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Pharyngeal Mucosal Pressures, Airway Sealing Pressures, and Fiberoptic Position with the Intubating versus *the Standard Laryngeal Mask Airway*

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Background: **The tube of the intubating laryngeal mask (ILM) is more rigid than the standard laryngeal mask airway (LMA), and the authors have tested the hypothesis that pharyngeal mucosal pressures, airway sealing pressures, and fiberoptic position are different when the two devices are compared.**

Methods: **Twenty anesthetized, paralyzed adults were randomly allocated to receive either the LMA or ILM for airway management. Microchip sensors were attached to the size 5 LMA or ILM at locations corresponding to the pyriform fossa, hypopharynx, base of tongue, posterior pharynx, and distal and proximal oropharynx. Mucosal pressures, airway sealing pressures, and fiberoptic positioning were recorded during inflation of the cuff from 0 to 40 ml in 10-ml increments.**

Results: **Airway sealing pressures were higher for the ILM (30 *vs.* 23 cm H_2O), but epiglottic downfolding was more common (56% *vs.* 26%). Pharyngeal mucosal pressures were much higher for the ILM at five of six locations. Mean mucosal pressures in the distal oropharynx for the ILM were always greater than 157 cm H_2O, regardless of cuff volume. There was no correlation between mucosal pressures and airway sealing pressures at any location for the LMA, but there was a correlation at three of six locations for the ILM.**

Conclusions: **The ILM provides a more effective seal than the LMA, but pharyngeal mucosal pressures are higher and always exceed capillary perfusion pressure. The ILM is unsuitable for use as a routine airway and should be removed after its use as an airway intubator. (Key words: Cervical spine pathology; intubating laryngeal mask; pharyngeal morbidity.)**

THE intubating laryngeal mask (ILM) is a new airway device designed to have better intubation characteristics than the standard laryngeal mask airway (LMA).[1] Published data about the ILM are limited,[2–7] but they suggest that ILM is an effective ventilatory device and airway intubator. The primary role of the ILM is as an airway intubator, but it has a potential role as an alternative to the LMA in routine practice because placement is conceptually easier and does not require insertion of the fingers in the patient's mouth. In addition, it has been suggested that the ILM can be left *in situ* after its successful use as an airway intubator (provided the cuff is fully deflated) and that it may be useful in patients with cervical spine pathology because placement does not require head and neck manipulation. Although the cuff portion of the ILM is identical to the LMA, the airway tubes are different: the ILM has a rigid, silicone-coated stainless steel airway tube; the LMA has a soft, silicone airway tube. As a result, the insertion technique is different (single-handed rotational technique for ILM; digital manipulation for the LMA), the ILM is heavier, and the fixed length of the ILM tube means that the cuff tip may not necessarily sit in the correct position. We hypothesized that these differences would lead to higher mucosal pressures, inferior fiberoptic positioning, and a less effective seal for the ILM compared with the LMA. To test these hypotheses, we compared pharyngeal mucosal pressures, airway sealing pressures, and fiberoptic position between the two devices.

Methods

Twenty American Society of Anesthesiologists physical status I or II adults were randomly allocated to receive

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either the LMA or ILM for airway management. Ethical committee approval and informed consent were obtained. Patients were excluded from the trial if they were aged less than 18 yr, had respiratory tract pathology, required surgery in the non-supine or non-lithotomy positions, were at risk of aspiration, or were considered otherwise unsuitable for the LMA or ILM. Pharyngeal mucosal pressures were measured using seven strain gauge silicone microchip sensors (Codman MicroSensor, Codman, Johnson and Johnson Medical Ltd, Bracknell, UK) attached to the external surface of the LMA with clear adhesive dressing that was 45 μm thick (Tegaderm, 3M, Ontario, Canada). The sensors had a tip diameter of 1.2 mm, a functional pressure range of -50 to 250 mmHg, a temperature sensitivity of less than 0.1 mmHg/°C, a zero drift of $<$ 3 mmHg/24 h, a frequency response of 0–10 Hz, and were accurate to $\pm$ 2%. Attachment of the sensors and sensor cables was performed manually by placing the sensor tip in the correct position on the LMA/ILM and then overlaying it with the adhesive dressing. Care was taken to ensure that the microchip was orientated away from the surface of the LMA/ILM and that the sensor cables did not overlay the sensors. The sensors were attached to the following locations on the LMA/ILM (corresponding mucosal areas): (1) anterior middle part of the cuff side (pyriform fossa); (2) the posterior tip of cuff (hypopharynx); (3) anterior base of cuff (base of tongue); (4) the backplate (posterior pharynx); (5) posterior tube 1 (distal oropharynx); (6) posterior tube 2 (proximal oropharynx); and (7) posterior base of cuff or proximal tube junction (non-mucosal) (figs. 1 and 2). All sensors were zeroed in water that was 0.25 cm deep at 37°C before insertion.

A standard anesthesia protocol was followed, and routine monitoring was applied. Patients were induced with propofol, 2.5 mg/kg, and anesthesia was maintained with 100% oxygen and sevoflurane, 1% or 2%. Muscle relaxation was induced with atracurium, 0.5 mg/kg. A single experienced LMA and ILM user inserted or fixed the LMA or ILM according to the manufacturer's instructions.[8,9] A size 5 LMA or ILM was used for all patients.[10] The pilot balloon was attached *via* a three-way tap to a 10-ml syringe and a calibrated pressure transducer. The intracuff pressure was reduced to -55 cm H_2O *in vitro*. Pharyngeal mucosal pressures, intracuff pressures, airway sealing pressures, and fiberoptic position were documented at zero volume and after each additional 10 ml up to 40 ml (maximum recommended cuff volume). The fiberoptic position of the LMA was determined using the following scoring system: 4, only vocal cords visible; 3, vocal cords plus posterior epiglottis visible; 2, vocal cords plus anterior epiglottis visible; 1, vocal cords not seen.[11] Any displacement of the cuff from the periglottic tissues was also noted. Measurements were made with the head and neck in the neutral position. The airway sealing pressure was measured by closing the expiratory valve of the circle system at a fixed gas flow of 3 l/min and by noting the airway pressure at which the dial on the aneroid manometer reached equilibrium.[12] The position of the anterior tip sensor was verified at the end of the procedure by observation of a pressure spike during the application of gentle cricoid pressure. The position and orientation of the sensors were checked by visual inspection after removal. The accuracy of the probes was tested before and after use in each patient by submerging the cuff portion in water at 37°C to a depth of 13.6 cm (10 mmHg) and 40.8 cm (30 mmHg) and noting the pressure readings.

Sample size was selected to detect a projected difference of 25% between the groups with respect to pharyngeal mucosal pressure for a type I error of 0.05 and a power of 0.9. The power analysis was based on data from a pilot study of six patients in whom pharyngeal mucosal pressures, airway sealing pressures, and fiberoptic scores were measured with the ILM and LMA. The distribution of data was determined using Kolmogorov-Smirnov analysis. Statistical analysis of airway sealing and mucosal pressures was done with paired t test (normally distributed data) and Friedman two-way analysis of variance (non-normally distributed data). Chi-square test was used to compare fiberoptic scores. The relationship between mucosal pressure and airway sealing pressure was determined using Pearson product-moment correlation coefficient. Unless otherwise stated data are presented as mean (95% confidence intervals). Significance was taken as $P < 0.05$.

Results

There were no demographic differences between groups (table 1). All LMA and ILMs were inserted at the first attempt and were positioned correctly as judged by fiberoptic laryngoscopy and the cricoid pressure spike. The position and orientation of the sensors were identical, and the pressures were accurate before and after usage. There was no displacement of the cuff from the periglottic tissues. Airway sealing pressures were higher with the ILM, but fiberoptic scores were lower (table 1). Pharyngeal mucosal pressures were higher for the ILM compared with the LMA at five of six mucosal locations,

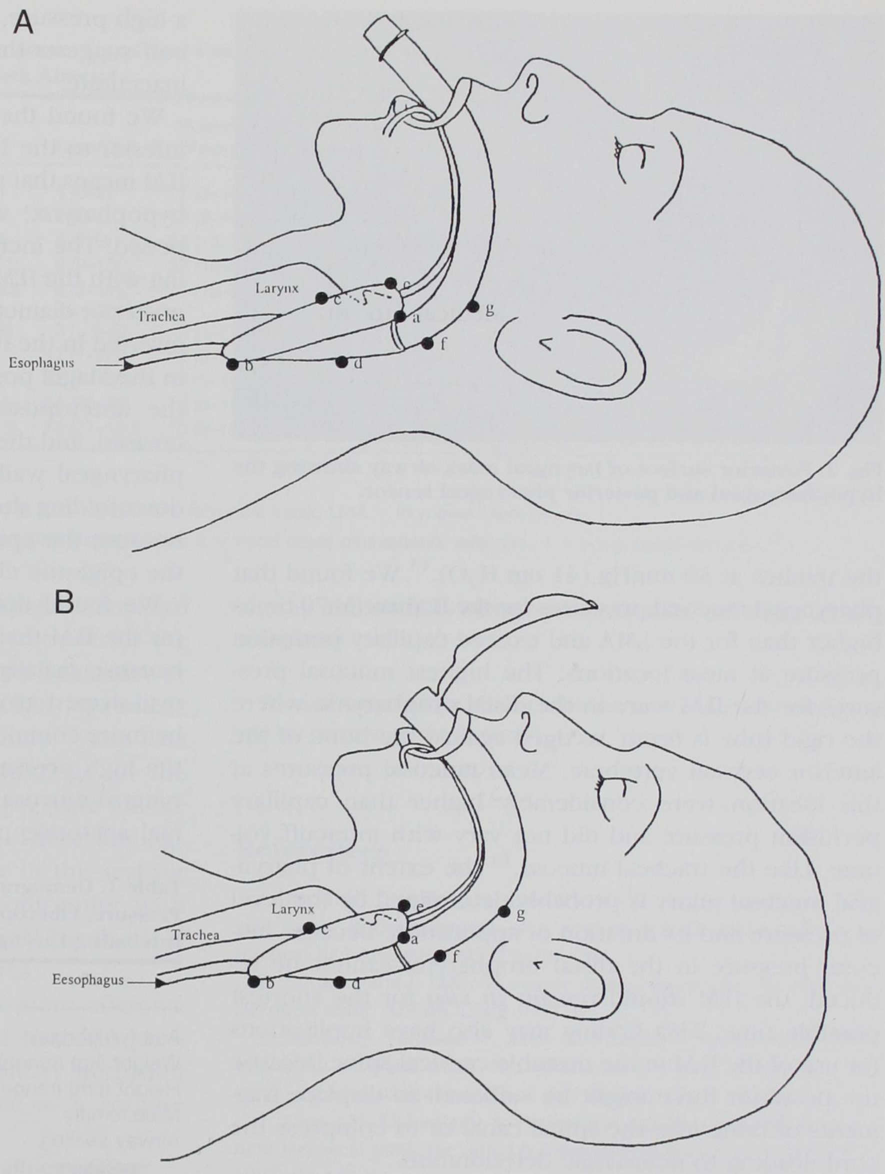

Fig. 1. (*A*) Location of sensors on laryngeal mask airway (corresponding area): (a) tube–cuff junction; (b) the posterior tip of cuff (hypopharynx); (c) anterior middle part of the cuff side (pyriform fossa); (d) the backplate (posterior pharynx); (e) anterior base of cuff (base of tongue); (f) distal posterior tube (distal oropharynx); and (g) proximal posterior tube (proximal oropharynx). (*B*) Location of sensors on intubating laryngeal mask (corresponding area): (a) tube–cuff junction; (b) the posterior tip of cuff (hypopharynx); (c) anterior middle part of the cuff side (pyriform fossa); (d) the backplate (posterior pharynx); (e) ante rior base of cuff (base of tongue); (f) distal posterior tube (distal oropharynx); and (g) proximal posterior tube (proximal oropharynx).

but the pressure at the cuff–tube junction was lower. The highest mucosal pressures were in the distal oropharynx for both devices. Mucosal pressures increased with increasing intracuff pressure and cuff volume for all locations with the LMA and five of six locations with the ILM, but the rate of increase varied between locations (table 2). Mean mucosal pressures in the distal oropharynx for the ILM were always greater than 157 cm H_2O and did not change with increasing intracuff pressure and volume. There was no correlation between mucosal pressures and airway sealing pressures at any location for the LMA, but there was a correlation at three of six locations for the ILM (table 3). Airway sealing pressure for the ILM increased with increasing intracuff volume from 0 to 10 ml ($P < 0.0001$), 10 to 20 ml ($P = 0.006$), and from 20 to 30 ml ($P = 0.023$), and it remained unchanged from 30 to 40 ml ($P = 0.9$). Airway sealing pressure for the LMA increased with increasing intracuff volume from 0 to 10 ml ($P < 0.0006$) and 10 to 20 ml ($P = 0.0001$), was unchanged from 20 to 30 ml, and decreased from 30 to 40 ml ($P = 0.04$).

Discussion

Pharyngeal capillary perfusion pressures have not been measured, but they are assumed to be similar to those in

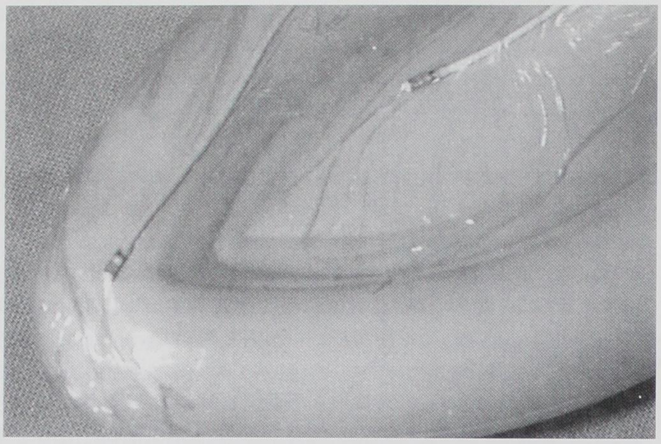

Fig. 2. Posterior surface of laryngeal mask airway showing the hypopharyngeal and posterior pharyngeal sensor.

the trachea at 30 mmHg (41 cm H_2O).[13] We found that pharyngeal mucosal pressures for the ILM are 3–70 times higher than for the LMA and exceed capillary perfusion pressure at most locations. The highest mucosal pressures for the ILM were in the distal oropharynx, where the rigid tube is firmly wedged against the bone of the anterior cervical vertebrae. Mean mucosal pressures at this location were considerably higher than capillary perfusion pressure and did not vary with intracuff volume. Like the tracheal mucosa,[14] the extent of pharyngeal mucosal injury is probably determined by the level of pressure and its duration of application. Because mucosal pressure in the distal oropharynx cannot be reduced, the ILM should remain *in situ* for the shortest possible time. This finding may also have implications for use of the ILM in the unstable cervical spine because the posterior force might be sufficient to displace fragments of bone into the spinal canal or to compress the cord, leading to neurologic deterioration.

Capillary perfusion pressure was rarely exceeded with the LMA and only at high intracuff volumes. Like the ILM, the highest mucosal pressures were in the distal oropharynx, where the curved tube is pressed firmly into the vertebral body by the expanding cuff and its own elastic recoil. However, the highest pressure on the LMA was not against the mucosa but rather between the tube and cuff. When the LMA is fixed in position, the tube compresses against the posterior aspect of the proximal cuff. This does not occur with the ILM because the rigid tube prevents the two non-mucosal surfaces from making contact. Several authors have calculated pharyngeal mucosal pressures for the LMA by subtracting *in vivo* from *in vitro* pressures.[13,15] The discovery of a high pressure, non-mucosal contact point for the LMA cuff suggests that calculated mucosal pressures will be inaccurate.

We found that fiberoptic positioning of the ILM was inferior to the LMA. The rigid, fixed-length tube of the ILM means that the cuff tip may not necessarily reach the hypopharynx, whereas the path of the LMA is unimpeded. The increased incidence of epiglottic downfolding with the ILM may be related to the increased anteroposterior diameter of the ILM or a result of the ILM being inserted in the neutral position compared with insertion in the Magill position for the LMA. In the Magill position the anteroposterior diameter of the pharynx is increased, and the epiglottis is elevated from the posterior pharyngeal wall.[16,17] As an airway intubator, epiglottic downfolding should not impede intubation with the ILM because the epiglottis is displaced during intubation by the epiglottic elevator bar.

We found that airway sealing pressures were higher for the ILM than for the LMA. This finding is surprising because malalignment of the oval-shaped cuff and the oval-shaped groove surrounding the glottic inlet should be more common with the ILM. It is therefore likely that the high pressures exerted by the ILM against the pharyngeal mucosa more than compensate for any suboptimal anatomic positioning. There was a correlation be-

Table 1. Demographic Data and Overall Airway Sealing Pressure, Fiberoptic Score, and Measured Pressures for the Intubating Laryngeal Mask *versus* the Laryngeal Mask Airway

	ILM	LMA	*P* Value
Age (yr) (range)	37 (21–60)	38 (24–59)	NS
Weight (kg) (range)	70 (46–91)	69 (52–90)	NS
Height (cm) (range)	171 (158–187)	171 (160–185)	NS
Male:female	5:5	5:5	NS
Airway sealing pressure	30 (27–33)	23 (20–25)	< 0.0001
FOS: 4/3/2/1 (n)	5/1/28/16	8/29/13/0	< 0.0001
Pressures (cm H_2O)			
Intracuff	100 (75–125)	79 (57–102)	NS
Tube/cuff	3 (2–5)	35 (23–48)	< 0.0001
Pyriform fossa	25 (10–39)	8 (7–10)	NS
Hypopharynx	59 (36–82)	11 (8–15)	0.007
Base of tongue	41 (29–53)	11 (8–15)	0.0004
Posterior pharynx	76 (43–110)	1 (1–2)	< 0.0001
Distal oropharynx	169 (113–224)	16 (11–21)	< 0.0001
Proximal oropharynx	22 (15–28)	2 (2–3)	< 0.0001

FOS = fiberoptic score; ILM = intubating laryngeal mask; LMA = laryngeal mask airway.

4 = only vocal cords visible; 3 = vocal cords plus posterior epiglottis; 2 = vocal cords plus anterior epiglottis; 1 = vocal cords not seen.[11]

Data are mean (95% confidence intervals) unless otherwise stated.

Table 2. Airway Sealing Pressures, Fiberoptic Score, Intra- and Extracuff Pressures with Increasing Cuff Volume for the Intubating Laryngeal Mask and Laryngeal Mask Airway*

	Volume (ml)	ASP	FOS (n) 4/3/2/1	Intracuff	Tube/Cuff	Pyriform Fossa	Hypopharynx	Base of Tongue	Posterior Pharynx	Distal Oropharynx	Proximal Oropharynx
ILM	0	15 (11–20)	1/0/3/6	−5 (−11–2)	1 (0–2)	7 (3–16)	35 (23–90)	28 (6–49)	30 (8–52)	164 (7–335)	9 (4–14)
	10	27 (21–33)	1/0/4/5	40 (35–44)	1 (0–2)	18 (8–44)	56 (15–128)	27 (8–45)	34 (8–60)	170 (16–323)	14 (5–23)
	20	33 (27–39)	1/0/6/3	86 (69–102)	3 (1–5)	28 (14–70)	73 (3–143)	40 (13–66)	54 (19–90)	169 (2–337)	22 (11–32)
	30	37 (33–41)	1/0/8/1	143 (115–171)	6 (2–10)	33 (15–81)	75 (18–132)	50 (16–84)	104 (28–181)	182 (59–306)	27 (12–41)
	40	37 (33–41)	1/1/7/1	236 (212–260)	6 (2–11)	37 (10–84)	59 (21–97)	61 (20–101)	160 (7–312)	158 (59–258)	36 (12–61)
LMA	0	14 (10–18)	0/7/3/0	−25 (−31–18)	3 (−2–8)	4 (1–7)	2 (0–4)	5 (1–7)	1 (0–1)	3 (0–5)	1 (0–3)
	10	21 (16–25)	1/6/3/0	31 (14–47)	11 (1–22)	7 (3–11)	4 (1–7)	7 (2–5)	1 (1–2)	6 (1–11)	2 (1–4)
	20	26 (21–32)	2/7/1/0	71 (54–88)	32 (14–50)	10 (5–14)	10 (5–15)	10 (5–14)	1 (1–2)	12 (4–20)	2 (1–3)
	30	27 (21–32)	3/4/3/0	123 (96–151)	54 (30–78)	10 (6–14)	17 (6–28)	10 (6–14)	1 (0–2)	22 (11–33)	3 (1–4)
	40	25 (20–31)	2/5/3/0	197 (180–213)	75 (27–123)	10 (6–15)	22 (11–34)	10 (5–16)	2 (1–3)	26 (10–43)	3 (1–5)

* 95% confidence intervals. Pressures are in cm H_2O.

ASP = airway sealing pressures; FOS = fiberoptic score; ILM = intubating laryngeal mask; LMA = laryngeal mask airway.

FOS: 4 = only vocal cords visible; 3 = vocal cords plus posterior epiglottis; 2 = vocal cords plus anterior epiglottis; 1 = vocal cords not seen.[11]

tween airway sealing pressure and pharyngeal mucosal pressure for the ILM in three locations, but not for the LMA. Two studies by this group have shown that airway sealing pressures for the LMA are higher at low rather than high intracuff volumes[18] and pressures.[19] The data from the current study confirm these findings for the LMA, but they show that airway sealing pressure for the ILM is not lower at high cuff volumes. These findings support the hypothesis that the efficacy of the seal for the LMA depends on the degree of conformity with pharyngeal tissues, but the efficacy of seal for the ILM depends on pharyngeal mucosal pressures.

We conclude that the ILM provides a more effective seal than the LMA, but that pharyngeal mucosal pressures are higher and always exceed capillary perfusion pressure. The ILM is unsuitable for use as a routine airway and should be removed after its use as an airway intubator.

Table 3. The Relationship between Airway Sealing Pressure and Extracuff Pressure for the Intubating Laryngeal Mask and the Laryngeal Mask Airway

	ILM		LMA	
	PPCC	*P* Value	PPCC	*P* Value
Tube/cuff	0.406	0.003	0.215	NS
Pyriform fossa	0.203	NS	0.101	NS
Hypopharynx	0.378	0.007	0.128	NS
Base of tongue	0.423	0.001	0.229	NS
Posterior pharynx	0.182	NS	0.058	NS
Distal oropharynx	0.065	NS	0.211	NS
Proximal oropharynx	0.528	0.0001	0.088	NS

ILM = intubating laryngeal mask; LMA = laryngeal mask airway; NS = not significant; PPCC = Pearson product-moment correlation; +1 = perfect positive correlation; 0 = no correlation; −1 = perfect negative correlation.

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