Positive pressure ventilation during fibreoptic intubation: comparison of the laryngeal mask airway, intubating laryngeal mask and endoscopy mask techniques

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Background. The efficacy of delivery of mechanical ventilation through different airway devices during fibreoptic intubation is not known.

Methods. We compared the laryngeal mask airway (LMA)1, intubating laryngeal mask (ILM) and endoscopy mask for positive pressure ventilation (PPV) during fibreoptic intubation. In 80 adult paralysed patients, fibreoptic intubation was performed during PPV using a combination of a size 3 or 4 LMA with a 6.0 mm nasal RAE tracheal tube (LMA3/4 group; n=22), a size 5 LMA with a 7.0 mm nasal RAE tube (LMA5 group; n=18), an ILM with an 8.0 mm special reinforced tracheal tube (ILM group; n=20) or an endoscopy mask (Patil mask) with a 7.5 mm standard tracheal tube (Patil group; n=20). The inspiratory and expiratory tidal volumes (V I and V E) with a ventilation pressure of 20 cm H2O were measured using a pneumotachograph.

Results. Mean V E values during fibreoptic intubation in the LMA5 [5.3 (SD 1.5) ml kg−1] and ILM [7.1 (2.3) ml kg−1] groups were greater than in the LMA3/4 group [2.6 (1.0) ml kg−1, P<0.0001]. The mean V E was greater in the Patil group [20.6 (4.9) ml kg−1] than in the other three groups (P<0.0001). Gastric insufflation during intubation was more frequent in the Patil group (30%) than in the other three groups (4.5–5.6%) (P<0.05).

Conclusion. PPV is possible with the LMA, ILM or endoscopy mask during fibreoptic intubation. With an airway pressure of 20 cm H2O, ventilation during intubation using a size 3 or 4 LMA was almost insufficient, while ventilation using a size 5 LMA or an ILM was almost acceptable. Ventilation during intubation with the endoscopy mask was greater than that with the LMA or ILM, but gastric insufflation was more frequent.

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The laryngeal mask airway (LMA)1 and intubating laryngeal mask airway (ILM) can aid management of the difficult airway as a ventilatory device and as a conduit for fibreoptic intubation.1–3 Positive pressure ventilation (PPV) can be applied during fibreoptic intubation to reduce the potential risk of hypoxaemia.4–5 Maintaining PPV during intubation is desirable in patients with an unexpectedly difficult airway, so we should know how well the LMA and ILM allow PPV during fibreoptic intubation. We studied the abilities of the LMA and ILM to allow PPV during fibreoptic intubation in comparison with that of the endoscopy mask.5–8

1 LMA® is the property of Intavent Limited.
Methods

Patients

After approval of the study by the institutional ethics committee (Moji Rosai Hospital Medical Ethics Committee), written informed consent was obtained from all patients. Patients with pharyngeal pathology, significant lung disease, morbid obesity or known difficult intubation and those at risk of aspiration were excluded. Eighty ASA physical status I or II patients who required general anaesthesia and tracheal intubation for elective surgery were allocated randomly into one of three groups using the closed envelope method. At the preoperative visit, the Mallampati class was assessed. In each patient, fibreoptic intubation was carried out while continuing PPV using an LMA (LMA group; n=40), ILM (ILM group; n=20) or endoscopy mask (Patil-Syracuse mask clear, Patil mask; Anaesthesia Associates, San Marcos, CA, USA) (Patil group; n=20). For intubation using a size 3 or 4 LMA, a 6.0 mm internal diameter tracheal tube should be used and for a size 5 LMA a 7.0 mm internal diameter tracheal tube is recommended. The size of the tracheal tube used will affect the ability to deliver PPV, and 40 patients in the LMA group were subdivided into an LMA3/4 (size 3 or 4 LMA) and an LMA5 (size 5 LMA) group.

Equipment and preparation

In the LMA and ILM groups, the size of the LMA and ILM was selected according to recent recommendations (size 3 for small females, size 4 for females and small males, size 5 for males). We used an appropriate size of nasal RAE tracheal tube (Mallinckrodt Medical, Athlone, Ireland) for intubation in the LMA3/4 and LMA5 groups, respectively because of its adequate length. An 8.0 mm internal diameter special straight, silicone wire-reinforced, cuffed tracheal tube (ILM Endotracheal Tube; Euromedical, Kedah, Malaysia) was used in the ILM group. A 4.0 mm outer diameter fibreoptic laryngoscope (FOL; Olympus, Tokyo, Japan) was used in the LMA3/4, LMA5 and ILM groups to obtain adequate air flow around the fibrescope. A second 5.0 mm, 6.0 mm internal diameter uncuffed tracheal tube or a special stabilizing rod (ET Stabilizer; Euromedical) was used as a stabilizer for the removal of the size 3 or 4 LMA or size 5 LMA or ILM, as appropriate. In the Patil group, for intubation with a modified endoscopy mask technique, a Patil mask was prepared as follows. A lubricated 7.5 mm internal diameter standard tracheal tube (Sheridan, Kendall Company, Mansfield, MA, USA) was passed through the diaphragm of the Patil mask port to about 10 cm. A fibreoptic swivel connector was attached to the tracheal tube adapter, and the side arm of the fibreoptic connector was blocked with tape. The modified Ovassapian intubating airway with a black line on the pharyngeal surface was used because this modification is useful when oral fibreoptic intubation is unexpectedly difficult. A 5.0 mm outer diameter fibreoptic bronchoscope (FOB; Olympus) was used in the Patil group to prevent difficulty in advancing the tracheal tube over the fibrescope by reducing the size gap between the fibrescope and the tracheal tube. A water-soluble lubricant was used for all devices.

Anaesthetic management

All patients received our customary premedication with hydroxyzine 25–50 mg and atropine 0.25–0.5 mg i.m. 30 min before induction of anaesthesia. In the operating room, the patients were monitored with an electrocardiogram, indirect blood pressure, pulse oximeter and capnograph. After preoxygenation for a few minutes, anaesthesia was induced with propofol 2 mg kg⁻¹ and fentanyl 1 µg kg⁻¹ i.v. Neuromuscular block was produced with vecuronium 0.1–0.15 mg kg⁻¹. Anaesthesia was maintained with propofol 5–10 mg kg⁻¹ h⁻¹ throughout the study period. The patient’s lungs were ventilated with 100% oxygen through a standard face mask for 5 min.

Placement of the airway devices

After paralysis had been confirmed with a nerve stimulator, the allocated airway device was inserted in the LMA and ILM groups, fixed using a standard method according to the manufacturer’s instructions, and connected to the anaesthesia breathing circuit. Oropharyngeal leak around the LMA or ILM cuff was detected by noise during manual bag ventilation, and the leak pressure at which the leak occurred was measured. If airway obstruction or a large leak was noted during manual ventilation, the LMA or ILM was replaced, or a different size was used. When manual bag ventilation was almost acceptable but the leak pressure was less than 15 cm H₂O, steady pressure was applied to the neck with the palm of an assistant’s hand during ventilation and intubation to reduce the leakage. In the Patil group, a modified Ovassapian intubating airway was inserted into the mouth. The Patil mask, previously fitted with the tracheal tube, was placed over the face with the distal 4 cm of the tracheal tube inserted into the airway. Gauze packing was used to facilitate a tight mask fit in edentulous patients if necessary. Then, the operator extended the patient’s head and applied forward thrust to the jaw. To maintain a constant airway opening and an adequate jaw thrust, a jaw support device (JSD; Arizono Orthopedic Supplies Company, Kitakyushu, Japan) was applied to both angles of the jaw. A standard head strap was used to fit the mask. An anaesthesia breathing circuit was connected with the Patil mask using an elbow adapter.

The number of attempts at insertion was recorded for each airway device, and the time for insertion of the device from the insertion of the airway into the mouth to
completion of insertion (until cuff inflation of the LMA or ILM) was measured using a stopwatch in each group.

**Mechanical ventilation**

After the confirmation of airway patency by manual ventilation, mechanical ventilation was started using a ventilator (Puritan-Bennett Ventilator 760; Nellcor Puritan Bennett, Pleasanton, CA, USA) in the pressure control mode with 100% oxygen. A ventilation pressure of 20 cm H₂O, a respiratory rate of 12 and an inspiratory:expiratory ratio of 1:2 were used in all groups.

**Fibreoptic intubation procedure**

Fibrescope-guided intubation was performed by an experienced anaesthesiologist (>100 uses of each technique) while mechanical PPV was continued with each airway device. A fibreoptic swivel connector was attached to the tracheal tube and ventilation was carried out through the tracheal tube during intubation (Fig. 1A). The fibrescope was advanced through the fibreoptic connector into the tracheal tube and through the glottis into the trachea. The tracheal tube was advanced over the fibrescope into the trachea. After the 15 mm adapter of the tracheal tube had been removed, the second 5.0 mm (LMA3/4 group) or 6.0 mm (LMA5 group) tracheal tube was connected to the proximal end of the intubated tracheal tube as a stabilizer. The LMA was slid over the tracheal tube until the tracheal tube was visible in the mouth. The intubated tracheal tube was held in the mouth, the second tracheal tube was removed and the LMA was removed over the tracheal tube. In the ILM group, an 8.0 mm special reinforced tracheal tube was introduced into the ILM tube, a fibreoptic swivel connector was attached to the tracheal tube, and mechanical PPV was performed through the tracheal tube (Fig. 1A). After the fibrescope had been advanced through the fibreoptic connector into the tracheal tube, the operator advanced the tracheal tube and pushed the epiglottic elevator bar with the tracheal tube according to the manufacturer’s instruction manual. The tracheal tube and fibrescope were advanced together through the glottis into the trachea after the tracheal tube had been aligned with the glottis. When the tracheal tube was not aligned with the glottis, the fibrescope was advanced into the glottis and then the tracheal tube was advanced over the fibrescope into the trachea. With the use of a special stabilizing rod, the ILM
was removed as the LMA was removed. In the Patil group, the tracheal tube and the connector were already in place and PPV was carried out through the Patil mask (Fig. 1B). The fibrescope was advanced through the fibreoptic connector into the tracheal tube and through the glottis into the trachea. The tracheal tube was advanced over the fibrescope into the trachea. The 15 mm adapter of the tracheal tube was then removed and the Patil mask and the Ovassapian airway were removed. In each group, the tracheal tube was advanced with rotation, but when the tracheal tube could not be advanced over the fibrescope, further tube rotation and/or external neck manipulation was applied to align the larynx with the tracheal tube. Correct placement of the tracheal tube was confirmed by capnography and auscultation in all groups.

During fibrescopy, the degree of exposure of the larynx was assessed using the following classification scheme: easy = good visualization of the glottis was obtained on initial introduction of the fibrescope, so that little or no manipulation of the tip of the fibrescope was necessary; moderately difficult = some manipulation of the fibrescope was required to see the glottis; difficult = extensive manipulation was required to visualize the glottis. The times required for fibrescopy and intubation were measured using a stopwatch. The fibrescopy time was the time from the insertion of the fibrescope into the fibroptic connector to the passage of the fibrescope through the vocal cords. The intubation time was the time from the insertion of the fibrescope into the fibroptic connector to correct placement of the tracheal tube into the trachea. The number of attempts at tube advancement over the fibrescope was recorded. In all groups, auscultation was performed at the stomach to detect gastric insufflation during intubation.

**Measurement of tidal volume**

The inspiratory and expiratory tidal volumes (Vt and VE) during fibreoptic intubation were measured using a pneumotachograph (VenTrak 1550; Novametrix Medical Systems, Wallingford, CT, USA) in each group. Before the intubation procedure started, Vt and VE during fibrescopy (SF stage) were measured with the tracheal tube and the fibrescope fixed to minimize the leak caused by manipulation of the tracheal tube and fibrescope (Fig. 1A and B). At this stage, the tracheal tube and fibrescope were inserted by an anaesthesiologist who was not the intubator. The tracheal tube and fibrescope were then withdrawn (the tracheal tube in the Patil group was still in place), and Vt and VE were measured at four stages (three in the Patil group) during the intubation procedure: (i) during ventilation through the airway device (Sairway stage); (ii) through the tracheal tube passed into the LMA or ILM tube before insertion of the fibrescope (Sairway stage); this stage was not used in the Patil group; (iii) at fibreoptic intubation (SFI stage); and (iv) through the tracheal tube after tracheal intubation (Safter stage). At the SF, Sairway, Sairway and Safter stages, measurements were made over 30 s (six breaths) and the mean VE was calculated for each patient. During intubation (SFI stage), Vt and VE were measured over the time for intubation and the mean VE was calculated. The leak fraction [(Vt - VE)/Vt]15 was calculated for each patient at each stage. The pneumotachograph was calibrated for gas and its accuracy (±5%) was checked before and after the study.

**Statistical analysis**

All ventilatory recordings were stored in a VenTrak computer and analysed on a personal computer using Analysis Plus software (Novametrix Medical System). Data are presented as mean (SD) or median (range). Most continuous variables (age, weight, height, time for airway insertion, leak pressure and tidal volume) were analysed using one-way analysis of variance and the Tukey–Kramer multiple comparisons test. The ordinal data (Mallampati class, number of attempts at airway insertion and tube advancement, and fibreoptic view) or the times for fibrescopy and intubation were compared by means of the Kruskal–Wallis test. The $\chi^2$ test was used for nominal data.
(male/female distribution and incidence of gastric insufflation). A $P$ value below 0.05 was considered statistically significant.

Results

The patient characteristics (Table 1) were similar for the three groups, but the LMA5 group differed from the other groups because of LMA size selection.

**Insertion of the airway devices**

The LMA, ILM or Ovassapian airway was quickly inserted in each patient (Table 1). There were no significant differences among the groups in the number of attempts at airway insertion (LMA, ILM or Ovassapian airway insertion). The leak pressure was higher in the ILM group than in the two LMA groups ($P<0.0001$). In four patients in the LMA3/4 and two in the LMA5 group, despite almost acceptable manual bag ventilation through the LMA itself, external neck pressure was applied by an assistant’s palm to reduce leakage around the LMA cuff during fibreoptic intubation, because the leak pressure was less than 15 cm H$_2$O.

**Fibreoptic intubation through each airway device**

Fibreoptic intubation through the airway device was successful in all patients in each group. There were no significant differences among the four groups in the fibreoptic view, the time for fibrescopy and the time for intubation (Table 2). In some patients in the LMA5, ILM and Patil groups, the first tube advancement with rotation was halted at the level of the larynx, but the tracheal tube could be advanced successfully into the trachea by application of further tube rotation and/or external neck manipulation by an assistant. Gastric insufflation was more frequent in the Patil group than in the other groups ($P<0.05$). Haemoglobin oxygen saturation did not fall

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**Table 2** Details of fibrescopy and intubation. Values are number of patients, percentages or median (range). LMA=laryngeal mask airway; ILM=intubating laryngeal mask; E=easy; M=moderately difficult; D=difficult. *$P<0.05$ compared with the other groups

<table>
<thead>
<tr>
<th>Group</th>
<th>LMA3/4</th>
<th>LMA5</th>
<th>ILM</th>
<th>Patil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibreoptic view</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E, M, D</td>
<td>20, 2, 0</td>
<td>15, 3, 0</td>
<td>15, 3, 2</td>
<td>16, 4, 0</td>
</tr>
<tr>
<td>Time for fibrescopy (s)</td>
<td>12 (8–17)</td>
<td>11 (6–16)</td>
<td>12 (8–85)</td>
<td>12 (7–35)</td>
</tr>
<tr>
<td>Time for intubation (s)</td>
<td>24.5 (20–30)</td>
<td>25 (15–120)</td>
<td>20 (12–100)</td>
<td>23 (15–90)</td>
</tr>
<tr>
<td>Number of attempts at tube advancement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>22 (100%)</td>
<td>14 (78%)</td>
<td>18 (90%)</td>
<td>19 (95%)</td>
</tr>
<tr>
<td>2</td>
<td>2 (11%)</td>
<td>2 (11%)</td>
<td>2 (10%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence of gastric insufflation</td>
<td>1 (4.5%)</td>
<td>1 (5.6%)</td>
<td>1 (5%)</td>
<td>6 (30%)*</td>
</tr>
</tbody>
</table>

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**Fig 2** Typical traces of tidal volumes during fibreoptic intubation through the size 4 laryngeal mask airway (LMA). The inspiratory volume ($V_i$) trace is upwards. After ventilation through the LMA ($S_{airway}$), a 6.0 mm nasal RAE tracheal tube was inserted into the LMA tube (TT insertion) and ventilation was performed through the tracheal tube ($S_{TT}$). A fibreoptic laryngoscope (FOL) was then introduced into the tracheal tube through the fibreoptic port (port open) and advanced into the trachea. The tracheal tube was inserted into the trachea over the FOL. During fibreoptic intubation ($S_{int}$) in this patient, tidal volumes were measured over six breaths because the time for intubation was 33 s, and six volumes were averaged to obtain the mean $V_e$ (mean $V_e$=194 ml in this patient). At the $S_{int}$ stage, leakage was noted after the tracheal tube cuff was passed below the mask aperture bars of the LMA (small arrow). Ventilation through the 6.0 mm RAE tracheal tube was adequate after the FOL had been removed ($S_{after}$).
below 98% and end-tidal carbon dioxide did not exceed 40 mm Hg in any patient during the study period.

**Expiratory tidal volume during intubation**

Typical traces of tidal volumes through the size 4 LMA at the \( S_{\text{airway}} \), \( S_{TT} \), \( S_{FI} \), and \( S_{after} \) stages are shown in Figure 2. At the \( S_{FI} \) stage, the tidal volumes were measured over two to 24 breaths according to the intubation time. At the \( S_{FI} \) stage in the LMA3/4 and LMA5 groups, a leak was noted after the tracheal tube cuff had been passed below the mask aperture bars of the LMA (Fig. 2, small arrow). The mean \( V_I \), \( V_E \) and leak fraction at five stages in each group are presented in Table 3. The mean \( V_E \) values in relation to patient’s weight at the \( S_{airway} \), \( S_{TT} \), \( S_{FI} \), and \( S_{after} \) stages are shown in Figure 3. A mean \( V_E \) of more than 10 ml kg\(^{-1}\) was obtained at the \( S_{airway} \), \( S_{TT} \), and \( S_{after} \) stages in most patients in all groups. The mean \( V_E \) values at the \( S_F \) and \( S_{FI} \) stages in the LMA5 [\( S_F 6.8 \) (SD 1.5), \( S_{FI} 5.3 \) (1.5) ml kg\(^{-1}\)] and ILM [\( S_F 7.9 \) (2.4), \( S_{FI} 7.1 \) (2.3) ml kg\(^{-1}\)] groups were greater than those in the LMA3/4 group [\( S_F 3.4 \) (1.3), \( S_{FI} 2.6 \) (1.0) ml kg\(^{-1}\)] (\( P<0.0001 \)). The mean \( V_E \) values at the \( S_F \) and \( S_{FI} \) stages were greater in the Patil group [\( S_F 21.6 \) (4.9), \( S_{FI} 20.6 \) (4.9) ml kg\(^{-1}\)] compared with the other three groups (\( P<0.0001 \)).

**Discussion**

During fiberoptic intubation, continuous PPV was possible through the LMA, ILM and endoscopy mask. From the tidal volumes obtained in the present study, ventilation during intubation using a size 3 or 4 LMA was insufficient, whereas ventilation using a size 5 LMA, ILM or endoscopy mask technique was almost satisfactory. The ability to deliver PPV during fiberoptic intubation depends on the space available for air flow and the effectiveness of each device in providing an airtight seal. With the LMA and ILM, PPV during intubation is performed through the tracheal tube inserted into the LMA or ILM tube. Thus, the largest size of tracheal tube that can be inserted into the LMA or ILM shaft should be used to ensure adequate air flow within the tracheal tube and to minimize leakage from the space between the tracheal tube and the LMA or ILM tube.\(^4\)

### Table 3 Inspiratory and expiratory tidal volumes at each stage during fiberoptic intubation. Values are mean (SD). LMA=laryngeal mask airway; ILM=intubating laryngeal mask; \( V_I=\) inspiratory tidal volume; \( V_E=\) expiratory tidal volume; \( S_{airway}=\) ventilation through the airway device; \( S_{TT}=\) ventilation through the tracheal tube and fibroscope fixed; \( S_{FI}=\) ventilation during fiberoptic intubation; \( S_{after}=\) ventilation after tracheal intubation; \( Lf=\) leak fraction=(\( V_I- V_E \))/\( V_I \). *\( P<0.0001 \) compared with the LMA3/4 group. †\( P<0.0001 \) compared with the LLM group; ‡\( P<0.0001 \) compared with the other groups.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Group</th>
<th>( S_{airway} )</th>
<th>( S_{TT} )</th>
<th>( S_F )</th>
<th>( S_{FI} )</th>
<th>( S_{after} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_I ) (ml)</td>
<td>LMA3/4</td>
<td>980 (209)</td>
<td>745 (75)†</td>
<td>224 (27)</td>
<td>288 (58)</td>
<td>692 (116)</td>
</tr>
<tr>
<td>( V_E ) (ml)</td>
<td>948 (214)</td>
<td>697 (101)‡</td>
<td>176 (36)</td>
<td>128 (45)</td>
<td>675 (118)</td>
<td></td>
</tr>
<tr>
<td>( Lf )</td>
<td>0.03</td>
<td>0.06</td>
<td>0.21</td>
<td>0.56</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>( LMA5 )</td>
<td>( V_I ) (ml)</td>
<td>1307 (158)</td>
<td>956 (67)</td>
<td>495 (57)</td>
<td>553 (49)</td>
<td>940 (114)</td>
</tr>
<tr>
<td>( V_E ) (ml)</td>
<td>1280 (157)‡</td>
<td>921 (66)‡</td>
<td>464 (69)*</td>
<td>355 (68)*</td>
<td>923 (112)*</td>
<td></td>
</tr>
<tr>
<td>( Lf )</td>
<td>0.02</td>
<td>0.04</td>
<td>0.06</td>
<td>0.36</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>( ILM )</td>
<td>( V_I ) (ml)</td>
<td>1018 (272)</td>
<td>1096 (200)</td>
<td>844 (90)</td>
<td>873 (136)</td>
<td>1003 (223)</td>
</tr>
<tr>
<td>( V_E ) (ml)</td>
<td>1003 (272)</td>
<td>586 (133)</td>
<td>432 (94)*</td>
<td>389 (93)*</td>
<td>995 (223)*</td>
<td></td>
</tr>
<tr>
<td>( Lf )</td>
<td>0.01</td>
<td>0.47</td>
<td>0.48</td>
<td>0.55</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>( Patil )</td>
<td>( V_I ) (ml)</td>
<td>1372 (255)</td>
<td>1382 (226)</td>
<td>1340 (253)</td>
<td>1340 (253)</td>
<td>966 (210)</td>
</tr>
<tr>
<td>( V_E ) (ml)</td>
<td>1261 (310)+</td>
<td>1250 (299)+</td>
<td>1188 (296)+</td>
<td>1188 (296)+</td>
<td>958 (229)*</td>
<td></td>
</tr>
<tr>
<td>( Lf )</td>
<td>0.08</td>
<td>0.10</td>
<td>0.11</td>
<td>0.008</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Therefore, we used a tracheal tube with internal diameter 6.0, 7.0 and 8.0 mm for intubation with a size 3 or 4 LMA, a size 5 LMA and an ILM respectively. In addition, a longer tracheal tube is required for the LMA technique to allow the tracheal tube cuff to pass completely between the vocal cords.2-4 We used a nasal RAE tracheal tube11,12 because it is long enough. This tube, with proper lubrication, could be inserted easily into the LMA tube and into the trachea, and the bend of the tube did not cause any problem.11,12 To obtain adequate air flow within the tracheal tube around the fibrescope, a 4.0 mm outer diameter FOL was used in the LMA3/4, LMA5 and ILM groups.6 If a larger fibrescope is used, air flow around the fibrescope (tidal volume) decreases. We believe that each of the devices we used is suitable for obtaining as great a tidal volume as possible and for easy fibreoptic intubation.

With fibreoptic intubation through a size 3 or 4 LMA, when a FOL was inserted into the 6.0 mm internal diameter tracheal tube, the free cross-sectional area around the FOL (space for air flow) was reduced, resulting in increased resistance. In addition, manipulation (advancement or rotation) of the FOL and tracheal tube during intubation (SF stage) caused a leak through the port of the fibreoptic swivel connector (around the FOL) and through the space between the tracheal tube and the LMA tube. After the cuff of the tracheal tube had passed through the mask aperture bars, the leak was increased because the seal between the tracheal tube cuff and the LMA tube was lost. Consequently, a mean \( V_E \) of only 2.6 ml kg\(^{-1}\) could be obtained during intubation (SF stage). The patients’ breathing tidal volumes (lung inflation and deflation volumes) at this stage may be larger than the measured \( V_E \) to some extent because leakage may occur during expiration. To minimize the effect of this leak, we examined the \( V_t \) and \( V_E \) while the tracheal tube and the fibrescope were fixed (SF stage) in each patient. Despite the small leakage at this stage, a mean \( V_E \) of only 3.4 ml kg\(^{-1}\) could be obtained. These results indicate that ventilation during fibreoptic intubation with a size 3 or 4 LMA is insufficient at a ventilation pressure of 20 cm H\(_2\)O. However, with the combination of a 4.0 mm fibrescope and a 6.0 mm RAE tracheal tube, fibrescopy and intubation through the size 3 or 4 LMA could be done quickly in all patients and the time range for these was very small. Oxygenation can probably be maintained for such times despite a small tidal volume.

With the size 5 LMA, ventilation during intubation was acceptable in most patients and was superior to that with the size 3 or 4 LMA. A combination of the size 5 LMA, the 7.0 mm internal diameter RAE tracheal tube and the 4.0 mm outer diameter FOL provided almost adequate space around the FOL for PPV. Therefore, if applicable, the size 5 LMA is preferable to the size 4 LMA for effective ventilation. With the size 5 LMA, however, more attempts at tube advancement were required because tube advancement was halted at the level of the larynx. This may be because of a larger gap between the 7.0 mm tracheal tube and the 4.0 mm outer diameter FOL. Although the gap may decrease with a larger fibrescope, adequate space for ventilation is also reduced and the tidal volume obtained may decrease. When tube advancement was halted at the larynx, tube rotation or aligning the larynx with the tracheal tube by external neck manipulation could overcome this problem. Acceptable ventilation could be maintained during the intubation attempts.

For adequate ventilation, correct placement of the LMA is essential to create an open airway and adequate seal around the neck. Although oropharyngeal leakage around the cuff can occur even when the LMA is properly placed, ventilation through the LMA is possible despite some leakage.14 15 18 19 During intubation, insertion of the tracheal tube and the FOL increased the leak, which made ventilation inadequate or impossible despite previously acceptable manual ventilation through the LMA itself. In these patients, external pressure applied to the neck reduced the leakage around the LMA cuff,16 which permitted PPV during fibreoptic intubation. By this manoeuvre, the leakage during ventilation through the LMA itself was smaller in this study than in previous studies.14 18 19

When the ILM was used, the seal around the cuff was adequate to deliver PPV during intubation without the need for external neck pressure, but some leakage between the ILM tube and the tracheal tube occurred (STT stage) even when the 8.0 mm internal diameter tracheal tube, i.e. the largest available special tracheal tube5,10 was used. Thus, tidal volumes (lung inflation/deflation volumes) may be larger than the measured \( V_E \) to some extent with the ILM. However, the \( V_E \) obtained during fibrescopy and intubation was clinically satisfactory [mean \( V_E \) 7.9 (2.4) ml kg\(^{-1}\) at SF and 7.1 (2.3) ml kg\(^{-1}\) at SF]. When a smaller tracheal tube is used (a 7.0 or 7.5 mm internal diameter special tracheal tube is available), tidal volumes may be less because the space for air flow decreases and the leak around the tracheal tube increases.

In contrast to the LMA and ILM techniques, with the endoscopy mask PPV during intubation is performed through the mask, not through the tracheal tube. Therefore, the size of tracheal tube and fibrescope would not affect the air flow. A 7.5 mm internal diameter standard tracheal tube (31 cm in length) was used for the endoscopy mask technique, because a 7.0 mm (30 cm) or smaller tracheal tube is not long enough to manipulate the tracheal tube over the Patil mask. The height of the Patil mask is about 7 cm and a tracheal tube more than 30 cm long is required to completely insert the tracheal tube into the trachea over the Patil mask. Because a smaller fibrescope is not necessary for adequate air flow, a 5.0 mm outer diameter FOB could be used in the Patil group to prevent difficulty in advancing the tracheal tube over the fibrescope by reducing the size of the gap between the fibrescope and the tracheal tube.6 With this technique, the Ovassapian intubating airway and the jaw thrust manoeuvre with the JSD maintained an open airway,8 which provided adequate
space to deliver PPV. Ventilation with the endoscopy mask technique was better than that with the LMA and ILM techniques. However, gastric insufflation during intubation at a ventilation pressure of 20 cm H₂O was most frequent with the endoscopy mask, although the extent of gastric insufflation in each group was unknown. This result is consistent with previous studies of mask ventilation. Gastric insufflation during fibreoptic intubation with the LMA or ILM is less likely to occur because a considerable decrease in pressure across the smaller tracheal tube occurs with the FOL. With the endoscopy mask technique, ventilation pressures less than 20 cm H₂O may be sufficient. In our previous study, a Ve of about 10 ml kg⁻¹ was obtained at about 15 cm H₂O ventilation pressure without gastric insufflation. Gastric insufflation, however, should be anticipated and monitored during intubation with either technique, especially when a long time is required for intubation.

In the present study, there were no significant differences in the ease of airway placement and ease of fibreoptic intubation among the groups. Ventilation during intubation with the endoscopy mask was better than that with the LMA and ILM techniques. Therefore, when mask ventilation is easy and an experienced assistant can help to fit a mask and to apply jaw thrust, the use of the endoscopy mask technique is reasonable. However, if mask ventilation and tracheal intubation are difficult, the LMA or ILM technique should be selected. In unexpectedly difficult airway situations, an LMA can achieve rescue ventilation reliably. Although ventilation during intubation with the size 3 or 4 LMA is insufficient, oxygenation can probably be maintained for a short time. If more ventilation is required, a higher respiratory rate should be applied to increase minute ventilation. Higher ventilation pressure may also be applied with the LMA technique because of a decrease in pressure across the smaller tracheal tube with the FOL. If applicable, the use of a size 5 LMA is preferable to a size 3 or 4 for effective ventilation. The recently introduced ILM has the potential to play an important role in airway management. Satisfactory ventilation through the 8.0 mm tracheal tube and the ILM during intubation could be obtained in the present study. In some patients, however, the view of the glottis was poor, which prolonged fibrescopy and intubation. In addition, we have reported a case in which ventilation through the ILM was difficult because of partial airway obstruction caused by the fixed length of the rigid metal airway tube. In some emergency situations, the standard LMA may be superior because of its flexibility. Further studies are required to establish the usefulness of the ILM for patients with a difficult airway.

The limitation of our study is that patients with a difficult airway, lung disease or morbid obesity were not included for ethical reasons. Our results may not always apply to these or critically ill patients, although the haemoglobin oxygen saturation and the end-tidal carbon dioxide were maintained within normal ranges in our healthy patients during the short study period. Tidal volume may be less in patients with obesity, decreased lung compliance or increased airway resistance, but our results may provide a useful comparison with ventilation during fibreoptic intubation using each technique.

We conclude that ventilation can be applied with the LMA, ILM and endoscopy mask throughout fibreoptic intubation. At a ventilation pressure of 20 cm H₂O, ventilation during intubation using a size 3 or 4 LMA was almost insufficient, and a higher respiratory rate should be applied to increase minute ventilation. Ventilation using a size 5 LMA or an ILM was almost acceptable, and the use of a size 5 LMA is preferable to a size 3 or 4 for effective ventilation, if applicable. Ventilation during intubation with the endoscopy mask technique was superior to that with the LMA or ILM, but gastric insufflation was more frequent. Careful choice should be made on the basis of other features of each technique in addition to the degree of ventilation.

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