increases in heart rate and rate-pressure products were greater after tracheal extubation than after removal of the laryngeal mask.[62] Both of these authors removed the laryngeal mask and the tracheal tube during light anaesthesia after reversal of the effect of muscle relaxants. There may be a difference in haemodynamic changes when the laryngeal mask or tracheal tube is removed after the patient has regained airway reflexes and is able to respond to the command to open the mouth, as is recommended for the laryngeal mask.

Intra-ocular pressure

Intra-ocular pressure increases less (or decreases) after placement of the laryngeal mask than after tracheal intubation when anaesthesia is induced with thiopentone,[62] etomidate[65] or halothane.[66]

When anaesthesia is induced with propofol in patients with normal eyes, the intra-ocular pressure does not increase above baseline values after tracheal intubation or placement of the laryngeal mask. Propofol decreases intra-ocular pressure more than does thiopentone[67] and suppresses the increase in intra-ocular pressure after tracheal intubation.[68] The intra-ocular pressure remains below baseline values after tracheal intubation when propofol is given as a bolus,[68] as a bolus sleep dose followed by an infusion,[69] or with a computerized technique;[70] these changes are similar to those after placement of the laryngeal mask.[70]

Barclay *et al.* showed that in patients with glaucoma, induction of anaesthesia with propofol descreased intra-ocular pressure, and this decrease was sustained after placement of the laryngeal mask. In contrast, tracheal intubation caused an increase in intra-ocular pressure, with values exceeding baseline in more than one-third of patients,[71] which did not occur in patients with normal eyes.

The change in intra-ocular pressure during emergence from anaesthesia is less when the laryngeal mask is used than with tracheal intubation.[62] Lamb *et al.* measured the intra-ocular pressure before and one minute after removal of either a tracheal tube or a laryngeal mask.[62] Intra-ocular pressure increased markedly after tracheal extubation, whereas it remained stable after removal of the laryngeal mask. The incidence of coughing, straining or breath-holding is lower during removal of the laryngeal mask than during tracheal extubation.[65,70] The lower incidence of complications on removal of the laryngeal mask means that intra-ocular pressure is less likely to increase.

Misplacement

Although placement of the laryngeal mask is relatively easy, failure to obtain adequate ventilation occurs in a small percentage of cases. In addition, even when satisfactory ventilation is obtained, the mask is sometimes not perfectly positioned. The incorrectly positioned mask is more likely to be dislodged or to activate airway reflexes. Although some of these failures of placement are undoubtedly due to poor technique, many of the causes of failure have yet to be elucidated.

Details

DIFFICULTY IN PLACEMENT

One point at which difficulty may occur is when the tip of the mask passes just behind the tongue, as it changes direction towards the hypopharynx. This difficulty may occur more frequently in children than in adults.[19,41] When the neck is flexed and the head extended, placement may be easier because these manoeuvres produce an angle between the oral and the pharyngeal axes of $>90°$ at the back of the tongue.[72,73] In adults in whom tracheal intubation is anticipated to be easy, placement is usually easy even when the head and neck are fixed in neutral position.[74,75] Whether this is also the case in children or in patients with some degree of anticipated airway difficulty is unknown.

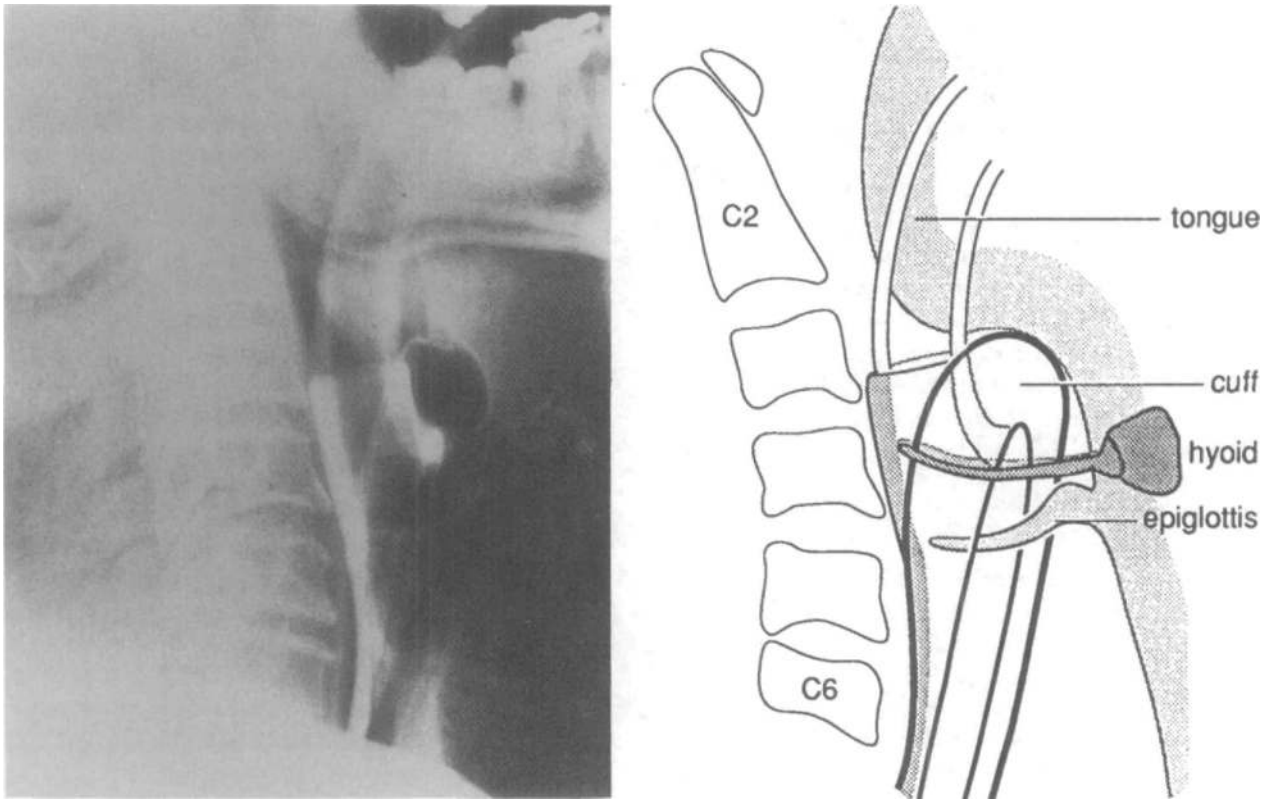

FIGURE 5 "Downfolding" of the epiglottis. The epiglottis is being pressed downwards by the laryngeal mask. (Reproduced with permission from Dr. P.R. Nandi *et al.*[48] and the publisher).

Placement may be difficult if the mask presses the tongue downwards. This is likely to occur if the laryngeal mask is held with the tube vertical rather than horizontal during placement.

The tip of the mask also may impact upon an irregularity or swelling in the posterior pharynx, such as tonsillar hypertrophy.[9,41,46,76]

POSTERIOR DEFLECTION ("DOWNFOLDING") OF THE EPIGLOTTIS

When the laryngeal mask is placed with its cuff partially or fully inflated, the tip of the cuff is likely to press the epiglottis downwards (Figure 5). Brimacombe and Berry compared the efficacy of several methods of placement. They showed that when the cuff was inflated during placement, the incidence of downfolding of the epiglottis increased from 10% to 57%.[22] The epiglottis is also more likely to be pressed down when the laryngeal mask is placed with the rim of the cuff facing towards the aperture of the mask.

MIGRATION OF THE MASK INTO THE LARYNX

When the tip of the mask is not pressed against the hard palate and posterior pharyngeal wall during placement, it is more likely to impact upon the larynx (Figure 6). This can cause downfolding of the epiglottis, obstruction of the glottis or contact with the arytenoid cartilages.[45] When the cuff is inflated with the tip of the mask resting upon the glottis, the tube is seen to be further out of the mouth than usual. Only the tissue over the thyroid cartilage bulges, because the cricoid cartilage will not be pressed anteriorly.[45] Manual ventilation may be difficult and stridor may be heard.

THE LARYNGEAL MASK NOT FAR ENOUGH

If the mask is not inserted far enough, the tip of the mask presses on the arytenoid cartilages, resulting in inward displacement of the aryepiglottic folds and an unstable position of the mask. This inward displacement obstructs the airway.[77] If the oesophagus is seen through the fibrescope in the aperture of the mask, the mask is not inserted far enough. Only the tissue over the thyroid cartilage bulges during inflation of the cuff. There has been a case report in which *x*-rays revealed the tip of the cuff to be in the oropharynx, despite a clinically acceptable airway.[78]

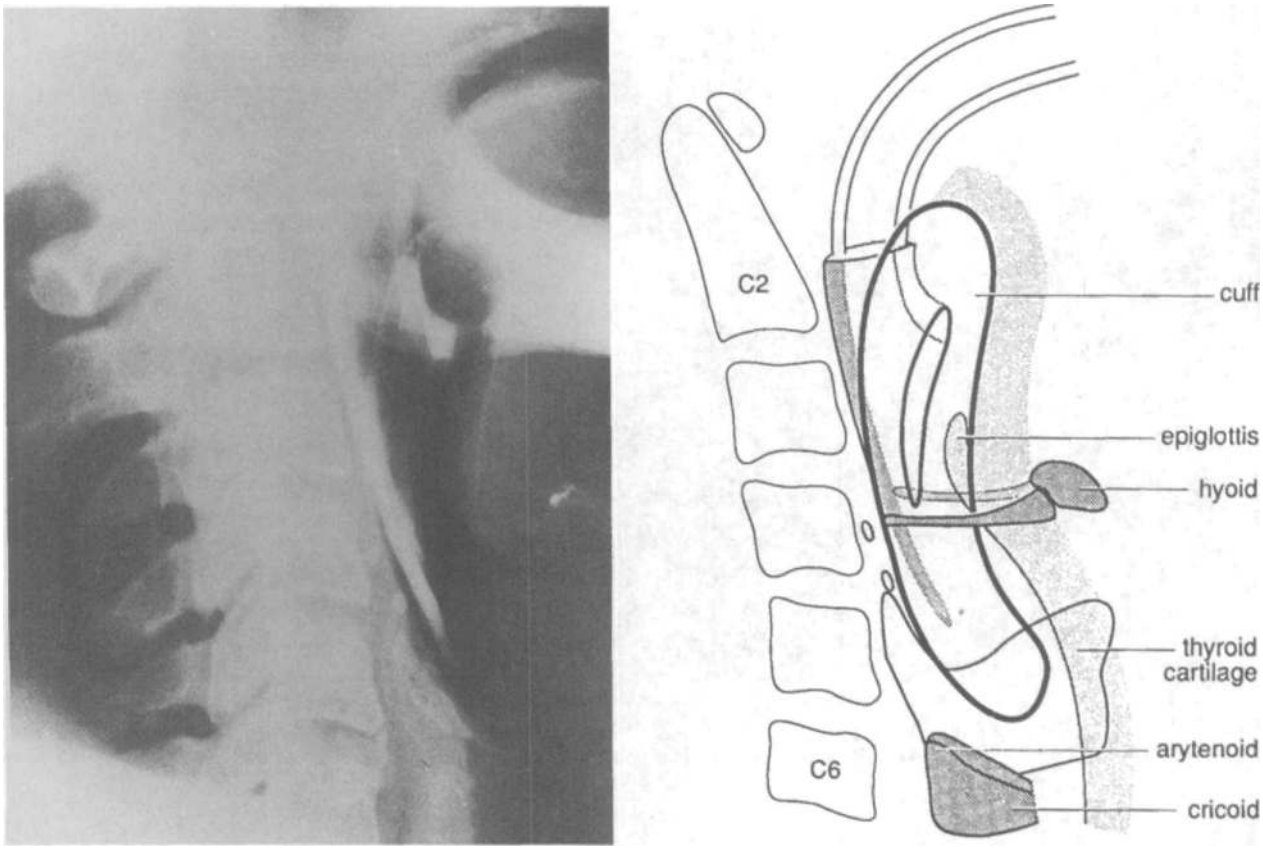

FIGURE 6 Migration of the mask into the larynx. The laryngeal mask is anterior to the arytenoids and within the laryngeal inlet. (Reproduced with permission from Dr. P.R. Nandi *et al.*[48] and the publisher).

THE LARYNGEAL MASK TOO DEEP

When an inappropriately small size is used, it can be advanced too far into the oesophagus, so that the proximal part of the mask can obstruct the glottis.[5] If the laryngeal mask is held or the breathing system is attached during inflation of the cuff, the mask cannot move outwards in the normal way and it remains wedged in the upper oesophageal sphincter, which may therefore be stretched by inflation of the cuff.

TORSION OF THE LARYNGEAL MASK

The laryngeal mask may be positioned with the mask twisted around the long axis of the tube. This is more likely to occur when it is rotated during placement.[22]

FOLDING OF THE MASK

The mask may fold over on itself when it is inserted with excessive force, or is not pressed upwards against the hard palate. This is also likely to occur when the cuff is not tightly deflated, or if the mask is not well lubricated, or has perished after repeated use. There has been a report in which a mask was placed easily but found to be folded through 180°, without any apparent airway obstruction[48] (Figure 7).

Solutions

Placement of the laryngeal mask is easier when the neck is flexed and the head extended. Folding of the tip of the cuff is less likely to occur when the posterior surface of the cuff is well lubricated. Difficulty in placing the mask can be avoided when it is placed with the tube parallel to the floor. The incidence of posterior deflection of the epiglottis and contact of the cuff with the larynx is decreased when the mask is pressed upward against the hard palate and posterior pharyngeal wall during placement. This can best be achieved with the index finger positioned at the junction of the tube and the mask so that the finger acts as a fulcrum. A fully deflated cuff with the rim facing away from the aperture of the mask is less likely to impact upon the larynx. The epiglottis

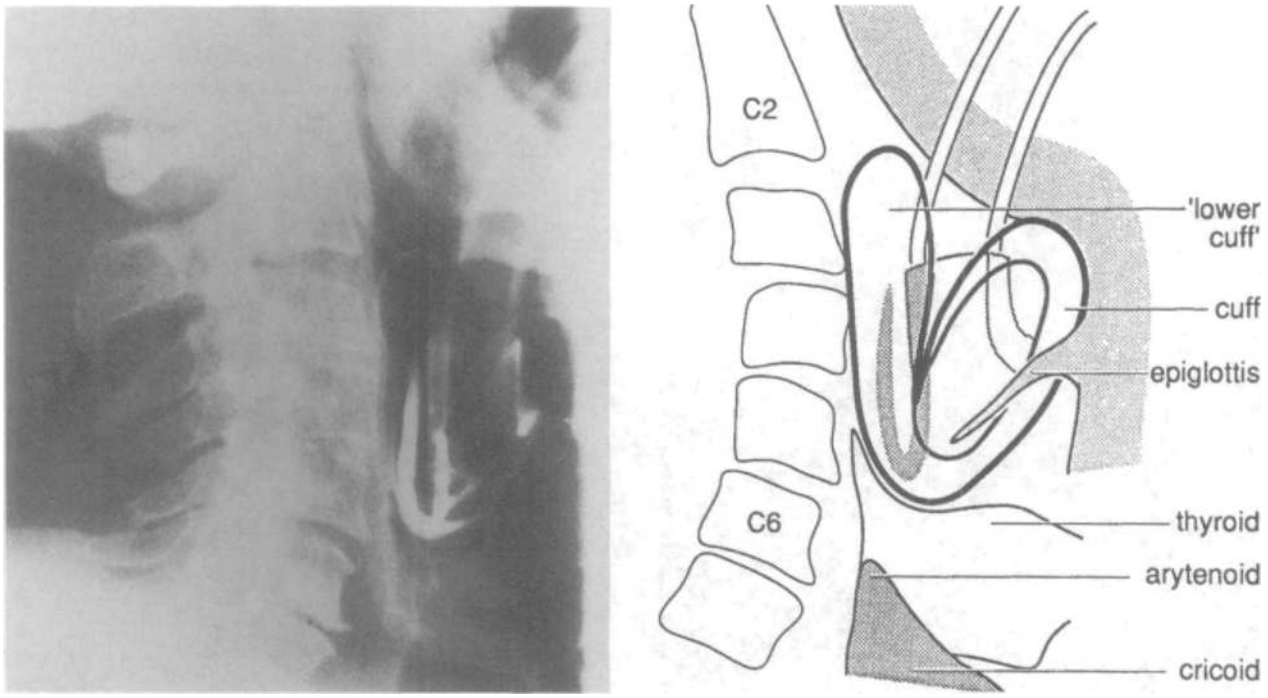

FIGURE 7 Folding of the mask. The laryngeal mask is folded through 180° in the pharynx. A clinically acceptable airway was obtained in this case. (Reproduced with permission from Dr. P.R. Nandi *et al.*[48] and the publisher).

tends to move posteriorly when patients are paralyzed; this is prevented by extension of the head[79] which should, in theory, reduce the incidence of posterior deflection of the epiglottis by the mask.

The standard technique originally described and later refined by Brain seems to have stood the test of time. The incidence of misplacement can be kept to a minimum if his instructions are strictly followed.

Confirmation of position

The position of the laryngeal mask is clinically determined by adequate chest expansion with a satisfactory compliance and auscultation of breath sounds with a stethoscope placed on the anterolateral part of the neck. However, even when adequate ventilation is obtained through the laryngeal mask, it is sometimes misplaced. The position can be confirmed by *x*-ray or MRI. Fibrescopy is useful, but this technique cannot always confirm whether the distal part of the mask is correctly occupying the hypopharynx.[80] Many anaesthetists consider that the mask is not in the correct position when part of, or the entire epiglottis is seen through a fibrescope passed through the laryngeal mask.[7,50,81] However, even when the mask is in the correct position, the epiglottis is sometimes situated in the aperture of the mask (see "Device"). The presence of the epiglottis in the aperture of the mask does not always indicate that the tip of the mask fails to occupy the hypopharynx. The mask may be considered to be in the correct position when the tissues overlying both the thyroid and cricoid cartilages bulge slightly, and neither the tip of the mask nor the oesophagus are seen through the fibrescope.

Incidence

The reported incidence of misplacement varies considerably. This difference may depend on the method of placement and experience of the users. Brimacombe and Berry have shown that the incidence of misplacement is higher when the laryngeal mask is placed by modified methods.[22] Transient laryngospasm after placement under inadequate anaesthesia may be mistaken for misplacement.

The incidence of a suboptimal position diagnosed by fibrescopy was considered to be higher in children than in adults.[7,50,81] The epiglottis was seen within the mask in 49% of children,[7] and 56% of infants.[50] However, as described above, the mask may be in the correct position even when the posterior surface of the epiglottis is visible. If the mask is arbitrarily judged to be correctly placed when only the glottis or the glottis and the posterior surface of the epiglottis is seen through the fibrescope, the

total incidence of misplacement is 20 to 35% in children and infants as well as in adults.[7,49,50,74,82] Thus, the difference in the incidence of misplacement between adults and children may not be as great as previously thought.[80] The true incidence cannot be determined retrospectively because of the different criteria used to define the correct position of the mask.

The reported incidence of posterior deflection of the epiglottis visible on fibrescopy is 0 to 10% in adults,[16,22,82] 0 to 33% in children[7,41] and 8% in infants.[50] When x-ray or MRI was used, posterior deflection of the epiglottis was detected in 63% of adults[48] and 74% of children.[47] The fact that fibrescopy cannot detect deflection of the epiglottis that occurred above the level of the grille may explain some of these discrepancies.

Complications

Regurgitation, vomiting and pulmonary aspiration

STUDIES

One study has shown that lower oesophageal sphincter pressure decreases during anaeasthesia when the laryngeal mask is used whereas it increases when the airway is maintained with a face-mask and Guedel airway.[83] In some patients, lower oesophageal sphincter pressure decreased sufficiently to allow regurgitation of gastric contents.[83] One of the possible reasons for this is that distension of the hypopharynx by the laryngeal mask transiently decreases the lower oesophageal sphincter pressure.[83]

The upper oesophageal sphincter can prevent regurgitation of gastric contents into the pharynx; this mechanism is intact during light general anaesthesia without muscle relaxants.[84] The laryngeal mask did not alter upper oesophageal sphincter pressure during anaesthesia with 1% halothane.[85]

The studies to date on the effect of the laryngeal mask on the incidence of regurgitation show conflicting results.[86,87] Barker *et al.* gave patients a gelatin capsule containing methylene blue to swallow before induction of anaesthesia. Postoperatively, they found dye in the pharynx in 25% of patients in whom the laryngeal mask was used, but in none of the patients in whom a face-mask and Guedel airway were used.[86] However, El Mikatti *et al.*, in a similar study, did not observe any regurgitation in either of the groups.[87] The reason for this discrepancy is not clear, but placement of the mask after an inadequate dose of propofol could be an explanation.[88] The method of placement also may affect the results. The incidence of regurgitation might be higher when the tube is held during inflation of the cuff, because the tip of the mask is likely to stretch the upper oesophageal sphincter, perhaps influencing lower sphincter tone and thus leading to regurgitation (see "Misplacement"). Alternatively, it is possible that the capsule did not reach the stomach and disintegrated in the lower oesophagus.[89] The incidence of regurgitation when a face-mask and Guedel airway are used has previously been shown to be 4.5%.[90]

It would appear therefore that the laryngeal mask has no advantage over the face-mask plus Guedel airway in the prevention of regurgitation; however, several other factors must be considered before this conclusion is reached. The incidence of regurgitation could be higher when the laryngeal mask is used, but the incidence of gastric distension may be lower. The incidence of pulmonary aspiration of regurgitated gastric contents should also be considered separately, since the laryngeal mask can prevent aspiration when the gastric contents regurgitate around the mask[36] or are held back by its tip. It has been suggested that if gastric contents regurgitate within the mask, the laryneal mask may encourage them to enter into the trachea.[91]

CASE REPORTS

Regurgitation of gastric contents,[92–99] vomiting[31,32] and pulmonary aspiration[31,92,95–98] associated with the use of the laryngeal mask have been reported. There has been no report of a death directly related to its use.

In some of these reports, the patients had risk factors predisposing to regurgitation and pulmonary aspiration. These included injury,[31,92] cholecystectomy,[95,97] laparoscopy,[92] history of oesophageal dilatation[31] and a history of upper gastrointestinal surgery.[31,98] There are, however, a few reports of pulmonary aspiration in patients who were considered to be at low risk of aspiration.[96,97,99,100]

The reported incidence of clinically apparent regurgitation during the use of the laryngeal mask is up to 2%[13,41,92,101] The incidence of pulmonary aspiration during the use of the laryngeal mask is not clear. Brimacombe and Berry carried out a retrospective survey of the incidence of aspiration over a two-year period in about 100 hospitals. They received eight reports of severe aspiration for which intensive care was required. They estimated that the overall incidence is between 1:9000 and 1:250,000.[98] The incidence of aspiration pneumonitis in all surgical patients is between one and six per 10,000.[42,102–104] In a recent report, the incidence of aspiration was 1:5670 in patients "at low risk," in whom either a tracheal tube or a face-mask was used.[42] Therefore, there may be no difference in the incidence of pulmonary aspiration whether the laryngeal mask or the face-mask is used.

Brain's recommendation for treatment of regurgitation is as follows. The patient should be tilted into the Tren-

delenberg position and the breathing system temporarily disconnected from the laryngeal mask to allow regurgitated material to drain. The inspiratory oxygen concentration should be increased to 100% and the patient's lungs gently ventilated. Anaesthesia should be deepened, for example with intravenous propofol, to prevent laryngospasm and the regurgitated material removed by suction, preferably through a fibrescope.[97,105]

The incidence of pulmonary aspiration can be reduced by careful use of the laryngeal mask. Obviously, when patients are anaesthetized, it must be used only in those who are considered to be at low risk of regurgitation. Anaesthesia should be deep enough to inhibit airway reflexes during placement and surgery, since gagging and hiccoughs are frequently associated with regurgitation, vomiting and thus pulmonary aspiration.[31,42,84] Removal or attempted repositioning of the mask during light anaesthesia may also cause gagging, leading to possible pulmonary aspiration. Preoperative administration of an H_2 blocker and metaclopramide, if considered suitable, may reduce the incidence and severity of pulmonary aspiration.[9,105]

Gastric distension

Gastric distension may occur when IPPV is performed through the laryngeal mask.[33,106] This is most likely to occur when the airway pressures are increased because of inadequate anaesthesia or excessive tidal volumes. It may also occur when the mask is not correctly placed, for example when the oesophagus is seen in the aperture of the mask. Gastric distension also occurs during spontaneous breathing due to recurrent swallowing when anaesthesia is too light.[30]

Air leakage

Air leakage between the laryngeal mask and the pharynx usually occurs when the peak airway pressure exceeds 1.7 to 2.0 kPa, both in adults[34,107] and in children.[47] In some cases it occurs at 0.8 to 1.0 kPa.[47,107] In one study, an air leak occured in half of 200 children when ventilation was performed by gentle manual compression of a reservoir bag.[41] Despite an air leak, ventilation is usually effective.[47] The minimum airway pressure that produces a leak did not change with time with prototype laryngeal masks.[107]

The presence of a nasogastric tube may reduce the effectiveness of the seal between the laryngeal mask and the pharynx. Graziotti showed that when a nasogastric tube was in place, air leaked in about 50% of cases even when ventilation was controlled with airway pressure less than 2.0 kPa.[108]

Although ventilation of the lungs through a prototype laryngeal mask at a peak pressure of 6.0 kPa with counter-pressure on the thyroid cartilage has been reported,[109] the efficacy of the laryngeal mask at high airway pressures has not been formally studied. The use of the laryngeal mask is inadvisable under these circumstances since the incidence of gastric insufflation becomes higher with increasing airway pressure.[33]

TABLE II Incidence of complications

	In adults	*In children or in infants*
During placement		
- Gagging	5%[12]	2%[41]
- Coughing	6–11%[5,12,107,111]	2.5%[41] 29%[112]
- Laryngospasm	1–4%[5,34,107,110,111]	2–5%[29,41,50] 10%[112]
During removal		
- Coughing	0–4%[70,110,111]	6%[41] 29%[113]
- Laryngospasm	1–4%[34,107,110,111]	2.5%[41] 8%[113]
After anaesthesia		
- Sore throat	0–30%[22,34,60,64,70,110,114,115]	

Pharyngeal and laryngeal reflexes

Coughing, gagging and laryngospasm may occur when the depth of anaesthesia is too light during placement of the laryngeal mask, maintenance of anaesthesia or removal. The incidence of these complications during placement in adequately anaesthetized patients or during removal after patients open their mouth to command has not been well studied.

The incidence of these complications at induction is a few percent in adults,[12,34,70,107,110,111] children[41] and infants[50] (Table II). When only thiopentone is used or the depth of anaesthesia is inadequate, the incidence increases.[12,112]

If complications occur during placement of the mask, it should be removed and anaesthesia deepened. In contrast, if they occur during maintenance of anaesthesia while the mask is in place, anaesthesia should be immediately deepened and the mask left in place, because the stimulus of removal may worsen the situation.

Sore throat, hoarseness and injuries

The incidence of sore throat and hoarseness after the use of the laryngeal mask is lower than that after tracheal intubation, and similar to that after the use of the face-mask. Patients reported the severity of these complications as mild.[64,70,114–116]

Pharyngeal erythema is seen more frequently after the laryngeal mask is used than after the face-mask.[117] Injury to the uvula,[21,111] posterior pharyngeal wall[118] and large

tonsils[76] have been reported after difficult placement. These injuries are unlikely to occur when the laryngeal mask is placed gently in patients with normal oropharyngeal anatomy.[73] The incidence of acute bacteraemia is less when the laryngeal mask is used than after nasotracheal intubation.[119]

Miscellaneous problems

The laryngeal mask can be dislodged,[120] and it has been claimed that this may occur more frequently in infants.[50] The incidence can be reduced by fixing the laryngeal mask firmly to a bite-block and by avoiding traction on the tube. The size #2 laryngeal mask had a tendency to kink,[7,121,122] but the incidence of this problem was reduced after the manufacturers improved the tube.

Biting can fracture the laryngeal mask,[25] and autoclaving at excessive temperatures may weaken the tube.[123] With overuse, the cuff of the mask can dissect into the airway aperture, causing partial obstruction.[124] The presence of foreign bodies, although reported,[125] can be excluded if the device is checked as recommended before use.

Advantages

The laryngeal mask and the tracheal tube

The laryngeal mask has several advantages over the tracheal tube. Placement of the laryngeal mask is easy to learn,[126] and the success rate by unskilled personnel is 94% to 100%.[107,126,127] Muscle relaxants and laryngoscopy are not necessary, and the laryngeal mask can be placed within 30 sec from induction of anaesthesia with propofol. The time taken for placement is also usually less than that for tracheal intubation.[126,127] Inadvertent endobronchial or oesophageal intubation does not occur.

Haemodynamic and intra-ocular pressure changes are less during placement and removal of the laryngeal mask than during tracheal intubation and extubation. The laryngeal mask produces minimal stimulation if left in place until protective airway reflexes have returned. Patients tolerate the laryngeal mask at a lighter level of anaesthesia than they do the tracheal tube.[28] The incidence of coughing[41,70,110,111] and interruption of spontaneous breathing[70] are much less during removal of the laryngeal mask than during tracheal extubation. The emergence and recovery times are shorter when the laryngeal mask is used, and are similar to those in patients in whom the face-mask is used.[64]

The laryngeal mask is less likely to cause injury than a tracheal tube. The teeth are unlikely to be damaged, since the laryngeal mask can be placed without a laryngoscope. In fact, there is no report of damage to the teeth associated with the use of the laryngeal mask. Injury to the airway is uncommon, because the laryngeal mask has a soft blunt edge and should not touch the vocal cords or trachea. Recovery of ciliary function in the trachea may be more rapid. In one study, the airway was examined with indirect stroboscopic laryngoscopy. All of six patients in whom tracheal intubation was used had some damage to the airway, whereas 7 of 11 patients in whom the laryngeal mask was used had none.[128] A similar study confirmed these findings.[129] The incidence of sore throat is less when the laryngeal mask is used.[70,114–116]

The laryngeal mask and the face-mask

The laryngeal mask has several advantages over the face-mask. Skill is required to obtain an air-tight seal with a face-mask. It is, in contrast, easy to obtain an air-tight seal with the laryngeal mask when airway pressures are less than 1.7–2.0 kPa (17–20 cm H_2O). Maintaining a good seal with a face-mask is particularly difficult in edentulous patients, whereas efficacy of the laryngeal mask is not affected by the absence of teeth. Oropharyngeal airway obstruction occurs frequently when the face-mask is used. The laryngeal mask avoids this complication by bypassing the tongue, soft palate and epiglottis. Thus, once the laryngeal mask has been placed, support of the jaw and re-positioning of the mask are usually not necessary. Hypoxaemia and interruption of surgery to re-establish a clear airway are less likely to occur with the laryngeal mask than a face-mask.[46,64,117] This allows safer anaesthetic management from a distance. The relative lack of need for manipulation of the position of the patient's head and neck may be advantageous in the patient with an unstable cervical spine. Compression of the eyeball or facial nerves, which may occur with a face-mask, are avoided with the laryngeal mask. The hands of the anaesthetist often get tired when holding a face-mask.[64] This does not occur when the laryngeal mask is used, allowing more effective airway management for longer periods.

Waste anaesthetic gases can be effectively scavenged when the laryngeal mask is used; nitrous oxide concentrations in the anaesthetist's breathing zone are usually well below 25 ppm during both spontaneous and controlled ventilation.[130,131] These values are lower than those when the face-mask is used and similar to those using a tracheal tube.[130] End-tidal gas concentrations also can be monitored more easily.

Disadvantages

The laryngeal mask cannot prevent air leakage at high inflation pressure and is not designed as an oesophageal obturator. The oesophagus can be seen through a fibrescope passed through the laryngeal mask in up to 9%

of cases.[36,49,77] Air can therefore be introduced into the stomach, and gastric contents can regurgitate into the pharynx and trachea particularly when the mask is not placed correctly.

The laryngeal mask does not secure the airway as effectively as a tracheal tube. Airway obstruction in the larynx, trachea or bronchus cannot be prevented. If the laryngeal mask is not fixed properly, the mask may be dislodged more frequently than the tracheal tube. Prolonged use in awake patients, for example in intensive care units, although attractive, may not be practicable.

Placement of the laryngeal mask is easy to learn, but may fail in up to 5% of cases. Prediction of problems with placement is still difficult, and the reasons for these failures have not been fully elucidated. It may be difficult, if not impossible, to place the mask when mouth opening is restricted.

Indications

The definitive role of the laryngeal mask has yet to be established. Some suggestions for its potential uses are based merely on anecdotal reports, and there are still insufficient properly controlled studies to justify these claims. In this review, the indications and contraindications for the use of the laryngeal mask are discussed, mainly based on the results of controlled studies but some theoretical but logical consideration is inevitable. Thus the indications and contraindications should be taken as relative rather than absolute.

General indications

The laryngeal mask may be used in any patient in whom anaesthesia can be safely maintained through a face-mask. The main exception to this rule is for patients with oropharyngeal pathology. There are a number of situations where the laryngeal mask is frequently used. These include anaesthesia for operations on the extremeties, minor urological and gynaecological procedures and surface operations on the trunk. It may also be used when tracheal intubation is required only because the surgery interferes with maintenance of the airway through a face-mask.[56] A relative indication also exists when the application of a face-mask may worsen lesions on the face.[132] In addition, there are a number of other types of surgery where the laryngeal mask has been used successfully, and may even provide advantages over conventional techniques, but some controversy still exists.

Oral surgery

Anaesthesia for patients undergoing minor oral surgery is frequently associated with airway problems. During dental surgery, hypoxia occurred in 20 to 50% of cases when a nasal mask was used,[133-135] whereas the incidence was 4% using the laryngeal mask.[135] The airway can be maintained more effectively and with less effort with the laryngeal mask.[135,136] Although Bailie *et al.* reported a slightly longer surgical time when the airway was maintained with the laryngeal mask, this study was carried out with the standard rather than the reinforced laryngeal mask.[135] One of the major advantages of the laryngeal mask during oral surgery is that it prevents soiling of the larynx from material in the pharynx. Insertion of a throat pack is not necessary, because it has been shown that the cuff provides an effective seal against methylene blue or barium placed in the pharynx.[36,37] The major concerns were that the surgical field may be obscured and airway obstruction or dislodgement of the laryngeal mask may occur. However, these problems do not usually arise when the reinforced laryngeal mask is used.[46] The reinforced laryngeal mask can be fixed to the chin with little risk of kinking or dislodgement, allowing easy access to the mouth.

ADENOTONSILLECTOMY

The laryngeal mask can be used effectively in patients undergoing adenotonsillectomy. Placement of the standard laryngeal mask is sometimes difficult in patients with large tonsils.[41,76] However, placement of the reinforced laryngeal mask is usually easy, because it twists and slides between the tonsils.[46,137] Williams and Bailey compared the efficacy of the reinforced laryngeal mask and the RAE preformed tracheal tube in patients who underwent adenotonsillectomy.[46] The laryngeal mask could be placed in 50 of 52 patients. In the remaining two patients, placement failed because of very large tonsils. The Boyle-Davis gag did not usually obstruct the laryngeal mask, and a good or adequate surgical field was obtained in all patients. They pointed out that when the gag was in place the surgeon could not distinguish whether the laryngeal mask or a tracheal tube was being used.[46] The laryngeal mask prevented aspiration of blood into the larynx in all patients, and in only one patient was blood seen within the mask. In contrast, blood entered the trachea in 54% of children and 15% of adults when a tracheal tube was used.[46]

OTHER ORAL SURGERY

The laryngeal mask has been used in patients undergoing surgery in the oral cavity other than dental extraction or adenotonsillectomy. These include suture of a torn uvula,[116] removal of a cyst on the base of the tongue,[116] fixation of mandibular fractures,[138] laser pharyngoplasty[139] and repair of cleft palate.[140] The laryngeal mask should be used with caution in these patients, because pathology in the mouth or pharynx is a relative contraindication.

Eye surgery

The laryngeal mask may be useful during elective eye surgery, since changes in intra-ocular pressure are smaller with the laryngeal mask than the tracheal tube (see "Physiology"). However, the laryngeal mask may kink or become dislodged while access to the patient is restricted by surgical drapes. Subsequent tracheal intubation after the eye has been opened might result in expulsion of intra-ocular contents. The use of a reinforced laryngeal mask is therefore advisable.[137]

It is not known if tracheal intubation influences morbidity after eye surgery. The incidence of complications after cataract surgery performed under local or general anaesthesia has been compared retrospectively. It appears that the changes in intra-ocular pressure associated with tracheal intubation and extubation do not affect the clinical outcome.[141,142] There is therefore no clear-cut advantage of the laryngeal mask over the tracheal tube in terms of the clinical outcome in patients with cataracts. No report of a comparison in patients undergoing surgery for glaucoma can be obtained.

Anaesthesia "at a distance"

In patients having daily radiotherapy under general anaesthesia, the use of the laryngeal mask can avoid repeated tracheal intubation.[143] It has been used in patients in the prone position, and usually a satisfactory airway has been obtained.[143,144]

It is necessary to monitor patients from a distance during MRI scanning, because the ferromagnetic anaesthetic equipment may interfere with the quality of the image. Airway management with the face-mask is impractical, because access to the patient is limited and movement of the patient interferes with the image. The laryngeal mask is now advocated in place of tracheal intubation in anaesthesia for MRI[145] (but see "Contraindications").

The laryngeal mask may interfere with MRI, since it contains a metallic spring in the valve. The manufacturer produces special colour-coded laryngeal masks with non-metallic valves, which are available in the UK. Another problem is that the mask has a resonance that is inseparable from the tissues when ^{13}C spectroscopy is used.[146]

Laparoscopy

Whether tracheal intubation is mandatory during laparoscopy is still controversial. If a face-mask is considered appropriate, it could be replaced by the laryngeal mask.

Goodwin *et al.* used the laryngeal mask in 40 patients breathing spontaneously during elective laparoscopy. There was no clinical evidence of pulmonary aspiration observed.[147] In a prospective survey of 2359 cases,[101] none of the 242 patients undergoing laparoscopy regurgitated during surgery (Verghese C., personal communication, 1994). Swann *et al.* compared the safety of the use of the laryngeal mask and the tracheal tube in 66 patients.[115] Ventilation was controlled in the tracheal tube group, whereas in the laryngeal mask group ventilation was spontaneous or assisted. There were no important clinical differences in the conditions during surgery between the two groups, and no regurgitation was observed.[115]

The laryngeal mask must be used with caution as an alternative to the face-mask in patients undergoing laparoscopy, since the incidence of regurgitation and pulmonary aspiration may be higher when the laryngeal mask is used (see "Complications"). There is one report of pulmonary aspiration in a patient who underwent elective laparoscopic sterilization[92] in whom ventilation was controlled during anaesthesia. There was no history of gastro-oesophageal reflex or indigestion, and the patient had fasted for 12 hr.[92]

Tracheal stenosis

The laryngeal mask has been used in patients with tracheal stenosis.[56,148] Insertion of a tracheal tube increases resistance to ventilation, because it further narrows the diameter of the airway and induces reflex airway constriction.[55] Tracheal intubation can worsen the tracheal stenosis by causing oedema. The laryngeal mask does not, in contrast, enter the trachea and thus airway damage is unlikely to occur. Airway resistance is lower because the diameter of the tube of the laryngeal mask is much larger than that of the tracheal tube.[57] If the stenotic segment is in the proximal trachea, it may be difficult to position the tracheal tube proximal to the stenosis. The laryngeal mask can, however, be used irrespective of the location of the stenosis. One of the limitations of this technique is that it is not suitable in patients who require high inflation pressures. Anaesthesia can be maintained more safely if the patient is allowed to breathe spontaneously.[148]

The laryngeal mask should not be used in patients with tracheomalacia or external compression of the trachea, since it cannot prevent collapse of the trachea.[56,149]

Contraindications

Increased risk of regurgitation

PATIENTS

The laryngeal mask should not be used in anaesthetized patients at increased risk of pulmonary aspiration of gastric contents unless the airway is protected against aspiration by, for example, cricoid pressure. Patients undergoing emergency surgery, or those with gastro-

TABLE III Contraindications

Increased risk of pulmonary aspiration
- Oesophagitis
- Gastritis
- Gastric ulcer
- Duodenal ulcer
- Pyloric stenosis
- Intestinal obstruction
- Hiatus hernia
- History of reflux or gastric surgery
- Morbid obesity
- Injury
- Pain
- Opioids
- Prolonged anaesthesia
Operation that may induce regurgitation
- Upper abdominal surgery
High inflation pressure
- Low compliance of lungs or chest wall
- Intrathoracic surgery
- Surgery for a large cervical tumour
Disease of the mouth, pharynx or larynx
Difficult access to the airway

oesophageal disease, gastro-intestinal obstruction,[42] increased intracranial pressure[104] or autonomic neuropathy[9] should be regarded as being at increased risk.

Obese patients are more likely to regurgitate.[104,150] The volume of gastric contents and the incidence of hiatus hernia are higher in obese patients.[150-152] Intra-abdominal pressure would be higher, which may further increase the risk of regurgitation. Thus, the use of the laryngeal mask cannot be considered safe in morbidly obese patients. If it is used in obese patients, preoperative treatment with an H_2 blocker and metoclopramide is advisable.[105]

Injured patients should be considered to be at increased risk of pulmonary aspiration.[153,154] These patients are often shocked, anxious, have pain, and have been given opioids. All these factors may delay gastric emptying.[104,155-158] Regurgitation and pulmonary aspiration after a long period of fasting has been reported in injured patients in whom the laryngeal mask was used.[31,92]

OPERATIONS

The use of the laryngeal mask is also contraindicated during surgery that may induce regurgitation of gastric contents. Surgical manipulation in the upper abdomen is likely to stimulate the stomach, leading to regurgitation.[90,104,159] In addition, the volume of gastric contents at induction of anaesthesia is higher in patients undergoing elective upper abdominal surgery than in patients undergoing surgery at other sites.[160] Gastric acid secretion tends to increase during biliary tract surgery,[160,161] and regurgitation of bile-stained gastric fluid is frequently observed during cholecystectomy,[162] particularly when cholangiography is performed.[163] Pulmonary aspiration has been reported in patients undergoing cholecystectomy in whom the laryngeal mask was used.[95,97]

The laryngeal mask should be used with caution in patients undergoing lower abdominal surgery, since retraction on upper abdominal viscera will reduce chest compliance and increase intragastric pressure. Stimulation of the peritoneum may increase the incidence of hiccoughs, which are frequently associated with regurgitation.[42,84] The use of the laryngeal mask during laparoscopy has already been discussed (see "Indications").

Prolonged anaesthesia

It is not clear whether the incidence of regurgitation increases with the duration of surgery when the laryngeal mask is used. There are some reports of the use of the laryngeal mask for more than five hours without apparent regurgitation.[30,164]

Procedures lasting longer than two hours are associated with a higher incidence of regurgitation than surgery of shorter duration,[90] and gastric volume increases during surgery.[160] These studies included patients who underwent intra-abdominal surgery and those whose lungs were ventilated mechanically. The incidence of regurgitation in anaesthetized patients who breathe spontaneously and undergo minor surgery is not known. However, even in fasted "low-risk" patients, the volume of gastric contents is often more than traditional critical values,[165] and the incidence of regurgitation is likely to increase with the duration of anaesthesia.[102] When ventilation is controlled through the laryngeal mask, gastric distension may occur, further increasing the risk of regurgitation. A small survey in the UK showed that about 60% of anaesthetists would not use the laryngeal mask during prolonged controlled ventilation.[166]

The use of the laryngeal mask for prolonged "balanced" regional anaesthesia in spontaneously breathing patients has been suggested.[164] The authors claimed that general anaesthesia can be maintained at a relatively light plane and the possible complications of tracheal intubation can be avoided. However, this is questionable. If anaesthesia is too light, recurrent swallowing[30] or increased airway reflexes may occur leading to possible regurgitation and pulmonary aspiration. Indeed, there are reports of vomiting and pulmonary aspiration when anaesthesia was too light.[31,32,100]

It is prudent, therefore, not to use the laryngeal mask for prolonged anaesthesia until controlled studies show that this is safe. It is not possible to define how long the airway can be safely managed with the laryngeal mask, but continuous vigilance is required during its use.

High inflation pressures

Positive-pressure ventilation through the laryngeal mask is contraindicated in patients in whom high pulmonary inflation pressures are required, because of inadequate ventilation due to air leakage and the risk of regurgitation secondary to gastric distension. The laryngeal mask is not suitable in patients with very low lung compliance or increased airway resistance. Patients with a mechanical obstruction to the larynx or trachea, such as tracheomalacia or external compression of the trachea, should not be managed with the laryngeal mask, since it cannot reliably prevent collapse of the airway.[56] There are reports in which the laryngeal mask was used successfully in infants with laryngomalacia[167] and with tracheobronchomalacia,[168] but it should not be considered the first choice of airway management.

The laryngeal mask is inappropriate for intrathoracic surgery. Expansion of collapsed portions of the lungs will be difficult without air leakage or gastric insufflation.[34] In addition, problems such as bleeding or occlusion of the airway with secretions are likely to occur.

The use of the laryngeal mask has been suggested for patients undergoing thyroid surgery because it allows observation of vocal cord movement with a fibrescope.[169,170] However, because surgical manipulation is likely to induce laryngospasm or obstruct the airway,[171] it cannot be recommended for routine use. The laryngeal mask cannot always prevent tracheal collapse which may occur during induction of anaesthesia or after surgery.[171,172] The use of the laryngeal mask should be limited to patients with small tumours.

Laryngospasm that occurred after tracheal extubation was relieved by placement of the laryngeal mask in a patient in whom tracheal intubation had been difficult and a tight fitting seal could not be obtained with a face-mask.[173] Great care should be taken in these circumstances, since gastric distension is more likely to occur in patients requiring high airway pressures. In addition, placement of the laryngeal mask in a semi-conscious patient may worsen laryngospasm if it is misplaced. Definitive treatment, in the form of percutaneous transtracheal ventilation, should be prepared without delay.[174]

Pathology of the mouth, pharynx or larynx

The laryngeal mask is unsuitable for patients with lesions of the oropharynx or epiglottis.[175] The standard laryngeal mask is not suitable for patients with large tonsils because it may damage the tissues.[41,46,76]

Restricted access to the airway

Some anaesthetists suggest that the laryngeal mask should not be used when access to the patient's head is restricted, because airway management may become impossible if the mask is dislodged or kinked, or if regurgitation or vomiting occur during surgery. The incidence of regurgitation is higher in the prone than the supine or lateral positions.[90,159] Pulmonary aspiration may be less likely in the prone position, but it is difficult to manage when it occurs.

The decision to use the laryngeal mask in this group of patients should be balanced against possible complications. For example, its use may be acceptable in patients undergoing eye surgery or repeated radiotherapy, but not in patients undergoing laminectomy in the prone position. A guideline would be not to use the laryngeal mask if there is no guarantee that it can be replaced if it becomes dislodged. It is prudent to maintain spontaneous ventilation and use the reinforced laryngeal mask when access to the patient's airway is difficult.

Difficult tracheal intubation

In some situations, the use of the laryngeal mask may be unsuitable in patients whose tracheas are known to be difficult to intubate (see "Difficult airways").

Cricoid pressure

Effect on placement of the laryngeal mask

Elective use of the laryngeal mask in anaesthetized patients at increased risk of aspiration of gastric contents is contraindicated. However, it has been successfully used to obtain ventilation in patients in whom both tracheal intubation and ventilation through the face-mask had failed.[176,177] Application of cricoid pressure is mandatory if the laryngeal mask is used in this situation, because the mask cannot prevent pulmonary aspiration.

Cricoid pressure applied *before* placement of the laryngeal mask prevents the distal part of the mask from occupying its proper position, because the hypopharynx is compressed as well as the oesophagus. However, it is controversial whether adequate ventilation can be obtained. Heath and Allagain stated that in 50 patients, they did not experience any difficulty in placing the laryngeal mask while cricoid pressure was maintained.[178] Brimacombe observed that the view of the laryngeal inlet through a fibrescope passed through the laryngeal mask was not affected by cricoid pressure.[49] In a subsequent study, he found that cricoid pressure only slightly affected the ease of placement.[179] Ansermino and Blogg, however, showed that successful placement (as judged by clinical criteria) was prevented by cricoid pressure; the success rate decreased from 86% to 15%.[180] Asai *et al.* also showed that when cricoid pressure was applied before placement, the success rate of clinically acceptable ventilation through the laryngeal mask decreased from 95% to 50%. Ventilation through the face-mask was possible

in those patients in whom placement of the laryngeal mask had failed. Fibrescopy showed that the frequency of proper positioning of the laryngeal mask was also decreased, usually because it was not inserted far enough.[82]

The reasons for the discrepancies among these studies are unclear, but it may be because of differences in the technique of application of cricoid pressure. There is a wide variation in the force used by different operators and in some instances the pressure is inadequate.[181] The laryngeal mask might be placed correctly if the pressure is inadequate. In none of the studies was the force of cricoid pressure measured. However, it is reasonable to conclude that the laryngeal mask does not always provide satisfactory ventilation when cricoid pressure is applied before placement. There may also be a greater risk of dislodgement of the mask because the tip is not positioned correctly. Thus, cricoid pressure should be temporarily released during placement to obtain a higher success rate, although this temporary release is associated with an increased risk of pulmonary aspiration.

Cricoid pressure applied *after* placement of the laryngeal mask is effective. Strang has shown in cadavers that cricoid pressure applied after placement of the laryngeal mask effectively prevents regurgitation of dilute barium in the oesophagus at a pressure of 7.8 kPa.[182] Cricoid pressure applied *after* placement does not usually dislodge the mask.[183]

Effect on tracheal intubation through the laryngeal mask

The trachea can be intubated by passing a tracheal tube through the laryngeal mask (see "Other applications"). If the mask is placed while cricoid pressure is applied, the success rate of subsequent tracheal intubation through the laryngeal mask is low. Heath and Allagain could intubate the trachea blindly through the laryngeal mask in 42% of patients at the first attempt when cricoid pressure was applied; when the time was not limited the success rate increased to 56% (the success rates without cricoid pressure were 72% and 96%, respectively).[184] Asai *et al.* used a fibrescope, but the success rate at the first attempt was only 15%. Moreover, even when cricoid pressure was released after placement of the mask, tracheal intubation was still difficult.[82] These results support the view that cricoid pressure should be temporarily released during placement when tracheal intubation through the laryngeal mask is planned.

The effect of application of cricoid pressure *after* placement of the laryngeal mask on the success rate of tracheal intubation has not been studied formally, but Asai states that tracheal intubation did not become difficult.[183]

Difficult airways

The laryngeal mask has enabled ventilation in patients whose tracheas were known to be difficult to intubate. The reported reasons for difficulty in tracheal intubation include a previous history of difficult intubation,[185-187] limited mouth opening,[116,188-190] and restricted neck movements[34,191,192] in adults, and Pierre-Robin syndrome,[140,193-195] Treacher-Collins syndrome,[196,197] Apert syndrome,[41] juvenile chronic arthritis[198] and cleft palate[41] in neonates and children. The laryngeal mask also permitted ventilation in patients in whom tracheal intubation had failed,[109,138,199-201] and in whom both ventilation through the face-mask and tracheal intubation had failed.[176,185,193,202] Removal of the laryngeal mask is associated with fewer airway complications than tracheal extubation.[65,70] Based on these clinical reports, some anaesthetists suggest the elective use of the laryngeal mask in patients known to be difficult to intubate[203,204] or advocate the introduction of the laryngeal mask as part of a failed tracheal intubation drill.[205-207]

These reports of successful use of the laryngeal mask after failed tracheal intubation support a potential role for the laryngeal mask in patients with difficult airways, but careful consideration is necessary. For instance, in some reports there was no necessity to use the laryngeal mask.[200,206] Although the laryngeal mask has successfully enabled ventilation in patients in whom tracheal intubation had failed, it should not be regarded as a substitute for a tracheal tube. Tracheal intubation would have been preferable to the laryngeal mask in those cases. Thus, while there may be a potential role for the laryngeal mask after failed tracheal intubation, these reports do not always justify its elective use in paralyzed patients known to be difficult to intubate.[208]

There are three occasions when the laryngeal mask may be useful: elective use, "cannot intubate, but can ventilate" and "cannot intubate, cannot ventilate." These are considered in turn. Although the incidence of difficult or failed tracheal intubation is relatively high in obstetric patients, the initial management of the airway in this situation does not differ from that in non-obstetric patients at increased risk of regurgitation. Thus, the use of the laryngeal mask in obstetric anaesthesia is not considered separately.

Elective use

When the laryngeal mask is used in patients whose tracheas are known to be difficult to intubate, they should not be paralyzed. The placement may fail in up to 6% of patients whose tracheas are predicted to be easy to intubate. The failure rate is likely to be higher in patients with difficult airways, particularly when the patient's neck movement or mouth opening is limited. There are several reports of failure of ventilation through the laryngeal mask in patients with difficult airways.[41,192,209-211] If place-

ment fails, ventilation through a face-mask is required, which is also not always successful. In addition, the laryngeal mask may not always be replaced if it becomes dislodged: muscle relaxation decreases the pharyngeal integrity,[212] which may make placement difficult.

The laryngeal mask may be used in patients breathing spontaneously in whom the use of the face-mask is considered suitable. Once the laryngeal mask is successfully placed, maintenance of airway patency may be easier than with the face-mask. However, there is a danger of the "cannot intubate, cannot ventilate" scenario if the laryngeal mask induces laryngo- or bronchospasm.

The laryngeal mask can be used more safely if the patient remains awake.[186] There is little danger even if placement fails or ventilation through the laryngeal mask becomes inadequate, because it can be promptly removed. After successful placement, anaesthesia can be induced and spontaneous ventilation maintained. Awake tracheal intubation through the laryngeal mask can also be performed[183] (see "Other applications").

Failed tracheal intubation, face-mask ventilation adequate

In principle, there is no need to place the laryngeal mask in patients in whom tracheal intubation has failed, but ventilation through a face-mask is adequate. As described above, placement in this group of patients may sometimes be difficult and may compromise the situation. In patients at increased risk of pulmonary aspiration, in particular, adequate ventilation may not be obtained through the laryngeal mask when cricoid pressure is applied before placement, even if the face-mask was effective.[82] In addition, there may be a greater risk of dislodgement of the laryngeal mask, because the distal part of the mask cannot be positioned correctly due to cricoid pressure. Furthermore, the incidence of regurgitation may be higher when the laryngeal mask is used compared with a face-mask and Guedel airway (see "Complications"). These problems are more likely to occur when the depth of anaesthesia and muscle relaxation have become inadequate, for example after rapid-sequence induction of anaesthesia.

The laryngeal mask might be placed for the purpose of subsequent tracheal intubation through it, but the success rate in this scenario is unknown. The same risks are present in patients in whom tracheal intubation has failed, but spontaneous breathing has resumed. Therefore, the decision to use the laryngeal mask when adequate ventilation is obtained with a face-mask after failed tracheal intubation should be made with caution. If tracheal intubation fails in paralyzed patients who are at low risk of regurgitation, the laryngeal mask may be tried, whereas it is prudent not to attempt to place the laryngeal mask in patients at increased risk of pulmonary aspiration.

Failed tracheal intubation and failed face-mask ventilation

The laryngeal mask may be tried when both tracheal intubation and ventilation through the face-mask have failed. This decision should be made at an early stage because placement may fail. A percutaneous transtracheal airway should be prepared during attempts at placement of the laryngeal mask in case ventilation through the laryngeal mask is inadequate and hypoxaemia persists. Cricoid pressure should be released during placement of the laryngeal mask in patients at increased risk of pulmonary aspiration, but it must be reapplied until the trachea is intubated or until airway reflexes return. Recovery of spontaneous breathing does not guarantee return of airway reflexes.[31]

When the laryngeal mask provides a patent airway and the patient is well oxygenated, a decision should be made whether to wake up the patient, perform a tracheostomy or continue the anaesthetic and planned surgery using the laryngeal mask to maintain the airway. Each situation will require an assessment of the possible risks, and an appropriate decision made for the individual patient.

Other applications

Fibreoptic bronchoscopy

The laryngeal mask has been used to aid diagnostic fibreoptic bronchoscopy in adults,[169,213-215] children[216] and infants.[217]

The laryngeal mask allows easy location of the laryngeal inlet whilst maintaining oxygenation. There is no difference in the time taken to locate the laryngeal inlet with a fibrescope passed either through the laryngeal mask or through the Williams Airway Intubator.[218] The laryngeal mask may be as effective as the combination of an airway intubator and Patil's face-mask,[219] through which a fibrescope can be passed.

In some patients, tracheal intubation is required. The laryngeal mask has several advantages over a tracheal tube.[217] The movement of the vocal cords can be observed since muscle relaxation is not required, and subglottic lesions are easy to examine. A fibrescope of large diameter with suction and biopsy channels can be used. The larger diameter of the laryngeal mask offers less resistance than a tracheal tube and allows more effective oxygenation and ventilation during bronchoscopy. The movements of the vocal cords can be observed after surgery to the neck, such as thyroidectomy.[220]

Removal of a foreign body from a bronchus in a fasted

child has been reported.[221] This was possible because the laryngeal mask allowed the use of a larger fibrescope through which biopsy forceps would pass.[221]

Laser resection of a tracheobronchial tumour with this technique has been suggested.[222] This application, however, is questionable, since compared with the rigid bronchoscope, the view through the fibrescope is less satisfactory and bleeding or airway collapse will be difficult to treat.[223]

Placement in awake patients

The laryngeal mask can be placed in awake or sedated patients for tracheal intubation, diagnostic fibreoptic bronchoscopy or removal of tracheo-bronchial secretions.[183,186,224-228] It has also been used to provide ventilation during induction of anaesthesia in infants with Pierre-Robin syndrome, in whom ventilation through the face-mask was anticipated to be difficult.[195]

The stimuli of placement or presence of the laryngeal mask are usually tolerable in sedated patients, but there is no comprehensive study on the incidence of complications. The incidence was studied in patients who received topical anaesthesia to the upper airway without sedation. The mask was placed with its cuff partially inflated and the patient was asked to swallow during insertion. Gagging and coughing occurred in 16% and 12% of the patients. These complications were overcome by sedation with midazolam and fentanyl.[227] It is possible that when the patient receives topical anaesthesia and sedatives, and the mask is placed with the standard technique (i.e., with the cuff fully deflated), the incidence of these complications may be lower. Brain states that in fully awake or lightly sedated patients, the incidence of gagging might be lower when patients swallow during placement (*Brain A.I.J.*: Personal communication, 1993). The success rate of placement and incidence of complications in awake children are unknown.

Tracheal intubation through the laryngeal mask

TECHNIQUES

The trachea can be intubated by passing a tube through the laryngeal mask. Several techniques using the laryngeal mask for tracheal intubation have been reported[186,188,192,229] since the first description by Brain.[109] This technique has been successfully used in patients known to be difficult to intubate[187,192] or in whom tracheal intubation both with a laryngoscope and a fibreoptic bronchoscope had failed.[199,228]

Heath and Allagain could intubate the trachea blindly through the laryngeal mask, when cricoid pressure was not applied, in 72% of patients at the first attempt, and in 96% of 25 patients when time was not limited.[184] Similar results are reported in children.[230] However, this technique requires practice; the patient's neck should be flexed and head extended, and the tracheal tube inserted with about 15 to 90 degrees anti-clockwise rotation.[231,232] They only studied patients in whom tracheal intubation was anticipated to be easy. The success rate of blind intubation through the laryngeal mask may be lower in patients in whom tracheal intubation is difficult, particularly in patients whose neck movements are restricted.

A gum elastic bougie can be used to aid tracheal intubation.[188] A high success rate was obtained in patients in whom difficult intubation was not anticipated[233] by inserting the bougie with its angulated end pointing anteriorly until it passed through the grille of the mask and then rotating through 180 degrees. This technique was also used successfully in an awake patient with a past history of a difficult intubation,[186] but failures have also been reported.[193,234,235]

A lighted stylet, in theory, may be used instead of a gum elastic bougie, although there are no reports of this technique being used with the laryngeal mask. The transillumination of the tissues of the neck is a reliable sign that the stylet is in the trachea rather than the oesophagus.[236] The lighted stylet must be flexible enough to bend as it passes through the laryngeal mask.

Fibrescope-aided tracheal intubation through the laryngeal mask is the most reliable of these techniques, because the bronchoscope can be inserted into the trachea under direct vision. Using this technique, Silk *et al.* intubated the tracheas in 46 of 48 patients with difficult airways.[192]

AWAKE TRACHEAL INTUBATION

The laryngeal mask can be used to aid tracheal intubation in awake patients. There is little risk even if placement of the mask is difficult or impossible. This technique was successful in a patient in whom tracheal intubation with a laryngoscope was previously difficult[186] and in patients in whom conventional fiberscope-aided tracheal intuba-

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geal inlet is usually positioned just below the grille of the mask and the distance between the grille and the vocal cords is only a few centimetres,[16] location of the laryngeal inlet with a fibreoptic bronchoscope is easier. With the conventional method, it is difficult to advance the tracheal tube over the bronchoscope in 80 to 90% of cases, because it impacts upon the epiglottis, right arytenoid or hypopharynx,[237,238] despite successful insertion of the fibrescope into the trachea. In contrast, tracheal intubation through the laryngeal mask over the fibrescope is easy, since the tongue, soft palate and epiglottis are bypassed, and lateral or posterior deviation of the tracheal tube from the laryngeal inlet is restricted by the laryngeal mask. Asai *et al.* have confirmed, in patients whose tracheas were predicted to be easy to intubate, that insertion of a fibrescope through the laryngeal mask into the trachea and advance of the tracheal tube over a fibrescope were easy. Once the fibrescope had been inserted into the trachea, tracheal intubation was easy even when the larynx was deviated from the midline.[82]

The main disadvantage of this technique is that a 6.0 mm ID tracheal tube is the largest that can be passed through the size 3 or 4 laryngeal mask (a 7.5 mm tracheal tube can be passed through the size 5 mask). A larger sized tracheal tube can be used if the mask is removed after an introducer has been inserted into the trachea[186,228,229,239] A modified laryngeal mask with a slit on the side of the tube has been proposed for tracheal intubation.[240] This modified device can be removed after insertion of a fibrescope and allows a larger tracheal tube to be passed over the fibrescope.[240] The disadvantage of these methods is that although the introducer can be easily inserted into the trachea, passage of a tube over the introducer into the trachea may be difficult.[237,238] A modified laryngeal mask that accommodates an 8 mm tracheal tube is under development (*Brain A.I.J.*: Personal communication, 1993).

When a standard, uncut 6.0 mm tracheal tube (length: 28.5 cm) is passed through the laryngeal mask into the trachea, the cuff of the tracheal tube often lies between the vocal cords. This could lead to injury to the vocal cords or incomplete protection against pulmonary aspiration.[16] There are three ways of avoiding this problem. First, the laryngeal mask can be removed after tracheal intubation whilst gently pressing the proximal end of the tracheal tube with the tip of another tracheal tube to prevent the tube being withdrawn with the laryngeal mask.[241] Second, a longer tracheal tube, such as the Malinckrodt reinforced tube (31 cm long) can be used.[242,243] Finally the ST-laryngeal mask, which has a tube that is 2 cm shorter than a conventional one, allows the tracheal tube to be advanced further.[16] The tube of the laryngeal mask could be cut short, but the manufacturer does not recommend this practice.

NASOTRACHEAL INTUBATION

An elaborate technique has been described in which the laryngeal mask was used to aid nasotracheal intubation in a patient with a difficult airway.[244] This technique may be of interest in situations where a fiberscope is not available.

Tracheostomy

The laryngeal mask might be used during surgical or percutaneous tracheostomy. There are several reports of its use during emergency tracheostomy after failed tracheal intubation and ventilation through a face-mask.[193,202,245] Its use in this situation can be justified because it might be the only means of providing oxygenation whilst the tracheostomy is being performed.

The device may be used during elective tracheostomy in some patients because the laryngeal mask can maintain a patent airway more easily than a face-mask. Caution is necessary if the tracheostomy is being performed because of pathology of the mouth, pharynx or larynx. It is inappropriate to use the laryngeal mask if the patient is at increased risk of pulmonary aspiration of gastric contents, requires high pulmonary inflation pressures or has a collapsible airway.

The correct insertion of a needle into the lumen of the trachea during percutaneous tracheostomy can be easily confirmed using a fibreoptic bronchoscope passed through the laryngeal mask.[246]

Emergency medicine

CARDIOPULMONARY RESUSCITATION

Effective airway management is one of the most important aspects of cardiopulmonary resuscitation (CPR). Tracheal intubation is the most reliable method of securing the airway, but it is not easy to master and practice is required to maintain competence.[126,247] Thus, until the person competent in tracheal intubation arrives, the airway is usually managed by other methods.

The face-mask and self-inflating bag are commonly used, but effective ventilation is sometimes difficult.[248,249] The Esophageal Obturator Airway (EOA) has been widely used during CPR, but ventilation is impossible when the EOA is inadvertantly inserted into the trachea. Ventilation sometimes fails because of difficulty in correct insertion and in securing a proper mask fit.[250] Oesophageal, gastric or tracheal rupture can occur. The Esophageal Tracheal Combitube (ETC) is also recommended during CPR.[4] It is a plastic twin-lumen tube, one lumen resembling an Esophageal Obturator Airway, the other a tracheal tube. It can be inserted blindly, and head and

neck movements are not required. Ventilation is possible if the ETC is inserted either into the oesphagus or into the trachea. The device, however, also has several disadvantages. The ETC cannot be used in patients with an intact gag reflex, in patients <16 yr or <1.5 m tall.[251] It is sometimes difficult to determine whether the tube is in the trachea or oesophagus[252] and if ventilation is performed through the wrong lumen and the patient does not breathe spontaneously, hypoxia and gastric distension occur. The Pharyngo-Tracheal Lumen Airway[3] shares similar problems.[253]

There is a high risk of gastic insufflation and pulmonary aspiration during CPR.[254-256] Nagel *et al.* report that the incidence of pulmonary aspiration among survivors and non-survivors of CPR was 8.9%.[254] Lawes and Baskett report that the incidence of pulmonary aspiration of blood or solids was 29% in patients who did not respond to CPR.[256]

The laryngeal mask has been proposed as the initial method of airway control because it is relatively easy to master the technique of placement, the success rate is high, and airway management is easier than the bag-mask method once the laryngeal mask is successfully placed. Several investigators have compared the effectiveness of ventilation through the laryngeal mask with the combination of face-mask, Guedel airway, and self-inflating bag when used by unskilled personnel. Davies *et al.* studied medical trainees' ability to place the laryngeal mask and intubate the trachea. The success rates of placement of the laryngeal mask and tracheal intubation were 94% and 51%, respectively. Placement of the laryngeal mask was also quicker (20 sec) than tracheal intubation (35 sec).[126] Martin *et al.* showed that nurses obtained a significantly higher tidal volume through the laryngeal mask than through the face-mask, Guedel airway, and self-inflating bag.[257] Alexander *et al.* compared the success rate of adequate ventilation through the laryngeal mask or the face-mask when performed by nurses or medical students. Adequate ventilation (no increase in end-tidal carbon dioxide and arterial oxygen saturation remaining greater than 90% after two minutes of ventilation) was obtained in 87% of patients when the laryngeal mask was used, compared with 43% of patients with the face-mask. Time to placement of either LM or the Guedel airway was similar.[258]

Tolley *et al.*, however, showed that the success rate of adequate ventilation (tidal volumes exceeding 800 ml within 40 sec) achieved by junior doctors was lower with the laryngeal mask than with the face-mask. The time to first successful ventilation was also longer with the laryngeal mask.[259]

It appears that although adequate ventilation may not be obtained for the first minute when the laryngeal mask is chosen, once it is in place, ventilation is more effective through the laryngeal mask than the face-mask. The major problem is that placement of the laryngeal mask fails in up to 6% of patients, and that repeated attempts may prolong hypoxaemia. There are also concerns that use of the laryngeal mask during CPR does not prevent regurgitation and pulmonary aspiration, and that the mask may be dislodged during external chest compression.[247]

A multi-centre study was performed to study the efficacy of the laryngeal mask during CPR at in-hospital arrests until tracheal intubation was performed.[260] In this study, almost all laryngeal masks were placed by nurses who had attended a training programme. The laryngeal mask was successfully placed in 160 of 164 patients within two attempts about three minutes from the arrest call. They experienced regurgitation in 34 patients. Twenty patients regurgitated before placement of the mask and ten after its removal. Regurgitation was observed in three patients while the laryngeal mask was in place although a self-inflating bag had been used in all these patients before placement of the laryngeal mask. In no case did the mask become dislodged during CPR (*McBeth C*: Personal communication, 1994). Therefore, the laryngeal mask may be successfully used as an initial method of airway control until the person competent in tracheal intubation is available. Paramedic ambulance staff in Japan, who are not trained in tracheal intubation, have been allowed to use the laryngeal mask during CPR since 1991. The mask may be useful during resuscitation of neonates.[261]

Application of cricoid pressure during CPR has been advocated because of the frequent occurrence of gastric insufflation and regurgitation.[262] When the laryngeal mask is in place, this requires only two people whereas effective bag-mask ventilation with cricoid pressure may need three. Cricoid pressure is effective in preventing regurgitation while the mask is in place.[182]

PRE-HOSPITAL USE OF THE LARYNGEAL MASK

The laryngeal mask has been used in patients in whom access for tracheal intubation or application of a face-mask was difficult. A clear airway was obtained in two patients who were trapped in crashed cars, and in whom tracheal intubation or ventilation through a face-mask had failed.[263]

The use of the laryngeal mask has been suggested in a patient with a cervical spine injury who was hypoxaemic after tracheal intubation had failed.[264] The laryngeal mask may cause less damage to the unstable spine than a face-mask, because it can be inserted and the airway maintained without moving the head and neck.[74,75]

The laryngeal mask has been used in semi-conscious patients with acute cerebrovascular disease because the pressor effect is less than that of tracheal intubation.[265] There is, however, an increased risk of pulmonary aspiration and rejection of the mask by the patient. In the report, no regurgitation was observed, but one of the six patients rejected the laryngeal mask.[265]

Conclusion

The efficacy of the laryngeal mask is well supported by its widespread use. However, it can be gleaned from the numerous publications that many anaesthetists overestimate the device and occasionally misuse it. At the same time, others have become sceptical as a result of reading reports of complications or from using the device inappropriately themselves. Many of the reported complications associated with the laryngeal mask could have been prevented if it had been used correctly. The conflicting results among the studies may also have resulted from suboptimal use of the device. The fact that the laryngeal mask can be placed easily and provides clinically acceptable ventilation in the majority of patients may make anaesthetists reluctant to make efforts to master the correct techniques. All anaesthetists receive formal training in the art of tracheal intubation, and the same should be true for the use of the laryngeal mask. The true features and role of the laryngeal mask will be established only through studies in which the device is used correctly.

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