Anesthesiology
1999; 90:395-7

Lippincott Williams & Wilkins, Inc.

Pulmonary Airway Resistance with the Endotracheal Tube versus *Laryngeal Mask Airway in Paralyzed Anesthetized Adult Patients*

Alison Berry, M.B.Ch.B., F.R.C.A.,[*] Joseph Brimacombe, M.B.Ch.B., F.R.C.A., M.D.,[†] Christian Keller, M.D.,[‡] Chandi Verghese, M.B.B.S., F.R.C.A.[§]

Background: The hypothesis that airway resistance is less with the laryngeal mask airway than with the endotracheal tube was tested.

Methods: Thirty-six paralyzed, anesthetized adult patients with no respiratory disease (American Society of Anesthesiologists physical status 1–3; age, 18–80 yr) were randomly allocated (9 men, 9 women in each group) to receive either a size-4 laryngeal mask airway or an endotracheal tube (men, 9-mm ID; women, 8-mm ID). A pulmonary monitor with flow transducer and esophageal balloon was used to measure peak airway pressure and mean airway resistance (device resistance plus pulmonary airway resistance) at three different tidal volumes (5, 10, and 15 ml/kg). Device resistance was measured *in vitro* with the distal end of the endotracheal tube or laryngeal mask airway open to the atmosphere and using the same ventilator settings. Pulmonary airway resistance was derived by subtracting the mean device resistance from the mean airway resistance.

Results: Peak airway pressure, mean airway resistance, device resistance, and pulmonary airway resistance were greater for the endotracheal tube (all $P < 0.0001$).

Conclusions: The laryngeal mask airway triggers less bronchoconstriction than does the endotracheal tube in paralyzed anesthetized adult patients. This may have implications for maintaining intraoperative pulmonary function and reducing the risk for atelectasis and pulmonary infection. (Key words: Anesthesia complications; atelectasis; bronchospasm; equipment; work of breathing.)

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

THE laryngeal mask airway (LMA) forms an airtight seal with the upper respiratory tract and is used widely in anesthesia practice.[1] Proved advantages compared with the endotracheal tube (ETT) include an attenuated hemodynamic stress response to insertion and removal, less coughing during emergence, fewer occurrences of postoperative sore throat, and less interference with mucociliary clearance.[2,3] Many of these advantages are possible because the highly innervated larynx and upper trachea are not penetrated.[4] Tracheal intubation produces reflex irritation and increased resistance in the airways distal to the tube.[5] We tested the hypothesis that pulmonary airway resistance is less for the LMA compared with the ETT.

Methods

Thirty-six consecutive patients, classified as American Society of Anesthesiologists physical status 1-3 and undergoing surgery in the supine position were randomly allocated to receive anesthesia through a size-4 LMA or an ETT. The local hospital ethics board approved the study, and all participants gave their written informed consent. Patients were excluded if they were younger than 18 yr or older than 80 yr, weighed less than 50 kg, had respiratory tract disease, were at risk for aspiration, or were taking medication that might trigger bronchospasm. In the ETT group, men (n = 9) received a 9-mm ID ETT, and women (n = 9) received an 8-mm ETT (Portex, Hythe, UK). In the LMA group, men (n = 9) and women (n = 9) received a size-4 LMA. Respiratory variables were measured and analyzed using a pulmonary monitor (CP-

---

[*] Staff Anesthesiologist, Department of Anaesthesia and Intensive Care, Nambour General Hospital, Nambour, Australia.

[†] Clinical Professor, University of Queensland, Department of Anaesthesia and Intensive Care, Cairns Base Hospital, Cairns, Australia.

[‡] Resident Anaesthetist, Department of Anaesthesia and Intensive Care Medicine, Leopold-Franzens University, Innsbruck, Austria.

[§] Consultant in Intensive Care and Anaesthesia, Royal Berkshire Hospital, Reading, Berkshire, United Kingdom.

Received from the Department of Anaesthesia and Intensive Care, Cairns Base Hospital, Cairns, Australia. Submitted for publication July 15, 1998. Accepted for publication October 21, 1998. Intavent Research Ltd. provided support to lease the CP-100 pulmonary monitor and for the esophageal catheters used in this study.

Address reprint requests to Dr. Brimacombe: Department of Anaesthesia and Intensive Care, Cairns Base Hospital, Cairns 4870, Australia. Address electronic mail to: 100236,2343@compuserve.com

100; BiCore Monitoring System, Irvine, CA) attached to a variable-orifice pneumotachograph (Var flex; Allied Health Products, Riverside, CA) and an esophageal balloon catheter (Smart Cath, Allied Health Products).[6-8] The catheter is an 8-French, 69-cm medical-grade polyurethane device that is connected directly to the catheter port on the monitor (BiCore). The balloon has a 0.9-cm diameter and is 10 cm long, with a frequency response of 30 Hz. The monitoring system (BiCore) automatically performs a vacuum leak test and fills the esophageal balloon with 0.8 ml of air.

A standard anesthesia protocol was followed and routine monitoring was applied. Anesthesia was induced with 1 μg/kg fentanyl and 2.5 mg/kg propofol. Anesthesia was maintained with 1.5% isoflurane and 33% oxygen in N_2O until all measurements were complete. Muscle relaxation was accomplished using 0.1 mg/kg vecuronium and 0.03 mg/kg boluses if the train-of-four count was more than one. The esophageal balloon catheter was introduced through the nose and fed into position (mid esophagus) using Magill's forceps. The LMA was inserted and fixed according to the manufacturer's instructions.[9] The ETT (cut to 25 cm) was inserted using a laryngoscope, and the cuff was positioned in the proximal trachea, immediately distal to the vocal cords. The ETT cuff was inflated with 4-8 ml air, and the LMA was inflated with 25-30 ml air. Airway function was assessed using gentle hand ventilation, observation of synchronized bilateral expansion of the chest, auscultation, and capnography. The pneumotachograph was connected directly to the proximal end of the airway tube. Airway pressure was measured at the pneumotachograph. The carbon dioxide sampling port was situated above the flow transducer. The same connectors were used for each type of airway. The position of the esophageal balloon catheter was checked and adjusted when necessary by observation of the cardiac artifact on the esophageal waveform, as recommended by the manufacturer. The machine pop-off valve was set at 40 cm of water. The flow transducer was calibrated for the anesthesia gas mixture.

Controlled ventilation with a constant square wave inspiratory flow profile was started. The tidal volumes were set using the CP-100 expiratory tidal volume reading from the flow transducer to avoid error caused by leaks in the breathing system. Respiratory rates were adjusted to achieve constant end-tidal carbon dioxide levels of 30 mmHg. The inspiratory:expiratory ratio was 1:2 and was held constant. Peak inspiratory pressure and mean airway resistance (transpulmonary pressure divided by the difference in flow taken at the same volume during both inspiration and expiration[10]) were recorded during 10 respiratory cycles when the end-tidal carbon dioxide level was stable. This was repeated at three different tidal volumes: 5, 10, and 15 ml/kg. Measurements began 5-10 min after induction of anesthesia and were completed before surgery began. Mean device resistance was measured *in vitro* at the same ventilator settings used for each patient. Measurements were repeated on 10 occasions for each ventilator setting and were made with the distal end of the ETT or LMA open to the atmosphere. Pulmonary airway resistance was calculated by subtracting device resistance from mean airway resistance. The leak fraction was measured by noting the difference between the inspired and expired tidal volume. Any data collected when the leak was 3% or more were excluded from the analysis.

Table 1. Demographic Data for Laryngeal Mask Airway (LMA) and Tracheal Tube (TT) Groups

	LMA	TT	*P* Value
Age (yr)	57 ± 18	60 ± 21	NS
Height (cm)	175 ± 13	180 ± 11	NS
Weight (kg)	78 ± 14	77 ± 22	NS
ASA 1/2/3 (n)	9/6/3	8/7/3	NS

Values are mean ± SD.

NS = not significant.

Data was analyzed using the Student's *t* test and analysis of variance for repeated measures. Unless otherwise stated, data are presented as the mean ± SD. Differences were considered significant at $P < 0.05$.

Results

There were no demographic differences between groups (table 1). Two patients in the LMA group had a leak of 3% or more at 15 ml/kg, and two patients in the ETT group could not be ventilated at 15 ml/kg, because the peak inspiratory pressure was more than 40 cm of water. These patients were excluded from the analysis at 15 ml/kg. No patient had clinically detectable bronchospasm at auscultation. Peak airway pressure, mean airway resistance, device resistance, and pulmonary airway resistance were less when the LMA was used (table 2).

Discussion

Gal and Surratt[5] showed that tracheal intubation caused a doubling of airway resistance in awake healthy

Table 2. Peak Inspiratory Pressure and Airway Resistances for the Laryngeal Mask Airway (LMA) and Tracheal Tube (TT) at Three Different Tidal Volumes (TV)

	TV (ml/kg)	LMA	TT	*P* Value
Peak inspiratory pressure ($cm\ H_2O$)	5	14.4 ± 3.7	16.5 ± 5.0	
	10	19.1 ± 7.1	24.6 ± 6.1	<0.0001
	15	24.0 ± 4.9	28.1 ± 6.1	
Mean airway resistance ($cm\ H_2O\ L^{-1}\ s^{-1}$)	5	5.1 ± 2.9	9.1 ± 4.7	
	10	5.5 ± 3.3	9.9 ± 4.4	<0.0001
	15	5.0 ± 2.4	10.8 ± 4.6	
Device resistance ($cm\ H_2O\ L^{-1}\ s^{-1}$)	5	1.7 ± 0.1	3.9 ± 0.2	
	10	1.7 ± 0.1	3.8 ± 0.1	<0.0001
	15	1.7 ± 0.1	3.8 ± 0.2	
Pulmonary airway resistance ($cm\ H_2O\ L^{-1}\ s^{-1}$)	5	3.4 ± 2.9	5.6 ± 4.7	
	10	3.8 ± 3.3	6.3 ± 4.4	<0.0001
	15	3.3 ± 2.4	7.2 ± 4.6	

Values are mean ± SD.

patients with topically anesthetized airways. They considered that this represented reflex bronchoconstriction because of the mechanical irritation of the tube. Patients with chronic obstructive pulmonary disease showed an even greater response. We showed that the LMA has lower pulmonary airway resistance than the ETT in paralyzed anesthetized patients, suggesting that the LMA triggers less reflex bronchoconstriction than the ETT. Pulmonary airway resistance for the LMA included glottic resistance (considered to be 33% of upper airway resistance in awake patients[11]), suggesting that the difference in the subglottic component of pulmonary airway resistance is even greater between the devices.

Our results are in contrast with those of Boisson-Bertrand *et al.*,[12] who performed a crossover study of 10 ventilated patients and showed that pulmonary airway resistance was similar between the LMA and ETT groups.[12] These differences in results may be related to the use of both airway devices in each patient, avoidance of muscle relaxants, and inclusion of patients with pulmonary disease or bronchoconstricting drugs in their study. Our data for device resistance is similar to that of a previous study.[13]

The LMA triggers less bronchoconstriction than does the ETT in paralyzed anesthetized adult patients. This may have implications for maintaining intraoperative pulmonary function and reducing the risk of atelectasis and pulmonary infection.

The authors thank Drs. D. Mecklem, M. Scully, and H. J. Sparr for advice with the manuscript.

References

1. Brimacombe J, Brain AIJ, Berry A: The Laryngeal Mask Airway: Review and Practical Guide. London, WB Saunders, 1997
2. Brimacombe J: The advantages of the LMA over the tracheal tube or facemask: A meta-analysis. Can J Anaesth 1995; 42:1017-23
3. Keller C, Brimacombe JR: Bronchial mucus transport velocity in paralyzed anesthetized patients: A comparison of the laryngeal mask airway and cuffed tracheal tube. Anesth Analg 1998; 86:1280-2
4. Brimacombe J, Berry A: The laryngeal mask airway—anatomical and physiological implications. Acta Anaesthesiol Scand 1996; 40: 201-9
5. Gal TJ, Suratt PM: Resistance to breathing in healthy subjects following endotracheal intubation under topical anesthesia. Anesth Analg 1980; 59:270-4
6. Petros AJ, Lamond CT, Bennett D: The Bicore pulmonary monitor. A device to assess the work of breathing while weaning from mechanical ventilation. Anaesthesia 1993; 48:985-8
7. Banner MJ, Kirby RR, Blanch PB, Layon AJ: Decreasing imposed work of the breathing apparatus to zero using pressure-support ventilation. Crit Care Med 1993; 21:1333-8
8. Thomas AM, Turner RE, Tenholder MF: Esophageal pressure measurements in cardiopulmonary exercise testing. Chest 1997; 112: 829-32
9. Brimacombe J, Brain AIJ, Berry A: The Laryngeal Mask Airway Instruction Manual. Henley-on-Thames, UK, Intavent Research Limited, 1996
10. Frank NR, Mead J, Ferris BG: The mechanical behaviour of the lungs in healthy elderly patients. J Clin Invest 1957; 36:1680-6
11. Tully A, Brantiscano T, Loring SH, Engel LA: Influence of posterior cricoarytenoid muscle activity on pressure-flow relationship of the larynx. J Appl Physiol 1991; 70:2252-8
12. Boisson-Bertrand D, Hannhart B, Rousselot JM, Duvivier C, Quilici N, Peslin R: Comparative effects of laryngeal mask and tracheal tube on total respiratory resistance in anaesthetised patients. Anaesthesia 1994; 49:846-9
13. Brimacombe J, Dunbar-Reid K: The effect of introducing fibreoptic bronchoscopes on gas flow in laryngeal masks and tracheal tubes. Anaesthesia 1996; 51:923-8