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Original Article

Comparison of Lightwand and Fiberoptic Techniques for Airway Topical Anesthesia in Patients with Difficult Airways

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ABSTRACT

Background: Awake intubation is often regarded as a cornerstone in the management of the known difficult airway, but needs adequate airway topical anesthesia. This randomized clinical study was designed to determine the feasibility, safety and efficacy of the lightwand technique to provide airway topical anesthesia for awake tracheal intubation (ATI) by comparing with the fiberoptic technique.

Methods: Eighty adult patients with difficult airways were randomly assigned to one of two study groups to receive airway topical anesthesia by lidocaine sprays with the lightwand (LW group) or fiberoptic bronchoscope (FOB group). After airway topicalization, ATI was also performed using the lightwand and fiberoptic techniques, respectively. Level of sedation, time for each lidocaine spray in different targeted areas, total times for airway sprays, and total dosages of lidocaine were noted. Operators assessed difficulty of the airway spray and ATI using the visual analogue scales (VAS). An independent investigator assessed patients' discomfort during airway topicalization, patients' reaction, coughing severity, and intubating condition during ATI, and observed changes of blood pressure (BP) and heart rate (HR) during airway manipulations. Serial blood samples were obtained for analysis of plasma lidocaine concentrations. Also the postoperative follow-up of complications was done.

Results: 96.7% of airway lidocaine sprays were successfully completed on the first attempt in the LW group compared with 84.7% in the FOB group. The operator VAS assessment of difficulty of the airway spray was significantly better, times for each supraglottic spray and first laryngeal spray, and total time for airway sprays were significantly shorter, and total dosages of lidocaine were smaller in the LW group compared with the FOB group. As compared with the FOB group, patients' reaction and coughing scores during ATI were significantly lower, intubating conditions and operator VAS assessment of difficulty of intubation were better, and systolic BP and HR at intubation were significantly lower in the LW group. However, there were not significant differences in the investigator scores of patients' discomfort during airway sprays, plasma lidocaine concentrations at all observed times and the postoperative interview variables between groups.

Conclusions: As compared with the fiberoptic technique, use of the lightwand technique to provide airway topical anesthesia is easier for the experienced anesthetists, requires shorter time of airway preparation and smaller dosages of lidocaine, can produce better intubating condition for ATI, and does not result in more postoperative complications in sedated patients with difficult airways.

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Awake intubation is the technique most commonly chosen in difficult airway management, but patients will rarely allow their airways to be instrumented without adequate airway topical anesthesia (1). Airway topical anesthesia is generally accomplished by either some form of spraying of a local anesthetic solution onto the respiratory mucosa or by applying it directly to the mucosa itself. Spraying of local anesthetic can be accomplished in several ways, including the use of commercially prepared aerosol spray cans, atomizers, nebulizers, and others. As a cornerstone in managing difficult airways, the fiberoptic bronchoscope (FOB) is not only an invaluable aid to awake intubation, but also it is often used to apply local anesthetics to the airway in a "spray-as-you-go" fashion for the patient preparation of awake intubation (2). Unfortunately, FOB comes with a relatively high cost of purchase/maintenance and fiberoptic techniques for airway topical anesthesia and awake intubation require special skills and experience (3). As a FOB is not always available in every institution and a physician trained in the fiberoptic techniques for difficult airway management is not always on hand (4), alternative methods need to be assessed.

The lightwand has become a useful tool to manage difficult airways. Unlike the fiberoptic technique, main advantages of the lightwand technique are the low cost of purchase of device, requirement of minimal preparation, and the facts that its use is easy and secretions and blood in the airway tend not to interfere with the process (5,6). The use of the lightwand has resulted in successful intubation where both direct and fiberoptic laryngoscopy have failed (5). After the airway is anesthetized with traditional methods such as sprays and translaryngeal injection of local anesthetic in patients with difficult airways, awake intubation with the lightwand has been achieved successfully in some studies (7,8). In awake or anesthetized patients, moreover, the lightwand technique has been used to provide airway topical anesthesia by an epidural catheter (9) or an infant feeding tube (10) or a atomizer (11,12) attached to a lightwand. However, the feasibility, safety and efficacy of the lightwand technique compared to the fiberoptic technique in providing airway topical anesthesia for awake orotracheal intubation (AOTI) have not been evaluated in a single clinical trial. Therefore, this prospective randomized clinical study was designed to determine whether there were clinically relevant differences in the feasibility, safety and efficacy between the lightwand and fiberoptic techniques to provide airway topical anesthesia for AOTI in patients with predicted difficult airways.

METHODS

Following institutional ethics committee approval, American Society of Anesthesiologists physical status classification 1-3 adult patients scheduled to undergo surgery under general anesthesia were recruited. Patient characteristics such as age, gender, weight, and height were noted. Before surgery, all patients received a full-scale airway evaluation. Patients were included in this study if a staff anesthesiologist not involving in the study determined that they would require an AOTI based on history of prior difficult intubation or the presence of clinical predictors for the difficult airways. These predictors included previous history of multiple or failed laryngoscopy, Mallampati class 3 or 4 with a history of severe snoring and observed pauses in breathing during sleeping in the supine position, thyromental distance < 60 mm, limited mouth opening with interincisor distance < 30 mm, and head and neck movement < 80° (13). The head and neck movement was measured as described by Wilson and colleagues (14) . The exclusion criteria were inability to cooperate with adequate airway assessment, respiratory tract pathology (e.g., intrinsic laryngeal abnormalities), history of cardiovascular, hepatic, renal and coagulation diseases, pregnancy, inadequate transillumination of the anterior neck (e.g., grossly obese patients or patients with neck scar), long-term use of opioids or sedatives and risk of regurgitation–aspiration.

A total of 85 patients that met the inclusion criteria were prospectively enrolled into the study. During the preoperative visit, the details of the lightwand and fiberoptic techniques for airway topicalization and AOTI were explained for each recruited patient. Patients were also informed that they had the right to decline from participation. Because 5 patients did not agree

to participate after interview, 80 cases were eventually included in the study and informed patient consent was obtained. Patients did not receive any premedication, were fasting for at least 6 hours and were restricted from oral intake of clear fluid for 4 hours. Perioperative monitoring included a 3-lead electrocardiogram (ECG), pulse oximetry, non-invasive blood pressure (BP) and capnography. In the preoperative holding area, a 20-gauge intravenous cannula was inserted and intravenous atropine 10 μg/kg was administered for its antisialogogue effect (1). A 18-gauge indwelling intravenous cannula was also inserted into the antebrachial or antecubital vein on the contralateral arm for serial plasma lidocaine level sampling. In all patients, the posterior pharynx was anesthetized with five intra-oral sprays using 10% lidocaine (Xylocaine® 10% oral spray, Astra® Pharmaceutical Products, Inc, Westborough, MA); each depression of the release button delivered 0.1 ml (10 mg). In the operating room, patients received fentanyl 1.5 μg/kg and midazolam intravenously to achieve anxiolysis as defined by an Observer's Assessment of Alertness/Sedation Scale (OAA/S) of 14-16 (15). If the OAA/S was less than 14, or the patient was not cooperative due to excess sedation, the patient was excluded from this study.

Once the desired level of sedation was achieved, patients were randomly assigned into the lightwand (LW) group and fiberoptic bronchoscope (FOB) group (N=40 per group). Randomization was performed using computer generated random numbers, enclosed in sealed envelopes. In the LW group, a middle size wand of the Trachlight™ (Laerdal Medical Corporation, New York, USA) and a MADgic® atomizer (Wolfe Tory Medical Inc, Salt Lake City, UT) were assembled together as the combined unit using the method previously described (11). In the FOB group, a 1.1 mm single-orifice end hole epidural catheter was threaded through the suction channel of a FOB with an outer diameter of 3.1 mm (Olympus LF-DP, Tokyo, Japan) (3). Both the airway topicalization and AOTI with the lightwand and fiberoptic techniques were accomplished by the experienced anesthetists using the two methods. They were trained in the same postgraduate education programme of difficult airway management, had been engaging in clinical anesthesia for at least 10 years, and had performed the awake intubation in more than 50 patients with known difficult airways using the lightwand and FOB, respectively, before the start of the study.

Patient was positioned supine with the head and neck in a neutral position. The jaw was lifted upward to elevate the epiglottis and enlarge the pharyngeal cavity. In the LW group, the combined unit was passed in the midline until a bright well circumscribed circle of light was seen at the level of the hyoid, which indicated that its tip was located in the epiglottic vallecula. At this time, 1 ml of 2% lidocaine was sprayed using the MADgic® atomizer. Then the fine left or right rotation of the combined unit was done to obtain a bright glow in the lateral aspect of the larynx, which indicated that its tip was placed in the pyriform recess, and 2 ml of 2% lidocaine was sprayed in two aliquots onto the bilateral pyriform recess. This procedure was repeated after 5 minutes. Five minutes after the second supraglottic spray, the combined unit was again inserted until a central, clear and bright transillumination on the cricothyroid membrane, which suggested a correct positioning of its tip in the laryngeal aperture, was observed. At this time, 3 ml of 2% lidocaine was sprayed during inspiration to anesthetize laryngeal and tracheal areas (11).

In the FOB group, the FOB was inserted through a suitable size Berman intubating airway (Vital Signs, Inc., Totowa, NJ, USA) into the hypopharynx (2) and its tip was first positioned at the epiglottic vallecula and then in vicinity of the piriform recess. Three ml of 2% lidocaine was slowly sprayed in three aliquots of 1-ml onto these supraglottic areas. After 5 minutes, this procedure was repeated. Following another 5-min waiting period, the FOB was reinserted to expose the glottis and 0.5 ml of 2% lidocaine was sprayed into the laryngeal area. This procedure was repeated at 3-min intervals until adequate topical anesthesia of the larynx, as evidenced by cessation of the laryngeal response to further lidocaine administration (16, 17). The FOB was then advanced into the trachea and its tip was positioned 2 cm below the glottis. During inspiration, 3 ml of 2% lidocaine was slowly sprayed into the trachea.

Failure of airway spray attempt was defined as

withdrawal of the combined unit or FOB from the patient's mouth because of inability to be directed to the targeted area. A maximum of three attempts was permitted. Both the number of attempts required for each airway spray and causes of failed attempts were noted. The time for each airway spray in different targeted areas, namely the period from initial insertion of the combined unit or FOB to its withdrawal from the patient's mouth after completion of airway topicalization (including the time required for repeating attempts), was recorded using a digital stopwatch. The total time for airway sprays were measured as the time from first insertion of the combined unit or FOB to its withdrawal from the patient's mouth after the last airway spray (including the awaiting time between repeated airway sprays). During each airway spray, an independent investigator assessed and scored a patient's discomfort using a 4-point scale: no response=1; slight gagging=2; moderate gagging=3; severe gagging or patient's inability to tolerate=4. Gagging was considered slight if only one episode of gagging occurred, moderate if 2-3 gagging episodes occurred, and severe if more than 3 episodes occurred (16). After completion of airway sprays, the operator was asked to grade his/her subjective opinion about the difficulty of the procedure by a visual analogue scales (VAS) ruler from 0 to 10 cm, where 0 was described as very easy and 10 as impossible. The total doses of lidocaine used for airway sprays (including 50 mg used for intra- oral sprays) were noted. Patients were also asked whether they had experienced any local anesthetic side-effects, such as dysphoria, dizziness, nausea, and shivering, visual and auditory disturbances, involuntary movements, etc. (17).

Five minutes after completion of airway topicalization, AOTI was performed using the lightwand and the FOB in the LW group and FOB group, respectively. After insertion of the endotracheal tube (ETT) into the trachea, an independent investigator scored patient's reaction using a modified 6-point scale (no reaction=1; no change or a single change in the facial expression: slight reaction=2; grimacing facial expressions: moderate reaction=3; severe facial grimace but retained ability to follow verbal command and a reflex with no head movements: severe reaction=4; severe facial grimace associated with discomforting head movements, but still ability to obey verbal command: very severe reaction=5; and severe facial grimace associated with protective head and limb movements hindering the procedure, and inability to obey any verbal command: noncooperation=6) (16). Cough severity was rated on a 4-point scale (no cough=1; slight coughing=2; moderate coughing=3; severe coughing=4). Coughing was considered slight if no more than 2 coughs in sequence occurred, moderate if 3-5 coughs in sequence occurred, and severe if more than 5 coughs in sequence occurred (16). Intubating conditions were assessed using a 3-point scale (excellent=no response and cough; adequate=both patient's coughing and reaction scores were $\leqslant 3$; unacceptable=both patient's coughing and reaction scores were $\geqslant 4$)(12). The intubation time, defined as the period from initial insertion of the lightwand or FOB to start of ventilation through the ETT, was measured with a stopwatch. The number of intubation attempts was also noted. The operator was asked to grade his/her subjective opinion about difficulty of intubation by a VAS ruler from 0 to 10 cm (12). The independent investigator also recorded BP and HR before airway sprays with the lightwand or FOB (baseline), immediately after completion of supraglottic and first laryngeal spray, at intubation, and 1 minute after intubation. Following confirmation of correct ETT placement by chest auscultation and capnography, general anesthesia was induced with intravenous propofol and maintained with intravenous fentanyl, 1-2% end-tidal isoflurane plus 60% nitrous oxide in oxygen, and vecuronium for muscle relaxation.

A baseline blood sample (5 ml) was obtained from the indwelling intravenous cannula before any lidocaine was administered (T0). Further blood samples were obtained immediately following the second supraglottic spray and the first laryngeal spray, and at 10-min intervals until 60 minutes had elapsed from the final lidocaine spray. The plasma lidocaine concentrations were assayed using high-performance liquid chromatography with ultraviolet detection accurate to 0.02 μg/ml.

At 24 hours following surgery, an indepen-

dent investigator unaware of the patient's group assignment, used VAS rulers marked 0-100 cm to determine the patients' recall, and levels of discomfort and pain during the periods of airway spray and AOTI. The patients were also asked whether they had sore throat or other uncomfortable sensation of the throat. The VAS rulers from 0 to 100 cm described "no recall" to "perfect recall", "no discomfort" to "extreme discomfort" and "no pain to intolerable pain" (15).

Sample size selections were based on the results of primary observed variables of our preliminary trial including 20 patients in each group. Power calculation indicated that 39 patients in each group would at least be required to detect a difference of 20% between the groups with respect to success rate of the first laryngeal spray by one attempt for a type I error of 0.05 and a power of 0.8 for a two-tailed 2×2 chi-squared test. A total of 40 patients per group was studied to account for methodological difficulties that could have led to exclusion from the study. Unless otherwise stated, the quantitative data were expressed as mean ± SD with a range and the non-quantitative data were expressed as median with a range. The statistical analysis of data was performed with SPSS (Version 11.5, SPSS Inc., Chicago, IL). Comparison of two means between groups was performed using the Student t-test, and comparison of two medians between groups was performed using the Mann-Whitney U test. Comparison of percentages between groups was performed using a chi square test, a Fisher exact test and a McNemar's test as appropriate. The intragroup comparisons of hemodynamic data at different observed points were done using repeated measures analysis of variance. All comparisons were two-sided and $P < 0.05$ was considered statistically significant.

RESULTS

The two groups were comparable with respect to the patients' demographic data, reasons for entry into study, doses of midazolam administered for the desired level of sedation and patients' OAA/S before and after airway topical anesthesia (Table 1).

In both groups, all patients could well tolerate insertion of the combined unit and the FOB, and airway sprays without severe gagging. There were no significant differences between groups in the investigator scores of patients' discomfort during airway sprays. However, the operator VAS assessment of difficulty of airway sprays was significantly better in the LW group compared with the FOB group (Table 2).

Table 1. Demographic Data, Reasons for Entry Into Study, Dosages of Midazolam for the Desired Level of Sedation, and OAA/S before and after Airway Topical Anesthesia.

Variables	LW group	FOB group
Gender (M/F)	24/16	25/15
Age (years)	34.2±7.5	33.5±9.2
Weight (kg)	68.5±10.2	67.6±11.3
Height (cm)	168.2±5.8	167.6±6.2
Reasons for entry into study		
Prior difficult laryngoscopy (> 3 attempts)	10 (25)	7 (17.5)
Prior failed laryngoscopy	9 (22.5)	10 (25)
TMD of < 60 mm plus LMO	7 (17.5)	8 (20)
MC 3 or 4 with severe snoring and observed pauses in breathing during sleeping	11 (27.5)	13 (32.5)
LMO plus HNM of < 80°	3 (7.5)	2 (5)
Doses of midazolam (mg)	2.2±0.5	2.3±0.6
OAA/S before airway anesthesia	15.1±0.8	14.3±0.6
OAA/S after airway anesthesia	14.7±0.9	14.5±0.7

Data are expressed as means±SD except for gender data (N) and reasons for entry into study [N (incidences)]. N=40 per group. There were no statistically significant differences in all variables between groups. LW, lightwand; FOB, fiberoptic bronchoscope; TMD, thyromental distance; LMO, limited mouth opening; MC, Mallampati classification, HNM, head and neck movement.

The success rate of airway sprays by first attempt was significantly higher in the LW group (96.7%, 116/120) compared with the FOB group (84.7%, 194/229). In the LW group, 4 failed first attempts of airway sprays were due to inappropriate bend angle and length of the combined unit. In the FOB group, 35 failed first and second attempts of airway sprays were contributed to the obscure vision of FOB due to secretions in the airway or fogging of the lens (31/35) and difficulty to introduce the FOB towards the targeted areas because of the patient's airway reflexes (3/35) or unexpected head movement (1/35). As compared with the FOB group, in the LW group, times for each supraglottic spray and first laryngeal spray and total time for airway sprays were significant-

Table 2. Number of Attempts and Times for Each Airway Spray in Different Targeted Areas, Total Times for Airway Sprays and Dosages of Lidocaine for Airway Sprays.

	LW group			FOB group		
Number of attempts	One	Two	Three	One	Two	Three
Supraglottic sprays						
1st spray (N=40)	37	3	0	29*	10*	1
2nd spray (N=40)	39	1	0	33*	7*	0
Laryngeal sprays						
1st spray (N=40)☆	40	0	0	32*	7*	1
2nd spray (N=40)	–	–	–	35	5	0
3rd spray (N=18)	–	–	–	16	2	0
4th spray (N=11)	–	–	–	10	1	0
Endotracheal sprays (N=40)				39	1	0
Time for each airway spray						
Supraglottic sprays						
1st spray (s, N=40)	41.3±9.7 (34-76)			61.7±12.3 (47-92)*		
2nd spray (s, N=40)	38.2±9.2 (30-65)			52.3±10.2 (45-85)*		
Laryngeal sprays						
1st spray (s, N=40)☆	19.2±8.5 (11-39)			31.4±10.2 (24-57)*		
2nd spray (s, N=40)	–			28.7±10.8 (20-61)		
3rd spray (s, N=18)	–			26.1±9.5 (19-51)		
4th spray (s, N=11)	–			22.3±8.2 (21-48)		
Endotracheal sprays (s, N=40)				26.1±9.0 (18-55)		
Total time for airway sprays (minute)	13.5±1.1 (11.9-16.4)			22.7±3.5 (19.2-28.2)*		
Dosages of lidocaine (mg/kg)†	3.5±0.6 (3.2-4.0)			4.1±0.9 (3.5-4.6)*		

Data are expressed as means±SD (range) except for numbers of attempts (N). *P<0.05, compared to the LW group.
☆ In the LW group, first laryngeal spray included intratracheal spray. †Including 50 mg of lidocaine used for five intra-oral sprays. LW, lightwand; FOB, fiberoptic bronchoscope.

ly shorter, and total doses of lidocaine used for airway sprays were smaller (Table 3).

When the ETT was inserted into the trachea, 25 patients in the LW group and 13 patients in the FOB group showed no response in facial expression. All of the remaining patients exhibited mild or moderate reaction. The incidences of slight and moderate coughing were 12.5% and 5%, respectively, in the LW group, and 52.5% and 10%, respectively, in the FOB group. One patient (2.5%) in the FOB group experienced severe coughing which required supplemental lidocaine (3 ml). The total incidence of coughing during AOTI was significantly higher in the FOB group than in the LW group. Except for one patient in the FOB group, all of the remaining patients in both groups exhibited excellent or acceptable intubating conditions. There were significant differences between groups in the patients' reaction and coughing scores during AOTI, intubating conditions, intubation time, and operators VAS assessment of difficulty of intubation (Table 4).

The plasma lidocaine concentrations at all observed times were not significantly different between the two groups (Figure 1). Also, peak plasma lidocaine concentrations were 1.8 and 1.9 μg/ml in the LW group and the FOB group, respectively. Throughout the study, no patient experienced any side-effect of lidocaine.

In both groups, systolic BP and HR increased gradually with each stage in the airway manipulation process and were significantly above baseline values at intubation. However, systolic BP and HR at intubation were significantly lower in the LW group than in the FOB group (Figure 2).

There were no significant differences between groups in all postoperative interview variables (Table 5). Also, most patients in both

groups (87.5-90%) had no any recall (VAS 0) for airway sprays and AOTI. The incidence of postoperative mild and moderate sore throat was 32.5% (13/40) in the LW group and 27.5% (11/40) in the FOB group, respectively.

DISSCUSSION

The primary aims of this randomized clinical study were to determine the feasibility, safety and efficacy of the lightwand technique to provide airway topical anesthesia in comparison with the fiberoptic technique. Our results clearly showed that compared with the FOB group, in the LW group, success rate of airway sprays by first attempt was significantly higher, operator VAS assessment of difficulty of airway sprays was significantly better, times for each supraglottic spray and first laryngeal spray and total time for airway sprays were significantly shorter. These results suggest that the airway topical anesthesia by the lightwand technique is easier and requires shorter time of airway preparation compared with the fiberoptic technique. This may be contributed to the following factors. First, during the supraglottic and laryngeal sprays, it is often difficult to guarantee that the FOB's tip is not away from the targeted areas because of patient's slight head movement, swallowing or coughing. Also, 2-3 attempts were even required to conduct the FOB tip to the targeted area and complete airway spray in some patients. In contrast, the tip of the combined unit was easily introduced into the targeted site because of a rigid wand. Second, the fiberoptic technique is easily interfered by the obscure vision of FOB (2,16). In the FOB group, 88.6% of the failed first and second attempts of airway sprays were caused by this problem. However, the lightwand technique is not affected by this problem (5,6). Third, when the fiberoptic technique is used for airway topicalization, adequate anesthesia of the larynx must be obtained by repeated lidocaine sprays before the FOB is advanced through the glottis into the trachea to inject further local anesthetic(2,16). This can undoubtedly increase the complexity of the airway manipulations and prolong the time for airway topicalization.

As compared with the flexible FOB, the combined unit is likely to produce more severe stimuli to the airway and result in a lower acceptable level of patients because of its rigidity and a relatively larger size. However, our results showed no significant differences between groups in the investigator scores of patients' discomfort during airway sprays. This may be contributed to sedation and analgesia management with fentanyl and midazolam (1,18) and preliminary intraoral lidocaine sprays (2,17) before induction of

Table 3. Investigator Scores of Patients' Discomfort during Airway Sprays in Different Targeted Areas and Operator VAS Assessment of Difficulty of Airway Sprays.

	LW group	FOB group
Investigator scores of patients' discomfort		
Supraglottic sprays		
1st spray (s, N=40)	2.0 (1.0-4.0)	2.0 (1.0-3.0)
2nd spray (s, N=40)	2.0 (1.0-3.0)	2.0 (1.0-3.0)
Laryngeal sprays		
1st spray (N=40)#	2.0 (1.0-4.0)	2.0 (1.0-3.0)
2nd spray (N=40)	–	1.0 (1.0-2.0)
3rd spray (N=18)	–	1.0 (1.0-2.0)
4th spray (N=11)	–	2.0 (1.0-4.0)
Endotracheal sprays (N=40)		
Operator VAS assessment of difficulty of airway sprays	2.2 ± 1.6 (0-5)	3.5 ± 2.1 (0-7)*

Data are expressed as median (range) or means ± SD (range).
*P<0.05, compared to the LW group.
#In the LW group, first laryngeal spray included intratracheal spray.
LW, lightwand; FOB, fiberoptic bronchoscope.

Table 4. Patients' Reaction and Coughing Scores During Awake Tracheal Intubation, Intubating Conditions, Operators VAS Assessment of Difficulty of Intubation, and Intubation Times.

	LW group	FOB group
Patients' reaction scores	2.0 (1.0-3.0)	2.0 (1.0-4.0)*
Patients' coughing scores	1.0 (1.0-3.0)	2.0 (1.0-4.0)*
Intubating conditions		
Excellent	25 (62.5%)	13 (32.5%)*
Adequate	15 (37.5%)	26 (65%)*
Unacceptable	0 (0%)	1 (2.5%)
Operators VAS assessment of difficulty of intubation	1.3±0.6 (0-2)	2.1±0.9(0-4)*
Intubation time (s)	17.4±6.3 s (10-29)	29.4±10.2 s (16-51)*

Data are expressed as median (range), number (%) or means ± SD (range). N=40 per group.
*P<0.05, compared to the LW group.
LW, lightwand; FOB, fiberoptic bronchoscope.

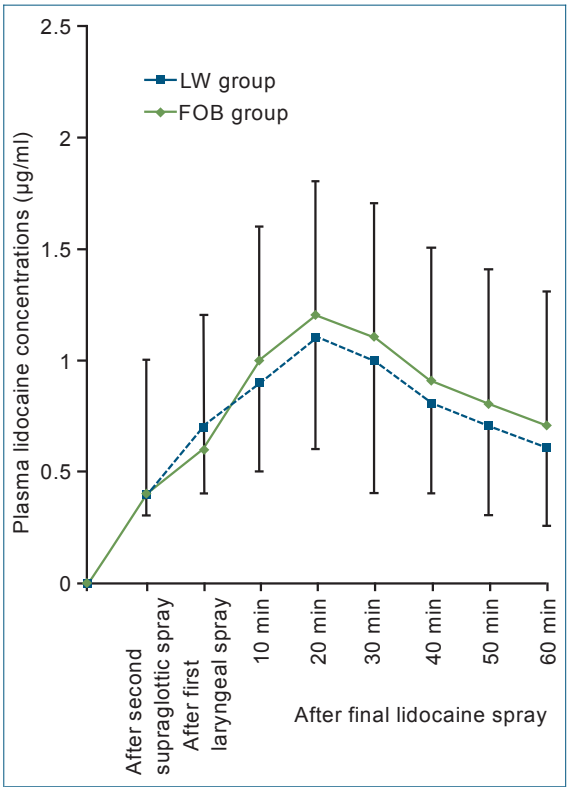

Figure 1. Serial Plasma Lidocaine Concentrations in Both Groups.
The blood samples at T0 were taken before any lidocaine was administered. Points are expressed as means ± SD. There were no statistically significant differences in the plasma lidocaine concentrations at all observed times between groups. LW, lightwand; FOB, fiberoptic bronchoscope.

Table 5. Postoperative Patient Interviews.

	LW group	FOB group
Recall of airway sprays	3	3
Recall of ATI	2	1
Discomfort during airway sprays	1	3
Discomfort during ATI	1	2
Pain during airway sprays	0	0
Pain during ATI	0	0
Mild sore throat (VAS 1-20)	7	5
Moderate throat (VAS 21-50)	4	6
Severe sore throat (VAS >50)	0	0
Pharyngolaryngeal abnormal sensation	3	2

There were not significant differences in all postoperative interview variables between groups.
ATI, awake tracheal intubation; LW, lightwand; FOB, fiberoptic bronchoscope.

the FOB and combined unit into the airway. Also, a shorter time for each airway spray and a less number of airway sprays with the lightwand technique compared to the fiberoptic technique may have resulted in a less stimulus to the airway, improving acceptable level of patients. In the FOB group, moreover, use of a Berman intubating airway may cause more stimuli to oral and pharyngeal tissues.

In this study, incidences of the grimacing response and coughing during AOTI were significantly lower in the LW group (37.5% vs.17.5%) than in the FOB group (67.5% vs. 62.5%). Also, patients' reaction, coughing scores and intubating conditions during AOTI were significantly better in the LW group compared with the FOB group. These results indicate that compared with the fiberoptic technique, the lightwand technique can provide more effective airway topical anesthesia for AOTI, though it includes a less number of airway sprays and requires a smaller dose of lidocaine. This may be explained by several factors. First, lidocaine solution cannot be aerosolized when delivered via an epidural catheter, as needed for penetration of the airway mucosa (3). Whereas, a MADgic® atomizer can provide effective atomized lidocaine solution to the airway mucosa (19). Second, because of flexibility of the FOB and active airway reflexes of awake patients, the stream of lidocaine injected by an epidural catheter can often not be directed, with any great deal of accuracy, to the targeted desired sites, especially for the supraglottic and glottic areas. Furthermore, each spray only covers a small airway area due to the fine but nonatomized stream of lidocaine (16). Therefore, spotty coverage of lidocaine for the airway structures is inevitable. In contrast, atomized lidocaine solution by a MADgic® atomizer may be sprayed into the desired targeted sites under the guide of transillumination of the anterior neck and can cover a wider airway area due to its larger radius of spraying (12). Third, when the endotracheal spray is performed with a fiberoptic technique, a monodirectional, nonatomized lidocaine solution is actually injected in the upper and middle trachea as the tip of the FOB is placed below the glottis (12). Also the spread of lidocaine solution is achieved mainly by patient's coughing immediately following injection (1). Thus, it is impossible to ensure that lidocaine solution is well distributed along the

infraglottic area and upper tracheal wall where the ETT contacts and stimulates the trachea. When the laryngotracheal spray is done using a lightwand technique, however, the tip of the MADgic® atomizer is positioned at the laryngeal aperture. Both a higher position of the MADgic® atomizer in the airway and its larger spraying radius help to produce more adequate coverage of atomized lidocaine solution for the infraglottic larynx and upper trachea. It has been demonstrated that compared with the spray-as-you-go technique using an epidural catheter through the FOB, translaryngeal injection of lidocaine at a more proximal site in the airway can produce more effective airway topical anesthesia for fiberoscopy (20).

In the present study, we also found that the total dose of lidocaine used for airway sprays was significantly higher in the FOB group than in the LW group, but the plasma lidocaine concentrations at all observed times were not significantly different between the two groups. This discrepancy between doses of lidocaine used in the airway and plasma drug concentrations may be due to a more drug loss with the fiberoptic technique and a more drug absorption with the lightwand technique. In our study, the increased lidocaine dose in the FOB group was actually used for laryngeal sprays. Like the supraglottic sprays, most of the non-atomized lidocaine solution used for the laryngeal sprays with a fiberoptic technique may have been swallowed by awake patients as they flowed downwards and pooled in the posterior oropharynx after sprays (12). Drug swallowed may reach the systemic circulation only after undergoing "first-pass metabolism" in the liver, which removes almost 70% of lidocaine (21). As compared with non-atomized lidocaine solution by an epidural catheter, atomized lidocaine solution by a MADgic® atomizer is more possible to be remained on the surface of the airway mucosa (1) and then be absorbed into the circulating blood. Also, a larger coverage area of atomized lidocaine solution by a MADgic® atomizer may increase the absorption of drug from the airway into the systemic circulation.

The results of our study also showed that peak plasma lidocaine concentrations assayed in all patients were within normal therapeutic limits (2-5 μg/ml) (16). We did not observe any side effect of local anesthetic in all patients. Also, there were no significant differences between groups in all postoperative interview variables. Therefore, we consider that use of a lightwand technique to perform airway topical anesthesia is same safe for the patient as use of a fiberoptic technique.

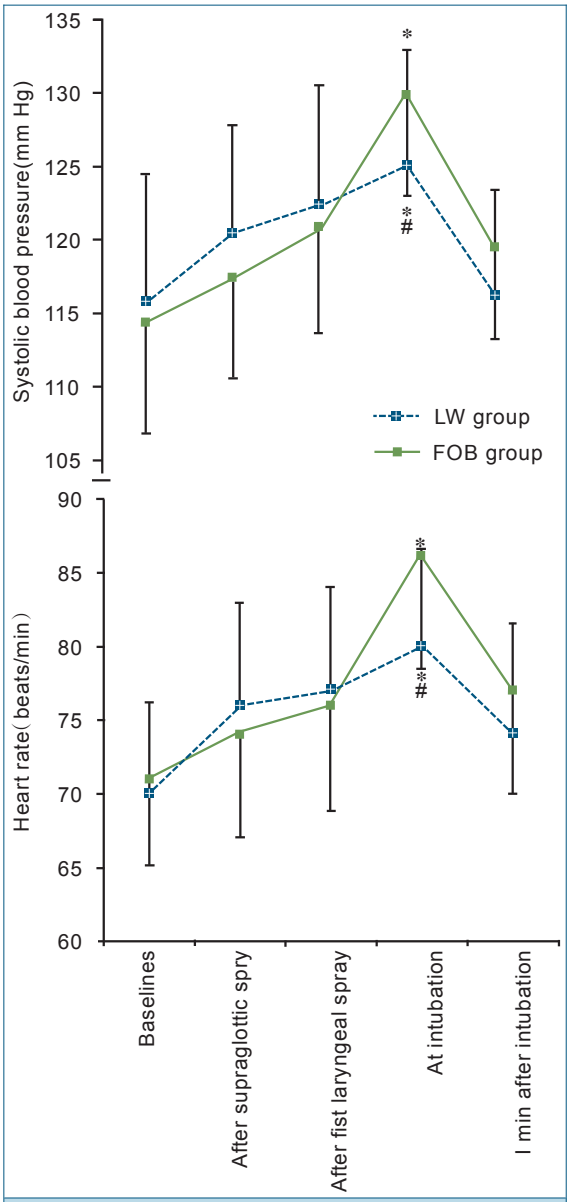

Figure 2. Changes of Systolic Blood Pressure and Heart Rate and Associated Each Stage of the Airway Manipulation Process in Both Groups.
Points are means ± SD. *P<0.05 compared to baseline values; #P<0.05 compared to the LW group. LW, lightwand; FOB, fiberoptic bronchoscope.

In this study, AOTI with lightwand was successfully completed on the first attempt within 25 seconds in all patients. Also the intubation time was significantly shorter and the intubating physician reported the intubation procedure easier in the LW group compared with the FOB group. In view of low costs of purchase and maintenance of the lightwand, and the facts that its use is easy and less affected by secretions or blood in the airway (5,6), we recommend that the lightwand technique for airway topical anesthesia and AOTI should be regarded as a useful alternative to the fiberoptic technique in managing difficult airways. However, it must be pointed out that as a blind procedure, a main limitation of the lightwand technique is unable to be used when the upper or lower airway pathology presents or when neck anatomy precludes transillumination (5,12). Under these circumstances, the fiberoptic technique is still the first line option to secure the airway safety (22). Moreover, an appropriate training is necessary to secure airway safety before using the lightwand technique to provide the airway topical anesthesia and AOTI in patients with difficult airways, though it is easy to learn (5).

BP and HR changes during a procedure may give an indirect indication of the distress or discomfort produced (17,23). In our study, systolic BP and HR at intubation were significantly higher in the FOB group than in the LW group. Expect for more tracheal stimulation by inserting the FOB into the trachea during intubation in the FOB group (24), more effective airway topical anesthesia in the LW group may also contribute to this difference.

There are two significant limitations of our study. First, the two techniques used were not blind to the independent investigator. This may have introduced a potential for bias. However, the simplicity of the grading systems used in our study lefts little room for interpretation. Also, many-sided evaluation by a combination of subjective and objective parameters can improve accuracy and reliability in comparison of the two techniques. Second, a initial sample size estimation was performed based on the results of primary observed variables in our preliminary trial. However, the small sample size of studied population (40 patients in each group) may have prevented us from excluding a type II error when comparing secondary observed variables with smaller intragroup differences, such as the investigator scores of patient' discomfort and incidences of postoperative complications. Therefore, a further randomized controlled trial with a large sample size is needed to elucidate the exact difference in these variables between the two techniques.

In conclusion, our study demonstrates that the lightwand technique may be superior to the fiberoptic technique in providing airway topical anesthesia for AOTI in sedated patients with predicted difficult airways. It appears to be easier, requires shorter time and smaller dose of lidocaine for airway preparation, and provides better intubating condition. Because of the simplicity, the efficacy and the safety of the lightwand technique, we consider that it may be a useful and readily available alternative to the fiberoptic technique for airway topical anesthesia and AOTI in the patients with difficult airways.

Declaration of Interests
All authors have no financial support and potential conflicts of interest for this work.

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