Anesthesiology
1999; 90:391–4

Endotracheal Intubation, but Not Laryngeal Mask Airway Insertion, Produces Reversible Bronchoconstriction

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Background: **Tracheal intubation frequently results in an increase in respiratory system resistance that can be reversed by inhaled bronchodilators. The authors hypothesized that insertion of a laryngeal mask airway would be less likely to result in reversible bronchoconstriction than would insertion of an endotracheal tube.**

Methods: **Fifty-two (45 men, 7 women) patients were randomized to receive a 7.5-mm (women) or 8-mm (men) endotracheal tube or a No. 4 (women) or No. 5 (men) laryngeal mask airway. Anesthesia was induced with 2 μg/kg fentanyl and 5 mg/kg thiopental, and airway placement was facilitated with 1 mg/kg succinylcholine. When a seal to more than 20 cm water was verified, respiratory system resistance was measured immediately after airway placement. Inhalation anesthesia was begun with isoflurane to achieve an end-tidal concentration of 1% for 10 min. Respiratory system resistance was measured again during identical conditions.**

Results: **Among patients receiving laryngeal mask airways, the initial respiratory system resistance was significantly less than among patients with endotracheal tubes (9.2 ± 3.3 cm water $\cdot l^{-1} \cdot s^{-1}$ [mean ±SD] compared with 13.4 ± 9.6 cm water $\cdot l^{-1} \cdot s^{-1}$; $P < 0.05$). After 10 min of isoflurane, the resistance decreased to 8.6 ± 3.6 cm water $\cdot l^{-1} \cdot s^{-1}$ in the endotracheal tube group but remained unchanged at 9.1 ± 3.3 cm water $\cdot l^{-1} \cdot s^{-1}$ in the laryngeal mask airway group. The decrease in respiratory system resistance in the endotracheal tube group of 4.7 ± 7 cm water $\cdot l^{-1} \cdot s^{-1}$ was highly significant compared with the lack of change in the laryngeal mask airway group ($P < 0.01$).**

Conclusions: **Resistance decreased rapidly only in patients with endotracheal tubes after they received isoflurane, a potent bronchodilator, suggesting that reversible bronchoconstriction was present in patients with endotracheal tubes but not in those with laryngeal mask airways. A laryngeal mask airway is a better choice of airway to minimize airway reaction. (Key words: Airway resistance; intratracheal intubation; isoflurane.)**

This article is featured in "This Month in Anesthesiology." Please see this issue of ANESTHESIOLOGY, page 11A.

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Received from the Puget Sound Veterans Affairs Health Care System, Seattle, Washington. Submitted for publication May 13, 1998. Accepted for publication September 2, 1998. Supported by the Office of Research and Development of the Department of Veterans Affairs.

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THE mechanical irritation caused by an endotracheal tube often leads to reflex bronchoconstriction, which may be especially profound in patients with reactive airway disease.[1–4] Bronchoconstriction after induction of anesthesia occurs much less frequently during anesthesia administered by face mask compared with anesthesia administered *via* an endotracheal tube (ETT).[5] The laryngeal mask airway (LMA) is a relatively new device to manage the airway during general anesthesia. It sits in the hypopharynx and surrounds the larynx.[6] Despite many reports of the clinical use of the LMA, few studies have evaluated the interaction of the LMA with the respiratory system.[7,8] The effect of the LMA on airway reactivity has not been studied, and because the larynx contains sensory receptors that may lead to airway constriction,[9] we were unsure whether the LMA would stimulate a reflex response of the airways. The current study was undertaken to test the hypothesis that insertion of an LMA would be less likely to result in reversible bronchoconstriction than would insertion of an ETT.

Methods

After we received approval for the study from the human subjects committees of the University of Washington School of Medicine and the Puget Sound Veterans Affairs Health Care System, we obtained written consent from 52 patients. Eligible patients were 18 to 80 yr old and undergoing elective surgery. Patients were excluded if they had increased intracranial pressure, an active upper respiratory tract infection, or a history of laryngeal or tracheal surgery or disease. Patients actively taking bronchodilators were excluded. Baseline peak expiratory flow was assessed with the patient awake and in a sitting position before anesthesia was induced.[10] Fifty-two (45 men and 7 women) patients were allocated randomly using a coin toss to determine placement of an ETT or an LMA. Sizes used were a 7.5-mm (for women) or an 8-mm (for men) ETT or a No. 4 (for women) or a No. 5 LMA (for men). Anesthesia was induced with 2 μg/kg fentanyl and 5 mg/kg thiopental, and placement of the airway device was facilitated with 1 mg/kg succinylcholine. When an LMA was used, the cuff was inflated until a seal was achieved at 20 cm water or greater pressure. The one patient for whom a seal to 20 cm water could not be achieved was excluded from the study. Mechanical ventilation was initiated at a tidal volume of 500 ml, a flow rate of approximately 0.35 l/s (mid range of low flow), an inspiratory:expiratory (I:E) ratio of 1:1.5, and a frequency of 10. The peak pressure was observed to ensure that it remained less than 20 cm water in all patients with LMAs. Immediately after airway placement and before delivery of isoflurane, respiratory system resistance (Rrs) was measured and blood pressure and heart rate were recorded.

Respiratory system resistance was calculated by measuring gas flow and tracheal pressure and using the isovolume method at a volume of 400 ml above functional reserve capacity.[2,11] This method involves measuring pressure and flow at the same volume above functional reserve capacity during the inspiratory and expiratory phase. The resistance can be calculated from the difference between these values because the contribution from lung elastance to the measured pressure will be the same at the same lung volume during inspiration or expiration. Full details of this method are available in Eames *et al.*[2]

The resistance of the ETT but not the resistance of the LMA was corrected. This correction was made based on a look-up table generated for the pressure decrease across the tube at any given flow. The pressure decrease across the tube for the inspiratory flow was subtracted from the pressure measured at the ETT connector to generate the inspiratory tracheal pressure, and the pressure decrease for the expiratory flow was added to the pressure measured at the ETT connector to generate an expiratory tracheal pressure. Before each study, the pneumotachograph (Capnomac Ultima, Datex Inc., Tewksbury, MA) was calibrated for volume using a 1-l syringe (Hans Rudolph, Kansas City, MO). Inhalation anesthesia was initiated using isoflurane to achieve an end-tidal value of 1% for 10 min and then the measurements were repeated. A subsequent dose of 1 mg/kg succinylcholine was administered to ensure that muscle tone did not affect respiratory system resistance. In patients with an LMA in place, the position was confirmed with fiberoptic laryngoscopy to ensure that the LMA was centrally placed and that a lumen existed that was sufficient to admit the scope to the level of the vocal cords without epiglottic obstruction. This examination was performed after all measurements were completed.

Table 1. Comparative Demographic and Hemodynamic Data for LMA *versus* ETT Patients

	LMA	ETT	Significance (*P*)
Age (yr)	52.7 ± 2.3	48.2 ± 3.0	NS
Sex (M/F)	24/2	21/5	NS
Smoker (Y/N)	18/8	14/12	NS
PEF (% predicted)	96 ± 0.04	90 ± 0.05	NS
After placement BP(mean, mmHg)	107.3 ± 6.2	125.5 ± 4.1	<0.05
BP following 10 min(mean, mmHg)	91.5 ± 4.4	92.9 ± 4.0	NS
After placement pulse (bpm)	70.9 ± 3.7	88.3 ± 3.2	<0.05
Pulse following 10 min(bpm)	70.3 ± 3.8	74.0 ± 3.0	NS

Data are mean ± SD.

LMA = laryngeal mask airway; ETT = endotracheal tube; PEF = peak expiratory flow; BP = blood pressure; NS = not significant.

Comparisons between the groups were made using the Student's *t* test for unpaired data, and within-group comparisons were made using the *t* test for paired data. Comparison of the gender distribution between groups was made using Fisher's exact test. Analysis of variance was used to assess the contribution of smoking history to the differences between groups. Data are presented as the mean ± SD.

Results

Table 1 shows the demographic and hemodynamic data for the entire study group and divided by the LMA and ETT groups. Peak expiratory flow as a fraction of the predicted value did not differ between the LMA and ETT groups. One patient was excluded because the LMA grille was obstructed completely by the epiglottis. Among patients with an LMA, the initial respiratory sys-

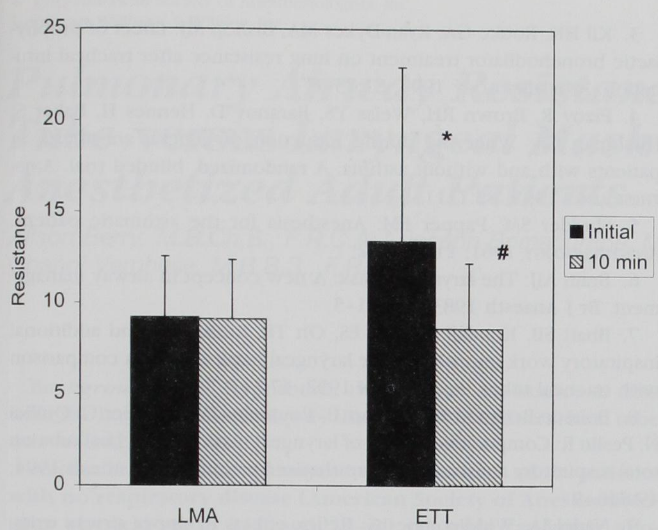

Fig. 1. Resistance after initial placement of a laryngeal mask airway and endotracheal tube and the value after 10 min of 1% isoflurane. Values are the mean ± SD, and resistance values are expressed in cm water · $l^{-1} \cdot s^{-1}$. *$P < 0.05$ *versus* laryngeal mask airway. #$P < 0.05$ *versus* the initial value.

tem resistance was significantly less than among patients with an ETT (fig. 1). After 10 min of isoflurane, the resistance decreased to 8.6 ± 3.6 cm water · $l^{-1} \cdot s^{-1}$ in the ETT group but remained unchanged at 9.1±3.3 cm water · $l^{-1} \cdot s^{-1}$ in the LMA group. The decrease in respiratory system resistance in the ETT group of 4.7 ± 7 cm water · $l^{-1} \cdot s^{-1}$ was highly significant compared with the lack of change in the LMA group ($P < 0.01$). Blood pressure and pulse after airway placement were significantly less for patients in the LMA group than among patients in the ETT group (table 1). There was no significant difference in smoking history between the two groups. A history of smoking exerted an independent effect on respiratory system resistance ($P < 0.02$), but analysis of variance showed a significant residual effect of ETT *versus* LMA on respiratory system resistance ($P < 0.05$ for the effect of airway in analysis of variance with smoking history as a factor).

Discussion

The findings of the current study show a reversible component of respiratory system resistance after ETT placement but not after LMA placement. Furthermore, the respiratory system resistance after ETT placement is substantially higher than after LMA placement. The difference in initial respiratory system resistance is even more remarkable considering that, for patients with LMAs, the resistance of the larynx is included in our measurement, whereas for patients with ETTs we measured resistance only for the respiratory system distal to the end of the ETT. Because of the potent bronchodilating effects of isoflurane,[12] the lack of any change in respiratory system resistance after 10 min of 1 minimum alveolar concentration anesthesia suggests that the LMA produces relatively little reversible bronchoconstriction.

Respiratory system resistance differed between groups in that the value for the LMA group included the resistance of the larynx and the LMA, whereas we used infraglottic pressures to determine resistance in the ETT group. We initially tried to use infraglottic pressures in the LMA group by placing a catheter through the vocal cords to measure infraglottic values. This would have permitted us to exclude laryngeal resistance from the LMA measurement, just as it is excluded from the ETT measurement. However, we could not reliably place the catheter without sometimes touching the vocal cords and risking provoking a reflex response. The difference in the respiratory system resistance measurement technique should have erred in favor of the resistance being higher in the LMA group. Not only was there a greater reversible component to respiratory system resistance after ETT placement, but the initial respiratory system resistance was less for the LMA, despite inclusion of the device and laryngeal resistance. Measurement of respiratory system resistance using the isovolume method necessitates that there be no significant leak of inspired gas. We used direct visualization to ensure proper seating of the LMA and listened for a leak. We verified that inspired and expired tidal volumes indicated no leak. A careful study of leak with properly seated LMA showed that only 1 of 30 patients had a leak at less than 20 cm water (at 19 cm), with the remaining 29 patients having no leak until 25 cm water,[13] which is consistent with our observation of only one failure resulting from an inability to maintain a seal.

Our study used thiopental as the induction agent to obviate any confounding effect from the bronchodilating effect of propofol.[2]

Although we hypothesized that the LMA would produce less bronchoconstriction because of the lack of direct tracheal stimulation, we also recognized that stimulation of the larynx can produce reflex effects on lung resistance.[9,14] These reflexes are mediated *via* the parasympathetic nervous system.[14] The extent of stimulation of the parasympathetic nervous system after placement of the LMA may be relatively minor, because the LMA covers the laryngeal inlet, but the actual contact is minimal.

Previous studies[15,16] have not evaluated the reflex response to placement of the LMA compared with an ETT. Ferguson *et al.*[15] reported that in awake volunteers airway resistance increased after placement of the laryngeal mask. However, this was in comparison with patients spontaneously breathing *via* their native airway rather than in comparison with an ETT. The increased resistance may be explained largely by the resistance of the device itself. Righini *et al.*[16] compared the additional inspiratory laryngeal mask airway and found that at the flow values we used, the resistance of a size-3 LMA would be relatively small compared with overall respiratory system resistance. For the size-5 LMA, the values would be even smaller, and in fact the pressure decrease across a size-5 LMA at the flows we used was too low to be measured reliably by our equipment.

The greater respiratory system response to ETT placement was also accompanied by a significant difference in cardiovascular response, consistent with previous studies.[17,18] Akbar *et al.*[19] found that an ETT group showed a 27% heart rate increase and a 42% mean arterial pressure increase compared with a 12% heart rate increase and a 23% mean arterial pressure increase in the LMA group after airway placement. Our study reports that the differences in reflex response extend beyond the sympathetic stimulation and include differences in airway responses. Our study supports the recent clinical observation that, in children with upper respiratory tract infections, bronchospasm was common after ETT placement but did not occur after LMA placement.[20] Based on our results and the results of this recent observational study, the LMA appears to be a viable alternative to mask anesthesia in patients at risk for significant airway reactivity, such as those with asthma or respiratory infections.

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