

## Prospective Comparison of Use of the Laryngeal Mask and Endotracheal Tube for Ambulatory Surgery

Randall C. Cork, MD, PhD\*, Raymond M. DePa, BA†, and James R. Standen, MD†

\* Department of Anesthesiology, Louisiana State University Medical Center, New Orleans, Louisiana, and †Department of Radiology, Arizona Health Sciences Center, Tucson, Arizona

We examined the response to the laryngeal mask (LM) compared to the endotracheal tube (ETT) in patients undergoing ambulatory anesthesia. The differences in management by the anesthesiologists for these two airways were also examined. Peripheral orthopedic procedures were studied in 44 outpatients randomized to receive a LM or ETT, and either spontaneous or controlled ventilation. Anesthesia was induced with propofol and succinylcholine intravenously (IV) and maintained with N<sub>2</sub>O and isoflurane. Anesthesiologists were allowed to determine ventilatory variables and anesthetic concentration. Hemodynamic and ventilatory measurements were made during the anesthesia. Barium sulfate was poured into the oropharynx after the airway was secure. Fiberoptic examination through the LM was performed at the beginning and at the end of the administration of each anesthetic. Radiographs were taken at the end of the anesthetic administration before LM or ETT removal to look for barium in the trachea. After airway removal, presence of blood on the airway, sore throat, coughing, nausea, vomiting, shivering, and amount of morphine demanded during recovery were noted. No barium in the trachea or

bronchial tree was seen in any of the radiographs. The ETT was associated with greater hemodynamic response not only to airway placement ( $P < 0.05$ ), but also to surgical incision ( $P < 0.05$ ) and airway removal ( $P < 0.05$ ). Spontaneous or controlled ventilation favored neither airway, although the ETT was associated with increased work of inspiration with controlled ventilation ( $P < 0.05$ ). Anesthesiologists tended to elect smaller tidal volumes, faster ventilation rates, and lower anesthetic concentrations for patients with the LM ( $P < 0.05$ ). The ETT resulted in more coughing after removal ( $P < 0.05$ ) than did the LM. Less morphine was required after removal of the LM ( $8.1 \pm 2.2$  mg) than after removal of the ETT ( $14.8 \pm 2.7$ ) ( $P < 0.05$ ). Both the LM and ETT protected the trachea from dilute barium placed in the oropharynx. The LM elicited less hemodynamic response to placement, incision, and removal than the ETT. Anesthesiologists manage the LM differently than the ETT. The LM induced less coughing at removal, and less analgesic was required during recovery.

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The laryngeal mask (LM) has become a very popular means of airway control. A recent review (1) shows a large number of case reports and letters relating to its use, but only a small number of randomized prospective studies. Notable among the prospective studies are those that have observed radiologic and fiberoptic examination of positioning (2), airway protection (3), work of inspiration (4), and hemodynamic response to insertion (5).

The LM is used for controlled ventilation as well as spontaneous ventilation; however, do anesthesiologists implement controlled ventilation the same way with a LM as with an endotracheal tube (ETT)? Standard recommendations for tidal volume for the

patient undergoing anesthesia with an ETT is 10-15 mL/kg, which decreases atelectasis, improves compliance, and eliminates the need for "sigh" breaths. Ventilation rate is usually set at 8-10 breaths/min, and subsequently adjusted to the desired P<sub>ETCO<sub>2</sub></sub>. The first hypothesis addressed was that anesthesiologists trained in the use of the LM would tend to ventilate patients at smaller tidal volumes due to fear of putting too much pressure on the pressure seal of LM to mucosa.

That placement of the LM results in less hemodynamic response compared to placement of an ETT implies that placement of the LM results in less nociceptive stimulation than laryngoscopy and insertion of an ETT. The second hypothesis addressed was that subsequent stimuli after LM placement (skin incision, removal of the airway) would result in more hemodynamic response, as measured by arterial blood pressure and heart rate, than subsequent stimuli after

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Address correspondence to Randall C. Cork, MD, PhD, Department of Anesthesiology, Louisiana State University Medical Center, 1542 Tulane Ave., New Orleans, LA 70112-2822.

ETT placement. A corollary to this was that given the freedom to adjust vaporizer concentrations, anesthesiologists would tend to administer a higher concentration of anesthetic if an ETT were in place, compared to a LM.

## Methods

After approval by our institutional human-subjects committee and informed consent, 44 patients scheduled for outpatient peripheral orthopedic surgery were randomized with two coin flips to receive 1) LM or ETT and (2) spontaneous or controlled ventilation. Obese patients and patients with a history of gastroesophageal reflux were excluded. Eight anesthesiologists volunteered to participate in the study. Each anesthesiologist, trained in placement of the LM using the technique described by Brain (6), was told that the purpose of the study was to observe the protection provided by the LM to the trachea when dilute barium was poured into the patient's mouth. They were not told that ventilation variables, hemodynamic response, and amount of anesthetic administered were also recorded. Demographic data collected from each patient included age, weight, height, and sex. Additional preoperative information collected included ASA physical status, smoking history, and Mallampatti airway assessment (7).

No preoperative medication was given. Anesthesia was induced with propofol 2.5 mg/kg intravenously. At loss of eyelid reflex, succinylcholine 1.5 mg/kg was administered intravenously. One minute later, either a LM or an ETT was placed for airway control. Size 3 LM was used for females; size 4 LM was used for males. Twenty milliliters of air was injected into the cuff of the size 3 LM and 30 ml of air into the size 4 LM. A Macintosh size 3 laryngoscope was used to insert a 7.5-mm ETT for women and an 8.0-mm ETT for men. Anesthesia was maintained with O<sub>2</sub> 33%, N<sub>2</sub>O 67%, and isoflurane 1%–2%. No intraoperative opiates were administered. The anesthesiologists were given full reign to administer whatever concentration of isoflurane and to deliver whatever tidal volume and ventilatory rate desired. Oxygen, CO<sub>2</sub>, N<sub>2</sub>O, and percent isoflurane were measured with Raman gas analysis (Rascal™; Albion Instruments, Salt Lake City, UT). Gas sampling was continuous from the junction of the circle system and the LM airway or ETT. Neuromuscular block (for those patients with controlled ventilation) was maintained with vecuronium titrated so that one twitch of a train-of-four was visible. Cuff pressure for the ETT was maintained at 25 cm H<sub>2</sub>O, and pop-off pressure for the LM was measured after insertion, 1 min prior to incision, 1 min after incision, and at the last skin stitch. At the last skin stitch,

neostigmine and glycopyrrolate were used for reversal of neuromuscular block, and the N<sub>2</sub>O and isoflurane were discontinued. Time intervals recorded included 1) anesthesia time, 2) surgery time, 3) airway time, 4) removal time (last stitch to airway removal), 5) awakening time (last stitch to responding to command), and 6) recovery time. Also, time taken to place the airway was noted. The LM and ETT were removed when the patient responded to command.

Fifteen milliliters of 10% barium sulfate was poured into the oropharynx of all patients after skin incision. A fiberoptic examination was then performed through the LM to verify placement and to look for barium. At the end of the procedure, as much barium sulfate as possible was suctioned from the oropharynx. The fiberoptic examination was repeated for patients with the LM, and an anterior-posterior radiograph of the upper chest and neck was taken. A lateral radiograph of the neck was done prior to suctioning the barium. Noted for each fiberoptic examination were 1) if barium was seen, 2) if blood or other secretions were seen, 3) if the esophageal opening was seen, and 4) if the epiglottis was seen between the bars in the LM.

Systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), and heart rate (HR) were measured throughout the procedure. Specific measurements were recorded at the following times: 1) awake, prior to induction; 2) after anesthetic induction, prior to LM or ETT insertion; 3) 2 min after airway insertion; 4) prior to surgical incision; 5) 2 min after incision; 6) prior to LM or ETT removal; 7) 2 min after removal; 8) on admission to the postanesthesia care unit (PACU); and 9) at discharge from the PACU.

Tidal volume and ventilatory rate were not set by protocol; each anesthesiologist set them as desired. The anesthesiologists were not told that these variables were being recorded. An intensive care unit VRP™ respiratory monitor (Research Development Corp., San Francisco, CA) was used to measure the following ventilation variables: tidal volume, minute ventilation, respiratory rate, compliance, resistance, work of inspiration, mean airway pressure, and maximum airway pressure. Resistance measured was non-elastic resistance, reflecting mainly airway resistance. Compliance measured included compliance of the chest wall as well as the lung. Pop-off pressure for the LM was determined by closing the pop-off valve and inflating the circuit until flow escaped around the LM. Ventilation variables were recorded 1) at 2 min after airway insertion, 2) immediately prior to skin incision, 3) 2 min after skin incision, and 4) at the last skin stitch.

PACU variables recorded after removal of the airway included presence of blood on the airway, sore throat, coughing, nausea, vomiting, shivering, and

amount of morphine administered in the PACU. Morphine 2 mg was administered for pain in the PACU as often as the patient requested it. However, at least 5 min was required between doses. The anesthesiologist who inserted the airway was asked whether he or she would grade the ease of insertion as "easy" or "difficult," and the experience of the anesthesiologist was noted. Aldrete scores (8) were determined by the PACU nurse at 15, 30, 45, and 60 min after PACU admission, and at discharge from the PACU. Amount of time in the PACU was recorded.

Data were analyzed with repeated-measures analysis of variance (ANOVA) for the between-subjects effects (type of airway and ventilation) and within-subjects effects (measurements repeated during the study). Two-way ANOVA with repeated measures enabled the examination of the independent effects of airway and ventilation, as well as their interactions.  $\chi^2$  analysis was used for comparison of categorical variables.

Power analysis for a two-way ANOVA shows that a 5% change in a dependent variable, with SD of 5% of the mean and  $n = 22$  at each level, is detectable with a power of 0.89 and  $\alpha = 0.05$ .

Continuous data are reported as mean  $\pm$  SE. Significance is defined as  $P < 0.05$ .

## Results

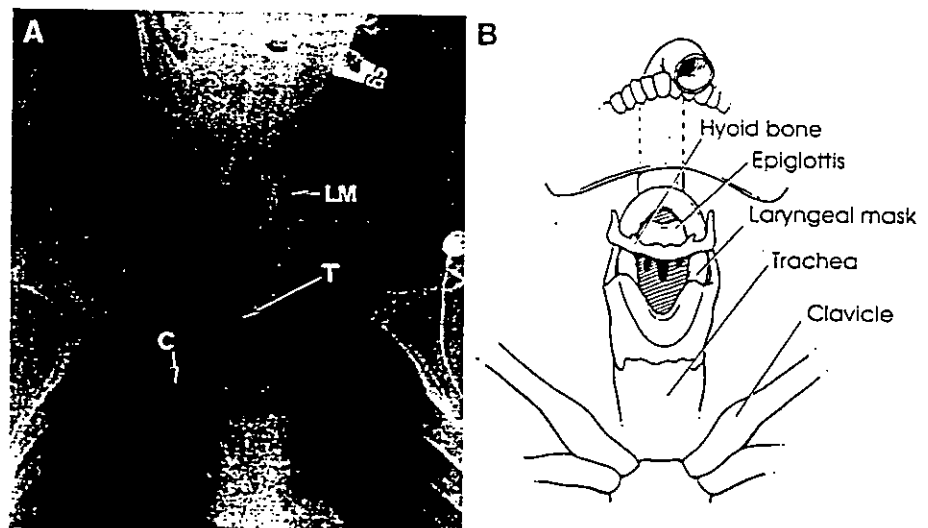
No differences between groups (LM versus ETT, spontaneous versus controlled ventilation) were observed in age, weight, height, sex, ASA physical status, smoking history, and Mallampatti airway assessment score. Table 1 lists the demographic comparisons. Time to placement for the LM was  $8.8 \pm 2.0$  s (mean  $\pm$  SEM), as compared to  $6.3 \pm 1.2$  s for the ETT, not a significant difference. Time to placement was not associated with Mallampatti airway assessment. There were no failed attempts at either LM or ETT placement. Total anesthesia time, surgery time, airway time, removal time (from last stitch to removal), and awakening time (last stitch to response to command) were not significantly associated with type of airway or mode of ventilation.

No barium was seen within the LM on any of the fiberoptic examinations. The opening to the esophagus was not seen on any of the examinations. Vocal cords were seen in 20 of the 22 patients examined (12 with spontaneous ventilation, 8 with controlled ventilation). In the remaining 2 patients, the fiberoptic scope could not be maneuvered around the epiglottis. Blood or secretions within the LM were seen in 6 patients (4 spontaneous, 2 controlled). The epiglottis was positioned between the bars in 18 patients (11

Table 1. Comparison of Groups

	Laryngeal mask		Endotracheal tube	
	Spontaneous ( $n = 13$ )	Controlled ( $n = 9$ )	Spontaneous ( $n = 9$ )	Controlled ( $n = 13$ )
Age (yr)	45 $\pm$ 5	41 $\pm$ 3	39 $\pm$ 5	41 $\pm$ 6
Weight (kg)	75 $\pm$ 5	81 $\pm$ 6	81 $\pm$ 3	73 $\pm$ 4
Height (cm)	174 $\pm$ 3	173 $\pm$ 4	171 $\pm$ 4	172 $\pm$ 3
Sex (M/F)	10/3	6/3	8/1	11/2

Figure 1. A, Anterior-posterior chest radiograph taken with patient in supine position at end of procedure prior to awakening. Most barium sulfate has been suctioned, but traces remain outlining the laryngeal mask. No barium sulfate is seen in the trachea or bronchial tree. LM = laryngeal mask; T = trachea; C = clavicle. B, Drawing of similar anatomic perspective as radiograph.



spontaneous, 7 controlled). For all 22 patients examined, the examination did not change between the initial examination after skin incision and the second examination at the end of the procedure. None of the anterior-posterior chest radiographs showed any barium in the trachea or bronchial tree (Fig. 1). The lateral neck radiograph in Figure 2 reveals how the barium pools behind the LM in the supine position.

Throughout the anesthetic and recovery, there was no effect of intraoperative mode of ventilation (spontaneous versus controlled) on SBP, DBP, MBP, and HR. However, there was a significant effect of type of

airway on SBP, DBP, MBP, and HR after airway insertion and after airway removal. Both insertion and removal of the ETT were much more hemodynamically stimulating than were insertion and removal of the LM ( $P < 0.05$ ). Figure 3 illustrates the changes in SBP, DBP, MBP, and HR at airway insertion, skin incision, and airway removal. At skin incision the increases in blood pressure were significant for the ETT compared to the LM ( $P < 0.05$ ), but no changes in HR as a function of airway were observed.

Ventilation variables and end-tidal isoflurane concentrations are listed in Table 2 for each measurement

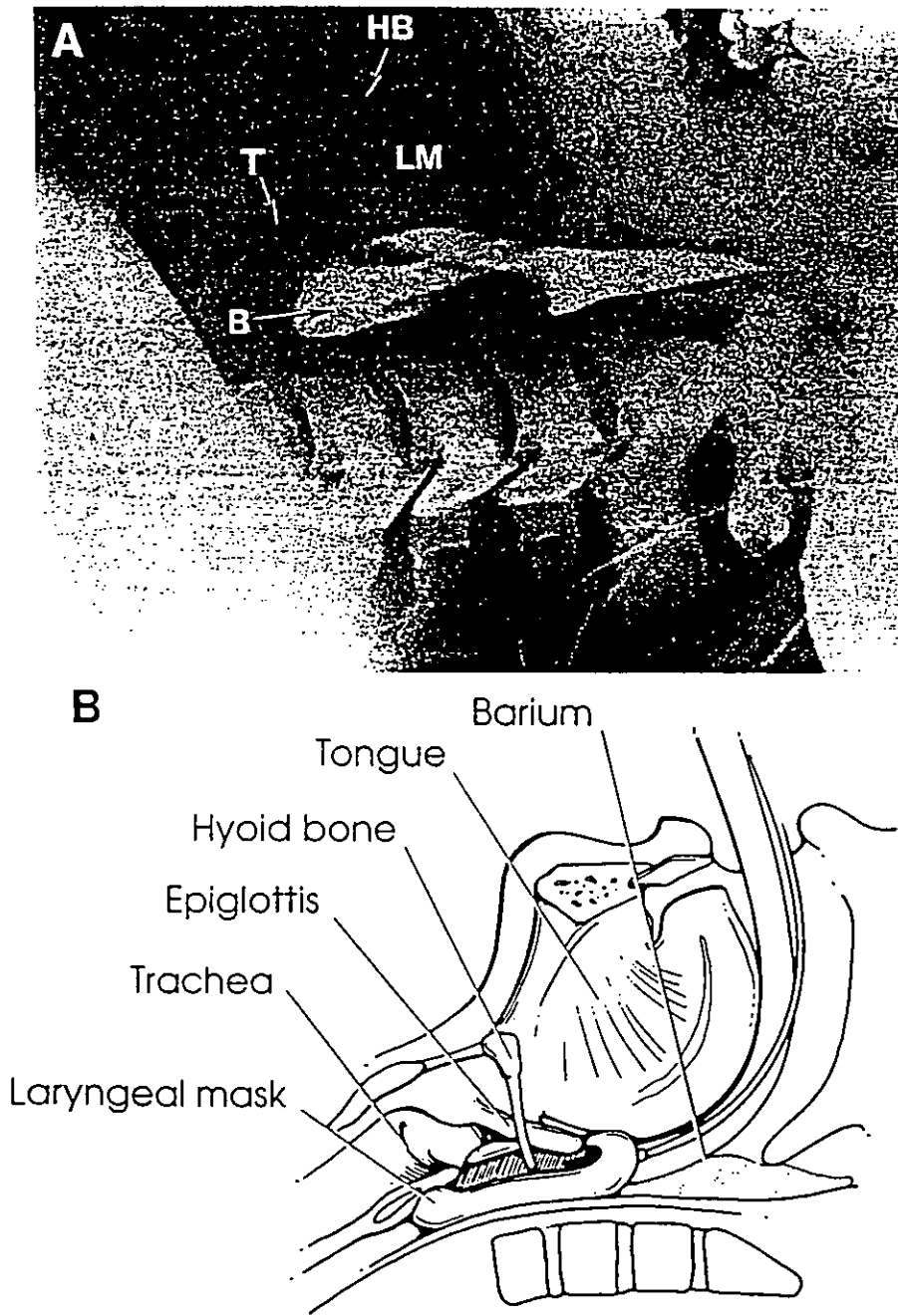


Figure 2. A, Lateral radiograph taken with patient in supine position at end of operative procedure and prior to suctioning the barium sulfate, which can be seen pooled in the posterior oropharynx. LM = laryngeal mask; T = trachea; HB = hyoid bone; B = barium. B, Drawing of similar anatomic perspective as radiograph.

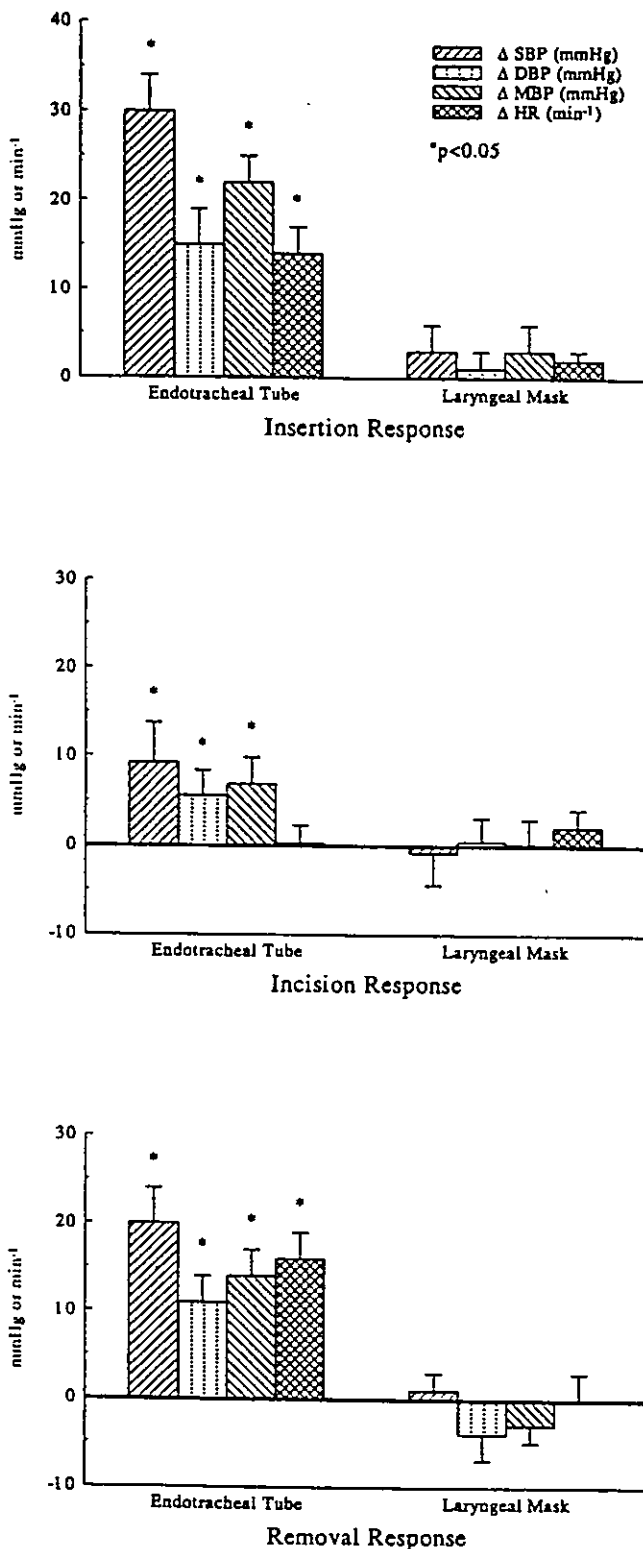


Figure 3. Hemodynamic responses to airway insertion, skin incision, and airway removal.  $\Delta$ SBP = change in systolic blood pressure (mm Hg);  $\Delta$ DBP = change in diastolic blood pressure (mm Hg);  $\Delta$ MBP = change in mean blood pressure (mm Hg); and  $\Delta$ HR = change in heart rate ( $\text{min}^{-1}$ ; bpm). All hemodynamic responses were significantly higher with the endotracheal tube ( $P < 0.05$ ), except for no difference in heart rate response to skin incision.

time: postinsertion, preincision, postincision, and at the last stitch. Tidal volumes, ventilation rates, and anesthetic concentrations were independently decided by each anesthesiologist, each unaware that these variables were being recorded.

With postinsertion the LM was associated with smaller tidal volumes, faster ventilation rates, lower work of inspiration, lower mean airway pressures, lower maximum airway pressures, and lower end-tidal anesthetic concentrations compared to the ETT ( $P < 0.05$ ). Spontaneous ventilation was associated with lower minute ventilation and lower maximum airway pressures compared to controlled ventilation ( $P < 0.05$ ).

With preincision the LM was associated with higher minute ventilation, lower airway resistance, lower work of inspiration, and lower end-tidal anesthetic concentrations compared to the ETT ( $P < 0.05$ ). Spontaneous ventilation was associated with lower tidal volumes, lower minute ventilation, higher ventilation rates, lower compliance, lower mean and maximum airway pressures, and higher  $\text{ETCO}_2$  compared to controlled ventilation ( $P < 0.05$ ).

At postincision the LM was associated with lower work of inspiration and lower end-tidal anesthetic concentrations compared to the ETT ( $P < 0.05$ ). Spontaneous ventilation was associated with lower tidal volumes, lower minute ventilation, higher ventilation rate, lower compliance, lower mean and maximum airway pressures, and higher  $\text{ETCO}_2$  compared to controlled ventilation ( $P < 0.05$ ).

With last stitch the LM was associated with lower work of inspiration compared to the ETT ( $P < 0.05$ ). Spontaneous ventilation was associated with lower tidal volumes, faster ventilation rate, lower compliance, and lower mean and maximum airway pressure ( $P < 0.05$ ).

PACU outcome variables of interest are listed in Table 3. No differences were observed based on type of airway used except for the incidence of coughing after removal and amount of analgesic demanded in the PACU. More patients coughed after removal of an ETT than after removal of a LM ( $P < 0.05$ ). Patients who had received a LM demanded less morphine in the PACU ( $8.1 \pm 2.2$  mg) than patients who had received an ETT ( $14.8 \pm 2.7$  mg) ( $P < 0.05$ ). There was no difference between the LM and ETT in perceived degree of difficulty of airway placement. Perceived degree of difficulty was not associated with years of experience of the anesthesiologist. Aldrete recovery scores in the PACU every 15 min for an hour and at discharge from the PACU are listed in Table 4. After 15 min in the PACU, patients with the LM scored significantly lower than those with an ETT ( $P < 0.05$ ). At 30 min, and from then on, there was no airway effect.

Table 2. Ventilation and Anesthetic Concentration

	Laryngeal mask		Endotracheal tube	
	Spontaneous (n = 13)	Controlled (n = 9)	Spontaneous (n = 9)	Controlled (n = 13)
Postinsertion				
Tidal volume (L) <sup>a</sup>	0.59 ± 0.09	0.59 ± 0.08	0.80 ± 0.11	0.86 ± 0.06
Minute ventilation (L/min) <sup>b</sup>	6.79 ± 0.78	8.80 ± 0.82	6.38 ± 0.41	7.66 ± 0.70
Ventilation rate (breaths/min) <sup>a</sup>	18.7 ± 3.0	21.0 ± 3.6	11.8 ± 2.3	9.6 ± 1.1
Compliance (mL/cm H <sub>2</sub> O)	63.8 ± 2.4	66.7 ± 5.9	53.0 ± 7.3	68.5 ± 5.5
Resistance (cm H <sub>2</sub> O·L <sup>-1</sup> ·s <sup>-1</sup> )	13.8 ± 1.9	9.2 ± 1.7	16.0 ± 3.4	15.8 ± 2.7
Work of inspiration (kg·m·min <sup>-1</sup> ) <sup>a</sup>	0.74 ± 0.10	0.69 ± 0.07	1.41 ± 0.23	1.46 ± 0.81
Mean airway pressure (cm H <sub>2</sub> O) <sup>a</sup>	5.9 ± 0.7	7.3 ± 0.6	7.8 ± 0.6	8.5 ± 0.9
Maximum airway pressure (cm H <sub>2</sub> O) <sup>a,b</sup>	8.7 ± 1.0	15.2 ± 1.0	11.4 ± 0.8	25.3 ± 2.8
Pop-off pressure (cm H <sub>2</sub> O)	26.4 ± 1.8	23.8 ± 2.2		
ETco <sub>2</sub> (mm Hg)	37 ± 2	34 ± 1	35 ± 1	36 ± 1
ET isoflurane (%) <sup>a</sup>	0.97 ± 0.12	1.03 ± 0.20	1.37 ± 0.20	1.22 ± 0.10
Preincision				
Tidal volume (L) <sup>b</sup>	0.51 ± 0.09	0.70 ± 0.08	0.55 ± 0.22	0.89 ± 0.05
Minute ventilation (L/min) <sup>a,b</sup>	7.25 ± 0.59	8.56 ± 1.06	4.66 ± 0.48	7.71 ± 0.61
Ventilation rate (breaths/min) <sup>b</sup>	19.3 ± 2.5	17.0 ± 2.8	20.7 ± 3.1	9.3 ± 1.1
Compliance (mL/cm H <sub>2</sub> O) <sup>b</sup>	65.8 ± 2.4	74.7 ± 5.9	57.0 ± 8.2	70.8 ± 4.9
Resistance (cm H <sub>2</sub> O·L <sup>-1</sup> ·s <sup>-1</sup> ) <sup>a</sup>	12.6 ± 1.9	10.9 ± 3.3	16.7 ± 3.4	17.0 ± 3.4
Work of inspiration (kg·m·min <sup>-1</sup> ) <sup>a</sup>	0.78 ± 0.10	0.79 ± 0.17	1.07 ± 0.23	1.32 ± 0.20
Mean airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	6.4 ± 1.0	7.9 ± 1.1	4.6 ± 0.8	9.6 ± 1.1
Maximum airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	10.2 ± 1.7	17.8 ± 2.9	7.0 ± 1.2	23.6 ± 2.2
Pop-off pressure (cm H <sub>2</sub> O)	26.4 ± 1.8	23.8 ± 2.2		
ETco <sub>2</sub> (mm Hg) <sup>b</sup>	36.8 ± 2.2	30.6 ± 1.8	41.2 ± 2.8	31.8 ± 2.0
ET isoflurane (%) <sup>a</sup>	0.77 ± 0.08	0.87 ± 0.19	1.48 ± 0.11	1.39 ± 0.10
Postincision				
Tidal volume (L) <sup>b</sup>	0.42 ± 0.06	0.62 ± 0.08	0.31 ± 0.06	0.86 ± 0.05
Minute ventilation (L/min) <sup>b</sup>	6.75 ± 0.67	7.23 ± 1.08	4.69 ± 0.82	7.38 ± 0.44
Ventilation rate (breaths/min) <sup>b</sup>	21.4 ± 2.5	16.2 ± 2.2	19.8 ± 3.6	9.5 ± 1.4
Compliance (mL/cm H <sub>2</sub> O) <sup>a,b</sup>	66.0 ± 1.8	70.3 ± 5.5	47.3 ± 6.2	67.2 ± 4.9
Resistance (cm H <sub>2</sub> O·L <sup>-1</sup> ·s <sup>-1</sup> )	13.2 ± 1.9	10.8 ± 3.6	14.2 ± 1.8	16.5 ± 3.0
Work of inspiration (kg·m·min <sup>-1</sup> ) <sup>a</sup>	0.77 ± 0.10	0.72 ± 0.11	1.51 ± 0.18	1.42 ± 0.23
Mean airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	6.4 ± 0.9	8.0 ± 1.1	4.7 ± 1.3	8.9 ± 0.8
Maximum airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	9.4 ± 1.2	17.3 ± 2.9	7.2 ± 2.0	22.9 ± 2.2
Pop-off pressure (cm H <sub>2</sub> O)	25.2 ± 1.5	23.0 ± 2.4		
ETco <sub>2</sub> (mm Hg) <sup>b</sup>	39 ± 2	33 ± 2	43 ± 3	32 ± 2
ET isoflurane (%) <sup>a</sup>	0.96 ± 0.10	0.98 ± 0.16	1.49 ± 0.14	1.33 ± 0.12
Last stitch				
Tidal volume (L) <sup>b</sup>	0.42 ± 0.04	0.59 ± 0.07	0.33 ± 0.04	0.72 ± 0.08
Minute ventilation (L/min)	7.92 ± 1.26	6.70 ± 1.26	5.68 ± 0.45	6.96 ± 0.97
Ventilation rate (breaths/min) <sup>b</sup>	19.2 ± 1.8	13.3 ± 1.8	21.1 ± 2.3	11.8 ± 2.8
Compliance (mL/cm H <sub>2</sub> O) <sup>b</sup>	60.7 ± 2.9	68.2 ± 5.2	46.7 ± 6.8	65.5 ± 5.5
Resistance (cm H <sub>2</sub> O·L <sup>-1</sup> ·s <sup>-1</sup> )	12.3 ± 1.8	11.9 ± 1.6	13.6 ± 1.8	15.5 ± 4.1
Work of inspiration (kg·m·min <sup>-1</sup> ) <sup>a</sup>	0.75 ± 0.12	0.78 ± 0.12	1.12 ± 0.23	1.27 ± 0.17
Mean airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	5.2 ± 0.9	7.8 ± 0.6	2.6 ± 0.5	8.5 ± 1.6
Maximum airway pressure (cm H <sub>2</sub> O) <sup>b</sup>	8.0 ± 1.3	17.0 ± 2.6	4.0 ± 0.7	22.2 ± 3.0
Pop-off pressure (cm H <sub>2</sub> O)	25.7 ± 1.9	24.8 ± 1.9		
ETco <sub>2</sub> (mm Hg)	37.6 ± 2.2	39.9 ± 4.6	45.6 ± 3.0	33.7 ± 2.1
ET isoflurane (%)	0.60 ± 0.10	0.76 ± 0.14	0.71 ± 0.18	0.67 ± 0.11

ET = end-tidal.

<sup>a</sup> Airway effect, *P* < 0.05; laryngeal mask vs endotracheal tube.<sup>b</sup> Ventilation effect, *P* < 0.05; spontaneous vs controlled.

## Discussion

There were two groups of subjects in this study—the patients and the anesthesiologists. We addressed the responses of the former to the LM and ETT under two different modes of ventilation and, in the latter, we

addressed the management decisions in ventilation and anesthetic concentration resulting from the use of different airways.

Many studies have already addressed the degree to which the airway is protected from blood and secretions from above the pharyngeal seal. We used barium

Table 3. PACU Outcome Variables

	Laryngeal mask		Endotracheal tube	
	Spon- taneous (n = 13)	Con- trolled (n = 9)	Spon- taneous (n = 9)	Con- trolled (n = 13)
Airway placement				
Easy	12	8	6	13
Difficult	1	1	3	0
Blood on airway				
Yes	1	2	3	1
No	12	7	6	12
Sore throat				
Yes	4	2	5	7
No	9	7	4	6
Coughing <sup>a</sup>				
Yes	2	1	5	8
No	11	8	4	5
Nausea				
Yes	3	2	0	3
No	10	7	9	10
Vomiting				
Yes	0	1	0	1
No	13	8	9	12
Shivering				
Yes	3	0	3	4
No	10	9	6	9
Morphine (mg) <sup>a</sup>	7.4 ± 2.0	9.1 ± 4.8	13.9 ± 3.8	13.8 ± 4.0

PACU = postanesthesia care unit.

<sup>a</sup> Airway effect, *P* < 0.05; laryngeal mask vs endotracheal tube.

Table 4. Aldrete Scores in PACU

	Laryngeal mask		Endotracheal tube	
	Spon- taneous (n = 13)	Con- trolled (n = 9)	Spon- taneous (n = 9)	Con- trolled (n = 13)
15 min <sup>a</sup>	8.6 ± 0.4	7.4 ± 0.9	9.1 ± 0.3	9.2 ± 0.4
30 min	9.3 ± 0.2	8.6 ± 0.9	9.7 ± 0.2	9.5 ± 0.2
45 min	9.7 ± 0.1	9.0 ± 0.6	9.8 ± 0.2	9.8 ± 0.1
60 min	9.7 ± 0.1	9.6 ± 0.3	9.7 ± 0.2	9.9 ± 0.1
Discharge	9.8 ± 0.1	9.8 ± 0.2	9.8 ± 0.2	9.9 ± 0.1

PACU = postanesthesia care unit.

<sup>a</sup> Airway effect, *P* < 0.05; laryngeal mask vs endotracheal tube.

instead of methylene blue (3) because we wanted to examine the radiologic position of the LM, and because radiologic evidence of barium in the trachea or bronchial tree is a more sensitive measure of airway protection than looking for methylene blue through a fiberoptic scope.

Also, we acknowledge that the LM can be easily passed with a propofol induction dose alone, with no need for succinylcholine. However, to make a fair hemodynamic comparison between the LM and ETT, we wanted the drugs administered prior to airway placement to be the same.

It has been recommended by Brain (9) that for controlled ventilation through a LM, a nasogastric tube be passed to permit gastric decompression. However, it

has been demonstrated that there is no difference in the volume of gas aspirated from the stomach when controlled ventilation is performed with either a LM or an ETT (10). It has been suggested that the reason for this finding is that the opening pressure of the upper esophageal sphincter is above the "pop-off" pressure of the LM cuff (11). In light of this controversial issue, we elected not to place nasogastric or orogastric tubes in any of our patients.

The protection of the bronchial tree by the LM demonstrated in our study is consistent with the results of the European study by John et al. (3), who poured methylene blue into the oropharynx and checked for blue coloration at the inside of the LM with a fiberoptic scope. In both studies, the LM provided protection to the trachea from fluid in the oropharynx. In addition, our study demonstrated protection during controlled ventilation. These studies should provide additional confidence to those wishing to use the LM during dental and other ear, nose, and throat procedures. Of course, it must be emphasized that the risk of regurgitation and aspiration is still very real.

Results of fiberoptic examination revealed that the LM did not change position during any of the 22 operations studied. The high incidence of sighting the epiglottis flipped down between the bars of the LM was not a surprise. As noted by Nandi et al. (2), in their radiologic and fiberoptic study of LM positioning, the epiglottis was visible between the bars of the LM in the majority of cases.

Braude et al. (5) demonstrated significant increases in SBP and DBP with insertion of both LM and ETT, but they showed that the increases in blood pressures were greater after ETT placement. Key differences between their protocol and ours are 1) they used thiopental for induction, compared to our use of propofol, and 2) they premedicated their patients. Our study also showed that the patients with the LM underwent much less of a hemodynamic response to removal of the airway than did those with an ETT. This has been shown by Lamb et al. (12) for patients undergoing ophthalmologic procedures with controlled ventilation.

Decreased response to airway removal with the LM compared to the ETT may be attributable not only to a lesser nociceptive stimulus from the LM, but also to central nervous system sensitization induced by the ETT. Patients with a LM in place might be expected to demonstrate a more pronounced hemodynamic response to skin incision than those with an ETT. It has been well demonstrated by Wilkins et al. (13), that the anesthetic requirement for the LM is less than that for the ETT, so patients with a LM might be under anesthetized for incision. However, we found that hemodynamic response to skin incision was significantly greater with patients with an ETT. The reason for this

might be the same reason for preemptive analgesia—the concept of central sensitization (14). An initial nociceptive stimulus increases the sensitivity to subsequent stimuli. Thus, patients with an ETT respond more to incision and airway removal because the stimulation of laryngoscopy and endotracheal intubation increased central sensitivity to painful stimuli. Numerous clinical studies support the concept of central sensitization (15-17), but these studies have focused on postoperative analgesia rather than intraoperative stress response.

The anesthesiologists demonstrated a tendency to choose smaller tidal volumes and faster ventilation rates when the LM was used. We believe that this is generally the case with the use of the LM because of the fear of larger tidal volumes forcing air down the esophagus or "popping off" around the pharyngeal seal of the mask. This could be a source of increased atelectasis and V/Q mismatch in patients undergoing controlled ventilation under anesthesia with the LM. The use of spontaneous or controlled ventilation did not favor one airway over another. However, work of inspiration was consistently higher in patients with an ETT. Bhatt et al. (4) compared resistance to flow and work of inspiration of the LM and ETT *in vitro*. Because of the larger diameter of the LM, resistance and work of inspiration were less. Our clinical results are consistent with these *in vitro* results. However, our results are confounded by the different ventilatory patterns chosen by the anesthesiologists for controlled ventilation with the LM compared to ETT. The lower tidal volumes selected for controlled ventilation with the LM would, of course, result in lower airway pressures and lower work of inspiration.

The higher anesthetic concentrations selected by the anesthesiologists for those patients with an ETT in place reflect their perception of the amount of anesthetic needed to provide adequate anesthesia. It is interesting that despite the apparent attempt to keep these patients deeper, the hemodynamic responses to incision and airway removal in this group were significantly greater. This increased hemodynamic response reflects not only the increased stimulus from the ETT *in situ*, but also the central sensitization to subsequent stimuli induced by laryngoscopy and endotracheal intubation.

The anesthesiologists studied perceived no more difficulty inserting the LM than the ETT. Incidence of sore throat was higher for both the LM and ETT than has been reported (1). We suspect that the method of obtaining this information may have been a factor. Our postoperative interview was at the time of discharge from the PACU, and the question asked was, "Do you have a sore throat?" One might expect that a common response from a patient in pain to such a

leading question might be positive. Most other surveys have interviewed patients on the day after surgery (5,18,19). Despite the lack of difference in incidence of sore throat, severe coughing immediately after airway removal was noted more after ETT removal than after LM removal. This would be consistent with the stimulation of airway removal noted by hemodynamic response and may be another manifestation of central sensitization. The decreased incidence of coughing on removal of the LM compared to the ETT has been mentioned by Holden et al. (20) to be especially important with intraocular surgery, since coughing may increase intraocular pressure by as much as 50 mm Hg.

Patients receiving the LM were given lower Aldrete scores after admission to the PACU. A possible explanation of this might be the way our anesthesiologists perceived the timing of the airway removal. They were quite happy to take a patient into the PACU with the LM in place and the patient breathing spontaneously. There was no criticism of this by the PACU nurses, since this practice has been recommended by the manufacturer of the LM (6). However, to bring a patient with an ETT in place into the PACU was not the usual procedure in our unit, and was perceived as embarrassing. Thus, every attempt was made to remove the ETT in the operating room. Since the criteria for airway removal, response to command, was the same for both airways, those who had the ETT removed in the operating room tended to be more awake on arrival to the PACU. Finally, the amount of analgesia demanded in the PACU was less for patients who had received the LM. Again, the concept of central sensitization may have played a role in this result.

In conclusion, both the LM and ETT were adequate in protecting the trachea from barium placed in the oropharynx. The LM was superior to the ETT in minimizing hemodynamic response to airway insertion, surgical incision, and airway removal. Mode of ventilation, spontaneous versus controlled, favored neither airway, but work of inspiration was higher with an ETT, independent of mode of ventilation. In addition, the anesthesiologists studied tended to use smaller tidal volumes, higher ventilation rates, and lower anesthetic concentrations when using the LM as compared to the ETT. Finally, the LM caused less coughing at removal and less analgesic requirement in the PACU. Overall impression of the LM during this clinical study was positive, and each anesthesiologist using it recommended it as an alternative to endotracheal intubation for spontaneous ventilation. The LM should be considered instead of the ETT when control of blood pressure and HR are clinically important.

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