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 H2O), 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 H2O, 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 introducer. (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). Published data about the ILM are limited, but they suggest that ILM is an effective ventilatory device and airway introducer. The primary role of the ILM is as an airway introducer, 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 introducer (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...
either the LMA or ILM for airway management. Ethical
committee approval and informed consent were ob-
tained. 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 ±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 overlap 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 phar-
ynx); (5) posterior tube 1 (distal oropharynx); (6) pos-
terior 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 rou-
tine 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 instruc-
tions.9,10 A size 5 LMA or ILM was used for all patients.9,10
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 H₂O in vitro.
Pharyngeal mucosal pressures, intracuff pressures, air-
way sealing pressures, and fiberoptic position were doc-
umented 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
scaling 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 pos-
tion 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 sub-
merging the cuff portion in water at 37°C to a depth of
1.36 cm (10 mmHg) and +0.8 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 pres-
sures, airway sealing pressures, and fiberoptic scores
were measured with the ILM and LMA. The distribution of
data was determined using Kolmogorov-Smirnov analysis. Statis-
tical 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 dis-
tributed data). Chi-square test was used to compare fibero-
ptic 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 inter-
vals). 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 identi-
cal, and the pressures were accurate before and after
usage. There was no displacement of the cuff from the
periglottic tissues. Airway scaling 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,
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 H₂O 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...
the trachea at 30 mmHg (±1 cm H₂O). 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, 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 vitro from in vivo pressures. 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 epiglotic downfolding with the ILM may be related to the increased anteroposterior diameter of the ILM or a result of the LMA 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. 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

<table>
<thead>
<tr>
<th></th>
<th>ILM</th>
<th>LMA</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr) (range)</td>
<td>37 (21–60)</td>
<td>38 (24–59)</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (kg) (range)</td>
<td>70 (46–91)</td>
<td>69 (52–90)</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm) (range)</td>
<td>171 (158–187)</td>
<td>171 (160–185)</td>
<td>NS</td>
</tr>
<tr>
<td>Male:female</td>
<td>5:5</td>
<td>5:5</td>
<td>NS</td>
</tr>
<tr>
<td>Airway sealing pressure</td>
<td>30 (27–33)</td>
<td>23 (20–25)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>FOS: 4/3/2/1 (n)</td>
<td>5/1/28/16</td>
<td>8/29/13/0</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pressures (cm H₂O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intra cuff</td>
<td>100 (75–125)</td>
<td>79 (57–102)</td>
<td>NS</td>
</tr>
<tr>
<td>Tube/cuff</td>
<td>3 (2–5)</td>
<td>35 (23–48)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Pyriform fossa</td>
<td>25 (10–39)</td>
<td>8 (7–10)</td>
<td>NS</td>
</tr>
<tr>
<td>Hypopharynx</td>
<td>59 (36–82)</td>
<td>11 (8–15)</td>
<td>0.007</td>
</tr>
<tr>
<td>Base of tongue</td>
<td>41 (29–53)</td>
<td>11 (8–15)</td>
<td>0.0004</td>
</tr>
<tr>
<td>Posterior pharynx</td>
<td>76 (43–110)</td>
<td>1 (1–2)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Distal oropharynx</td>
<td>169 (113–224)</td>
<td>16 (11–21)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Proximal oropharynx</td>
<td>22 (15–28)</td>
<td>2 (2–3)</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

FOS = fiberoptic score; ILM = intubating laryngeal mask; LMA = laryngeal mask airway.
4 = only vocal cords visible; 3 = vocal cords plus posteri epiglottis; 2 = vocal cords plus anterior epiglottis; 1 = vocal cords not seen.
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

<table>
<thead>
<tr>
<th>Volume (ml)</th>
<th>ASP</th>
<th>FOS (n)</th>
<th>Intracuff</th>
<th>Tube/Cuff</th>
<th>Pyriform Fossa</th>
<th>Hypopharynx</th>
<th>Base of Tongue</th>
<th>Posterior Pharynx</th>
<th>Distal Oropharynx</th>
<th>Proximal Oropharynx</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILM</td>
<td>0</td>
<td>15 (11-20)</td>
<td>1/0/3/6</td>
<td>-5 (11-2)</td>
<td>1 (0-2)</td>
<td>7 (3-16)</td>
<td>35 (23-90)</td>
<td>28 (6-49)</td>
<td>30 (8-52)</td>
<td>164 (7-335)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>27 (21-33)</td>
<td>1/0/4/5</td>
<td>40 (34-44)</td>
<td>1 (0-2)</td>
<td>18 (8-44)</td>
<td>56 (15-128)</td>
<td>27 (8-45)</td>
<td>34 (8-60)</td>
<td>170 (16-323)</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>33 (27-39)</td>
<td>1/0/6/3</td>
<td>86 (69-102)</td>
<td>3 (1-5)</td>
<td>28 (14-70)</td>
<td>73 (3-143)</td>
<td>40 (13-66)</td>
<td>54 (19-90)</td>
<td>169 (2-337)</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>37 (33-41)</td>
<td>1/0/8/1</td>
<td>143 (115-171)</td>
<td>6 (2-10)</td>
<td>33 (15-81)</td>
<td>75 (18-132)</td>
<td>50 (16-84)</td>
<td>104 (28-181)</td>
<td>182 (59-306)</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>37 (33-41)</td>
<td>1/1/7/1</td>
<td>236 (212-260)</td>
<td>6 (2-11)</td>
<td>37 (10-84)</td>
<td>59 (21-97)</td>
<td>61 (20-101)</td>
<td>160 (7-312)</td>
<td>158 (59-258)</td>
</tr>
</tbody>
</table>

* 95% confidence intervals. Pressures are in cm H2O.

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

between 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 volumes18 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.

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References


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