Bronchial Mucus Transport Velocity in Paralyzed Anesthetized Patients: A Comparison of the Laryngeal Mask Airway and Cuffed Tracheal Tube

C. Keller, MD*, and J. Brimacombe, MB ChB, FRCA, MD†

*Department of Anaesthesia and Intensive Care Medicine, Leopold-Franzens University, Innsbruck, Austria; and †Department of Anaesthesia and Intensive Care, University of Queensland, Cairns Base Hospital, Cairns, Australia

We compared bronchial mucus transport velocity (BTV), an index of mucociliary clearance, between the laryngeal mask airway (LMA) and the tracheal tube (TT). Forty patients were studied during propofol anesthesia and muscle relaxation with rocuronium. BTV was measured 10 and 60 min after insertion of the airway device by fiberoptic observation of the movement of methylene blue dye injected onto the dorsal surface of the left main bronchus. BTV for the LMA was similar at 10 and 60 min (13.9 ± 2.0 and 13.6 ± 2.1 mm/min, respectively). BTV for the TT was significantly faster at 10 min that at 60 min (13.0 ± 1.4 vs 6.9 ± 1.2 mm/min, respectively; $P < 0.00001$). BTV was similar for both devices at 10 min (TT 13.0 ± 1.4 mm/min versus LMA 13.9 ± 2.0 mm/min), but was significantly faster for the LMA than for the TT at 60 min (LMA 13.6 ± 2.1 mm/min versus TT 6.9 ± 1.2 mm/min; $P < 0.00001$). We conclude that the LMA impedes mucociliary clearance less than the TT in anesthetized patients. This may have implications for reducing the risk of retention of secretions, atelectasis, and pulmonary infection. **Implications:** This study compares bronchial mucus transport velocity, an index of mucociliary clearance, in anesthetized patients between two airway devices, the cuffed tracheal tube and the laryngeal mask airway. We have shown that the laryngeal mask airway impairs mucociliary clearance less than the tracheal tube. This may have implications for reducing the risk of retention of secretions, atelectasis, and pulmonary infection.

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The standard cuffed tracheal tube (TT) depresses mucociliary clearance (1,2), thus putting the patient at risk of retention of secretions, atelectasis, and pulmonary infection (3,4). The laryngeal mask airway (LMA) does not penetrate the tracheobronchial tree and, in theory, should not depress mucociliary clearance (5), but this has not been studied. The following randomized trial tests the hypothesis that the LMA may impair mucociliary clearance less than the cuffed TT.

Methods

Our research and ethical committees approved this study, and written, informed consent was obtained from all patients. Forty ASA physical status I or II patients scheduled for elective musculoskeletal surgery in the supine position were randomly assigned to one of the two treatment groups. Group I (n = 20) was managed with a tracheal tube (TT), and Group II (n = 20) was managed with the LMA. Patients were excluded from the study if surgery was expected to last less than 60 min or if they were less than 19 yr of age or more than 65 yr of age, had respiratory tract pathology, had a known difficult airway, had a body mass index more than 32 kg/m^2 had a history of smoking, had a history of atopia, were receiving drugs that could influence mucociliary clearance (catecholamines, theophylline, β-adrenergic blockers, cortisone, or atropine), or were at risk of regurgitation/aspiration (previous upper gastrointestinal tract surgery, known or symptomatic hiatus hernia, esophageal reflux, peptic ulceration, or had not fasted).

Patients were randomly assigned to treatment groups (by using sealed, randomized envelopes) 1–2 h preoperatively. Anesthesia management was standardized. Premedication was with oral midazolam 7.5 mg approximately 1 h before the induction of anesthesia. Standard monitoring was used. An IV cannula was inserted, and 1000 mL of lactated Ringer's solution was infused. After breathing 100% oxygen for 3 min, the patients were given fentanyl 1–3 μg/kg

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Address correspondence to Dr. J. Brimacombe, Department of Anaesthesia and Intensive Care Medicine, University of Queensland, Cairns Base Hospital, Cairns 4870, Australia. Address e-mail to 100236,2343@compuserve.com.

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followed 1 min later by propofol 2.5–3.5 mg/kg given over 30 s and rocuronium 0.6 mg/kg. Immediately before insertion, the TT (Lo-Contour™; Mallinckrodt Medical, Athlone, Ireland) and the LMA (The Laryngeal Mask Company, Nicosia, Cyprus) were lubricated with saline. No attempt was made to ventilate the lungs via a face mask or to instrument the airway with suction catheters at any time during the anesthetic. The TT and the LMA were inserted 60 s after completion of the bolus dose of rocuronium. The LMA was inserted using the standard recommended insertion technique (5) with the cuff deflated and the rim facing posteriorly. The TT was inserted using a laryngoscope, and the cuff positioned in the proximal trachea immediately distal to the vocal cords. A size 4 LMA or a 7.5-mm inner diameter (ID) TT was used for female patients, and a size 5 LMA or an 8.5-mm ID TT was used for male patients (6). The cuff was initially inflated with 20 mL of air in the size 4 LMA and with 30 mL of air in the size 5 LMA. The TT cuff was initially inflated with 10 mL of air. Chest wall movement and capnography during manually assisted ventilation was used to judge successful placement. After successful placement, the TT and the LMA were fixed in place in the midline using adhesive tape. A wad of gauze swabs rolled into a cylindrical shape was placed alongside the TT and the LMA to function as a bite block. Cuff pressures were measured immediately after cuff inflation using a calibrated aneroid manometer (Mallinckrodt Medical), which was attached to the pilot balloon. TT and LMA cuff pressures were reduced to ensure that cuff pressures were <25 cm H_2O for the TT and <60 cm H_2O for the LMA. These pressures were maintained throughout anesthesia by intermittently withdrawing gas from the cuff. Patients underwent positive pressure ventilation with tidal volumes of 6–8 mL/kg; peak airway pressures were limited to 20 cm H_2O and positive end-expiratory pressure (PEEP) was not used. The respiratory rate was adjusted to maintain P_{ETCO_2}) in the normal range (33–43 mm Hg). Anesthesia was maintained with an air/oxygen mixture (fraction of inspired oxygen 0.4) and propofol (6–8 mg $\cdot$ kg^{-1} $\cdot$ h^{-1}).

Muscle relaxation was maintained with intermittent boluses of rocuronium 0.1 mg/kg. Airway gases were sampled from the proximal end of the TT and the LMA. A circle anesthetic breathing system was used. The air was humidified using an antimicrobial filter (Sterivent "S"; Mallinckrodt Medical) placed between the tube and the ventilation hoses. Fresh gas flow was 2 L/min.

Bronchial mucous transport velocity (BTV), an index of mucociliary clearance, was determined using a modification of the method of Sackner et al. (7). BTV measurements were made with the patient in the supine position, without elevating the upper part of the body, 10 and 60 min after the insertion of the TT or LMA. A pediatric fiberoptic bronchoscope (FOB) (FB 15 X; Pentax, Hamburg, Germany) was passed through a self-sealing connector at the proximal end of the TT or LMA. A one-orifice 18-gauge epidural catheter (Perifix; Braun, Melsungen, Germany) was passed through the working channel of the FOB and positioned above the dorsal mucosa of the left main bronchus (0.5 cm above the osteum of the superior segment of the lower lobe), and 0.015 mL of methylene blue dye was applied. Great care was taken to avoid touching the mucosa. The time required for visually controlled application of the dye was 2–3 min. The FOB with angulation control in neutral position was moved so that the lens was positioned at the front edge of the dye at the end of expiration. The length between the lens and self-sealing connector was recorded using markers on the side of the FOB 0, 2, 4, and 6 min after application of the dye. The velocity was calculated by dividing the distance traveled by the elapsed time. The core temperature (nasopharyngeal) and oxygen saturation was noted during BTV measurements. An unblinded investigator (CK) made all observations.

Statistical analysis was performed using Student's t-test, two-factor analysis of variance, and χ^2 test. Unless otherwise stated, data are presented as mean ± SD. Significance was taken as $P < 0.05$.

Table 1. Patient Characteristics and Variables Measured During Anesthesia with the Tracheal Tube (TT) and the Laryngeal Mask Airway (LMA)

Patient data	TT	LMA
n	19	20
Age (yr)	39 (32–45)	38 (32–44)
Weight (kg)	72 (66–77)	69 (65–73)
Height (cm)	174 (169–177)	173 (170–176)
Sex (m/f)	13/6	12/8
Duration of surgery (min)	95 (85–107)	98 (87–110)
Oxygen saturation (%)		
10 min	98 (97–98)	98 (97–98)
60 min	98 (97–98)	97 (97–98)
Core temperature (°C)		
10 min	35.7 (35.5–35.9)	35.7 (35.5–35.9)
60 min	36.3 (36.1–36.5)	36.4 (36.2–36.6)

Values are mean (range).

Results

One patient in the TT group was excluded from the analysis because the surgery lasted less than 60 min. There were no demographic differences between the groups, and the core temperature and oxygen saturation during BTV measurements were similar (Table 1). Both intubation and LMA insertion were accomplished on the first attempt, and there were no complications. BTV for the LMA was similar at 10 and 60 min (13.9 ± 2.0 and 13.6 ± 2.1 mm/min, respectively). BTV for the TT was significantly faster at 10 min than at 60 min (13.0 ± 1.4 vs

6.9 ± 1.2 mm/min, respectively; $P < 0.00001$). BTV was similar for both devices at 10 min (TT 13.0 ± 1.4 mm/min versus LMA 13.9 ± 2.0 mm/min), but was significantly faster for the LMA than for the TT at 60 min (LMA 13.6 ± 2.1 mm/min versus TT 6.9 ± 1.2 mm/min; $P < 0.00001$).

Discussion

Mucociliary clearance depends on the complex interaction between ciliated columnar cells of the tracheobronchial tree and the special viscoelastic properties of the bronchial secretions (3). This system represents an important protective mechanism of the upper and lower respiratory tract whereby inhaled particles and microorganisms are removed from the tracheobronchial system. The potential consequences of impaired mucociliary clearance are retention of secretions, atelectasis, and infection (3,4). Factors affecting mucociliary clearance include primary ciliary dyskinesia (8), smoking (9), drugs (10) (catecholamines, β-blockers, theophylline, cortisone, atropine, and large doses of inhaled anesthetics), high oxygen concentration (11), inadequate humidification of inspired gases (12), activation of the inflammatory mediators system (13), and trauma to the tracheal mucus membrane (14).

TTs with inflated cuffs exert significant pressure on the tracheal wall, which can decrease mucociliary clearance (1,2). TTs that exert no pressure on the tracheal wall seem to have little influence on mucociliary clearance (2,15). The LMA exerts no pressure on the tracheal mucosa, but it does exert pressure on the pharyngeal mucosa (16). We have shown that mucociliary clearance does not decline during anesthesia with the LMA compared with the cuffed TT. Although baseline measurements were not taken before LMA insertion, the values for BTV were high enough to suggest that mucociliary clearance is also unaffected during placement. The mechanism by which mucociliary clearance is suppressed after the standard cuffed TT is inflated is unknown. Possible mechanisms include the formation of a mechanical barrier, edema of the mucosal layer distal to the cuff, a neurogenic reflex triggered by tracheal distension, and decreased ciliary activity (2). It seems that none of these mechanisms is triggered by the presence of a low-pressure cuff in the pharynx.

Our findings correspond well with those of Sackner et al. (2), who found a 37% decrease in mucociliary clearance after 1 h with the cuffed TT, but no change with the uncuffed TT. Our findings also correspond well with those of Trawoger et al. (15), who showed that a new TT with a no-pressure seal positioned at the level of the glottis did not impede mucociliary clearance after 3 h of intubation, whereas it declined by 67% with the standard TT. We found that the baseline BTV values for the cuffed TT were slightly higher than particle transport studies using Teflon® (DuPont, Wilmington, DE) (2,17) or tantalum (15) disks. This may be related to the fact that particle transport techniques measure the mean velocity of several individual markers, whereas our dye technique measured the frontal movement of a solution that is faster than the average transport rate. Our baseline BTV values were similar to that obtained using India ink in awake dogs (17).

We conclude that the LMA impedes mucociliary clearance less than the TT in anesthetised patients. This may have implications for reducing the risk of retention of secretions, atelectasis, and pulmonary infection.

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