

Does the Suggested Lightwand Bent Length Fit Every Patient?

The Relation between Bent Length and Patient's Thyroid Prominence–to–Mandibular Angle Distance

Tsai-Hsin Chen, M.D.,* Shen-Kou Tsai, M.D., Ph.D.,† Chen-Jung Lin, M.D.,‡ Cheng-Wei Lu, M.D.,§ Tsung-Po Tsai, M.D., Ph.D.,‖ Wei-Zen Sun, M.D.‡

Background: **To date, no study has explored the effect of bent length on lightwand intubation. For successful intubation in daily practice, the authors found that bent length should be approximated to the patient's thyroid prominence-to-mandibular angle distance (TMD), but some patients have a TMD much shorter than the suggested bent length range. The purposes of this study were to understand TMD distribution in adults and to test the influence of bent length on lightwand intubation.**

Methods: **The TMD, airway, and demographic data of 379 patients were collected. To test the bent length influence, patients were enrolled in group A (158 patients, TMD ≤ 5.5 cm) and group B (131 patients, TMD > 5.5 cm) and were intubated randomly using the lower (6.5 cm) and upper (8.5 cm) limits of the suggested range. Success rate and lightwand search time were compared.**

Results: **In group A, the success rate was 98.8% with 6.5-cm bent length and 78.2% with 8.5-cm bent length ($P < 0.05$). Search times were 5.7 ± 2.90 and 8.9 ± 5.80 s with 6.5- and 8.5-cm bent length, respectively ($P < 0.01$). In group B, there was no statistical difference in success rate and search time between 6.5- and 8.5-cm bent length.**

Conclusion: **The suggested range was suitable for patients in group B (TMD > 5.5 cm). However, in group A (≤5.5 cm), the large discrepancy between the upper limit of the suggested range and this TMD caused difficulty in lightwand intubation. A 6.5-cm bent length is more suitable than an 8.5-cm bent length in these patients.**

RECENTLY, transillumination of the soft tissue of the neck by lighted stylets (lightwands) has been reported to be useful for airway management. The overall success rates of lightwand intubation are between 97.9 and 100%.[1–5] However, the success rate on the first attempt has been variable, between 72 and 92.3%.[1–5] The manufacturer of the Trachlight (Laerdal, Armonk, New York) recommends that the device be bent at 6.5–8.5 cm (with a "bent here" maker on the shaft). It has been suggested that the bent length of a lightwand should be according to the estimated distance between the back of the pharynx and the vocal cords.[6,7] However, there were no suggestions on how this distance should be measured, and there were no previous studies about the influence of the bent length on lightwand intubation.

In our daily practice, we found that the bent length of a lightwand should be approximated to the individual's thyroid prominence–to–mandibular angle distance (TMD) for a smooth lightwand intubation. The purposes of this study were to obtain knowledge of the distribution of the TMD in adult patients and to test the applicability of the suggested bent length in patients with different TMDs.

Materials and Methods

The protocol of this study was approved by the review board of National Taiwan University (Taipei, Taiwan). From February to November 2002, all adult patients requiring intubation for elective (abdominal and gynecological) surgery in our university hospital were selected for inclusion in this study.

Distribution of the TMD in Adult Patients

To understand the distribution of the TMD in adult patients, we collected the airway and demographic data (see Results) in patients with the following requirements: (1) age between 18 and 60 yr; (2) body mass index below 30 kg/m^2; (3) no known airway abnormality; (4) no limited head–neck movement; and (5) no history of previous difficult intubation. The measurement of airway parameters was performed the day before surgery. With the patient in a semisitting (45°) position and their head in neutral position, the TMDs of both sides were measured (one from the right side and the other from the left side). We used a specialized three-sided ⊓-shaped ruler that had an adjustable width and length that are perpendicular to one another. This allows for the measurement of patient's TMD bilaterally by adjusting the two arm lengths (fig. 1). The individual's TMD is the average of these two measured TMDs. We also measured the distance between the mentum and the hyoid bone (hyomental distance) and the distance be-

* Previous position: Resident, Department of Anesthesiology, National Taiwan University, College of Medicine and Hospital. Current position: Staff Anesthesiologist, Chung Shan Medical University and Hospital. † Professor, ‡ Associate Professor, § Resident, Department of Anesthesiology, National Taiwan University, College of Medicine and Hospital. ‖ Professor and Superintendent, Department of Cardiothoracic Surgery, Chung Shan Medical University and Hospital.

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Address reprint requests Dr. Sun: Department of Anesthesiology, National Taiwan University Hospital, 7 Chung-Shan S. Road, Taipei, Taiwan. Address electronic mail to: wzsun@ccms.ntu.edu.tw.

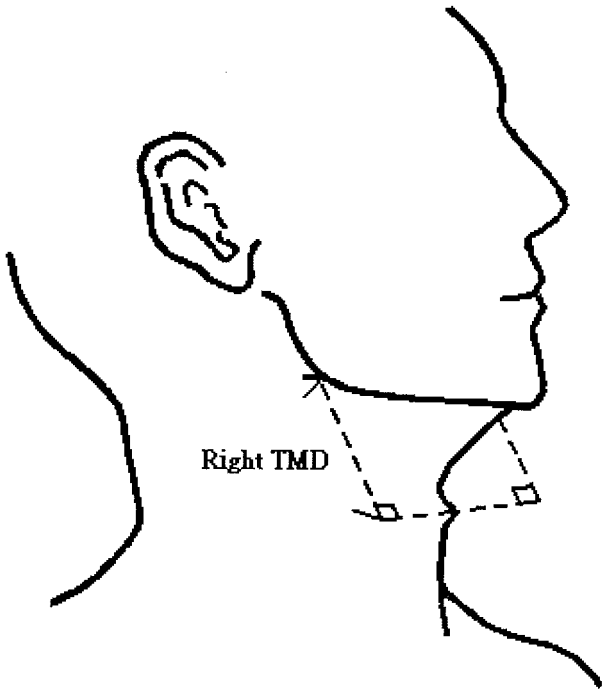

Fig. 1. Using a three-sided ruler to measure the individual's thyroid prominence–to–mandibular angle distance (TMD). This figure shows the TMD from the right side (the other TMD is from the left side). The individual's TMD is the average of these two measured TMD values.

tween the hyoid bone and the thyroid prominence (hyothyroid distance) with the neck in full extension. The pharyngeal structures were assessed with the patient's mouth fully opened as described by Mallampati *et al.*[8] Demographics such as age, sex, height, and weight were also noted.

Influence of Bent Length on Lightwand Intubation

After explanation of the study and obtaining informed consent, patients who met the listed requirements were divided arbitrarily into two groups; group A included patients with a TMD of 5.5 cm or less, and group B included patients with a TMD of greater than 5.5 cm. Either a 6.5- or an 8.5-cm bent length (the upper or lower limit of the suggested range) would be used to intubate patients from both groups by a coin toss. The success rate and the search time (see the second paragraph in the following section) were recorded.

Lightwand Intubation and Lightwand Search Time

The lightwand was bent at 90°, and the bent length was measured from the tip of the light bulb. The endotracheal tube (ETT) was loaded onto the lightwand, without protruding beyond the tip of the lightwand. ETTs with an ID of 7 mm were used for female patients, and ETTs with an ID of 7.5 mm were used for male patients. Each patient was placed with the neck slightly extended by a pillow under the shoulder and neck. Patient monitoring included electrocardiography, noninvasive arterial blood pressure monitoring, and pulse oximetry. Anesthesia was induced with 2 μg/kg fentanyl, 5 mg/kg thiopentone sodium, and 1 mg/kg rocuronium. Lightwand intubation was performed after the absence of response to train-of-four stimulation of the ulnar nerve at the thumb.

Lightwand intubation was divided into two steps. First, one anesthesiologist introduced the endotracheal tube–lightwand (ETT-LW) into the patient's mouth without turning on the bulb. The ambient light was dimmed. Then, another anesthesiologist (T.-H. C.), who was blind to the bent length, performed lightwand intubation of all patients. Lightwand search time was counted from turning on the lightwand to the moment of transillumination over the cricothyroid membrane. The ETT was then advanced over the lightwand using the one-handed Trachlight technique described by Crosby.[9] Successful intubation was confirmed by capnography.

Definition of a Failed Lightwand Intubation Attempt

The result of the first attempt was considered a failure when the transillumination pattern could not be seen over the cricothyroid membrane after 25 s of search time (lightwand would blink). If esophageal intubation occurred, the result was also considered a failure. Failed intubations were not included in the determination of the lightwand search time in either group.

How to Change the Lightwand Bent Length after a Failed Attempt

Lightwand intubations were permitted up to two times, with ventilation interposed. Two sets of ETT-LW with different bent lengths (6.5 and 8.5 cm) were prepared for every patient. After a failed attempt, the bent length of the second attempt was changed (6.5 cm changed to 8.5 cm and *vice versa*). Conventional laryngoscopic intubation was conducted if both lightwand intubation attempts failed.

Maintenance of and Emergence from Anesthesia

After successful intubation, the ETT was secured, and the cuff pressure was maintained below 20 cm H_2O. Maintenance of anesthesia was provided by isoflurane and additional muscle relaxant if indicated. At the end of each case, the residual neuromuscular blockade was reversed, and the patient was extubated. Postoperative analgesia was provided by 0.6 mg/kg meperidine intramuscularly during the closure of incision.

Postoperative Sore Throat and Hoarseness Evaluation

A nurse who did not know the grouping and the bent length examined patients 4 h after surgery and asked about

Table 1. Demographic Data and Airway Characteristics of Patients Measured Consecutively

	Male	Female	*P*
Patients, n	176	203	—
Age, yr	43.6 ± 15.90	44.9 ± 12.33	NS
Height, cm	170.0 ± 6.82	157.1 ± 6.22	<0.001
Weight, kg	67.8 ± 9.45	54.9 ± 8.01	<0.001
Mallapatti score, 1:2:3	53:67:56	46:90:67	NS
TMD, cm	6.5 ± 0.55	5.3 ± 0.48	<0.001
Hyomental distance, cm	6.0 ± 0.84	5.1 ± 0.66	<0.001
Hyothyroid distance, cm	2.5 ± 0.41	1.9 ± 0.30	<0.001

Values are shown as mean (±SD) in continuous data. In nominal data, values are the number of the patients.
NS = not significant; TMD = thyroid prominence-to-mandibular angle distance.

the presence of sore throat and hoarseness. Patients who had been anesthetized longer than 4 h and/or sent to the intensive care unit postoperatively were excluded from the analysis of postoperative complications.

Statistical Analysis

A pilot study in patients with a TMD of 5.5 cm or less revealed that the success rate was 100% (12 of 12) with a 6.5-cm bent length and 74% (14/19) with an 8.5-cm bent length, whereas there was no such difference in patients with a TMD of greater than 5.5 cm. If the success rate with the 6.5-cm bent length is approximately 95–100%, the sample size should be at least 65 patients in each bent length to have a 90% power of detecting a 20% change in success rate with $P < 0.05$ in group A. The primary outcome measure was the success rate on the first attempt. The secondary outcome measure was the lightwand search time. The success rates between the two bent lengths in each group were compared using the z test with the Yates correction. Continuous data were analyzed by Student t test. Nominal data were compared using the chi-square test with the Yates correction. For continuous data, values were presented as the mean (± SD). A P value of less than 0.05 was considered statistically significant.

Results

During the study period, we consecutively collected the TMD, airway, and demographic data of 379 adult patients (table 1). The distribution of TMD in the patients we studied was similar to normal distribution (fig. 2). The distribution of the male TMD was significantly different from that of the female TMD ($P < 0.001$). The mean TMD was 6.5 cm with an SD of 0.55 cm in men (n = 176) and 5.3 cm with an SD of 0.48 cm in women (n = 203).

We enrolled 158 patients (10 men and 148 women) with a TMD of 5.5 cm or less in group A and 131 patients (71 men and 60 women) in with a TMD of greater than 5.5 cm group B. The demographic and airway data of these two groups are listed in table 2. The success rate of lightwand intubation on the first attempt (table 3) in group A shows a significant difference between the 6.5- and 8.5-cm bent lengths (98.8% *vs.* 78.2%, $P < 0.05$),

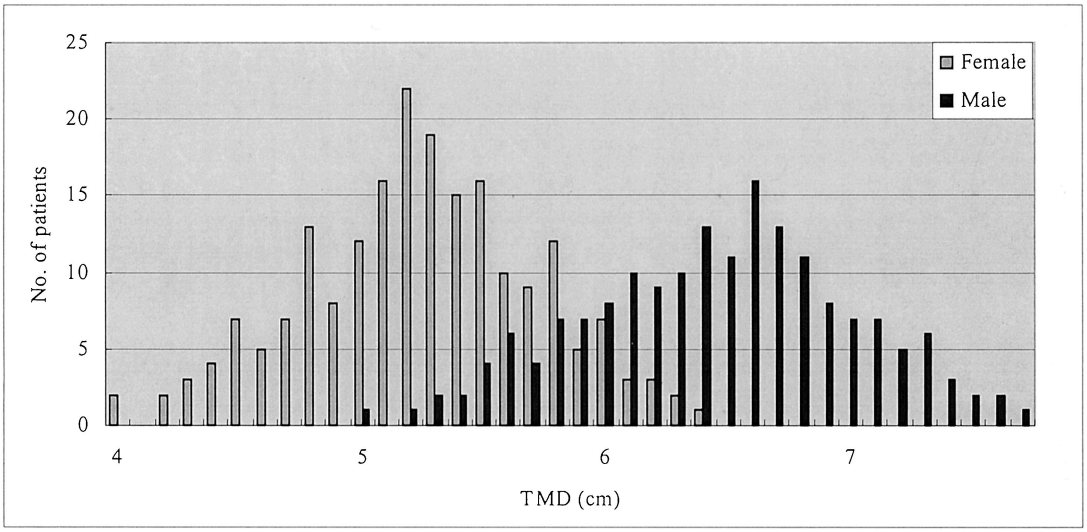

Fig. 2. The distribution of the thyroid prominence–to–mandibular angle distance (TMD) of the patients we consecutively measured. The distribution of the male TMD is significantly different from that of the female TMD.

Table 2. Demographic Data and Airway Characteristics of the Two Studied Groups

	Group A	Group B	*P*
Patients, n	158	131	—
Age, yr	44.2 ± 12.3	44.6 ± 15.2	NS
Gender, male/female	10:148	71:60	<0.001
Height, cm	157.2 ± 6.82	164.6 ± 8.0	<0.001
Weight, kg	54.2 ± 7.6	63.4 ± 10.9	<0.001
Mallampati score, 1:2:3	37:76:45	33:66:32	NS
TMD, cm	5.1 ± 0.35	6.1 ± 0.66	<0.001
Hyomental distance, cm	5.1 ± 0.64	5.4 ± 0.84	<0.002
Hyothyroid distance, cm	1.9 ± 0.31	2.2 ± 0.44	<0.001

Values are mean (±SD) in continuous data. In nominal data, values are the number of the patients.
NS = not significant; TMD = thyroid prominence-to-mandibular angle distance.

whereas there was no such difference in group B (100% with the 6.5-cm bent length, 98.5% with the 8.5-cm bent length). There were 19 patients from both groups who were not intubated in the first attempt and required a second attempt with a different bent length. After changing the bent length in the second attempt, 17 among these 19 patients were intubated successfully (table 4). Two patients were not intubated after a second lightwand attempt, and conventional laryngoscopic intubation succeeded in these two patients. In one patient, an omega-shaped epiglottis was found during direct laryngoscopic intubation. In the other, the fissure of the glottis was small, and a smaller ETT (6.5-mm ID) was inserted under direct vision. In group A, the lightwand search time of first attempt (8.9 ± 5.8 s) with an 8.5-cm bent length was significantly longer than that with a 6.5-cm bent length (5.7 ± 2.9 s). There was no significant difference in the search time between the two bent lengths in group B (table 3).

There were 49 patients excluded from the analysis of postoperative sore throat and hoarseness. Postoperative sore throat and hoarseness occurred in 28.8% and 5.4% of all investigated patients, respectively (table 5). In patients who were successfully intubated during the first lightwand attempt, there were no significant difference in the occurrence of sore throat and hoarseness regardless of which bent length was used. However, the occurrence of sore throat in patients who received more than one lightwand attempt was significantly higher than that in patients who were successfully intubated during the first attempt ($P < 0.005$).

Discussion

In addition to the experience of the anesthesiologist, an appropriate shape (angle and bent length) of the lightwand should facilitate lightwand intubation. To achieve a successful lightwand intubation, the tip of the ETT-LW should be located beneath the glottic opening first, and then a rocking movement could direct the tip into the trachea. The more adequate the bent length, the better the success rate of lightwand intubation should be. The thyroid prominence is near the insertion of the vocal cords, and the mandibular angle is close to the tongue base in the sagittal plane. We assume that our measured TMD could represent the estimated distance between the tongue base and the vocal cords (fig. 3). The bent length should be longer than the TMD to allow some part of the ETT-LW entering the trachea. Nevertheless, the longer the bent length, the more difficult the tip of the ETT-LW could be turned into the trachea through the two adjacent angles (one between the oral and pharyngeal axis, the other between the pharyngeal and laryngeal axis). In other words, the difference between the bent length and the individual's TMD (ΔBL-TMD) should be within an acceptable range.

Based on the data we measured, the 95% confidence

Table 3. Results of First Lightwand Attempt

	Group A, Bent Length		Group B, Bent Length	
	6.5 cm	8.5 cm	6.5 cm	8.5 cm
Patients, n	80	78	66	65
Success rate, %	98.8*	78.2*	100	98.5
Patients with failed intubation, n	1	17	0	1
Search time > 25 s	1	15	0	1
Esophageal intubation	0	2	0	0
Lightwand search time, s	5.7 ± 2.9†	8.9 ± 5.8†	5.9 ± 3.1	6.1 ± 3.4

* The success rate between the 6.5-cm and 8.5-cm bent length in group A are significantly different from each other ($P < 0.05$). † The search time between the 6.5-cm and 8.5-cm bent length in group A are significantly different from each other ($P < 0.01$).

Table 4. Effect of Changing Bent Length in Patients Who Were Not Intubated in the First Attempt

	Group A, Original Bent Length		Group B, Original Bent Length	
	6.5 cm	8.5 cm	6.5 cm	8.5 cm
Patients, n	1	17	0	1
Bent length of second attempt, cm	8.5	6.5	—	6.5
Patients being successfully intubated in the second attempt, n	0	16	—	1
Mean search time (±SD), s*	—	6.1(± 2.9) †	—	6.4
Laryngoscopy finding of patients not intubated after second attempt	An omega-shaped epiglottis	A small fissure of glottis	—	—

* The mean search time among the patients who were intubated in the second attempt. † No significant difference from the search time of first attempt with 6.5-cm bent length in group A.

interval of patients' TMDs would be 5.40–7.60 cm in men and 4.34–6.26 cm in women. Compared with the suggested bent length range (6.5–8.5 cm), the ΔBL-TMD could be large when an 8.5-cm bent length was chosen to intubate patients with a short TMD. For testing the practicability of the suggested bent length range, we arbitrarily divided patients into one group with a TMD of 5.5 cm or less (much shorter than the suggested range) and the other with a TMD of greater than 5.5 cm (close to the suggested range) and intubated them with a 6.5- or an 8.5-cm bent length. We found that the success rate and search time of lightwand intubation had no significant difference between the 6.5- and 8.5-cm bent lengths in the group with TMD greater than 5.5 cm. In the group with TMD of 5.5 cm or less, however, the success rate and search time of lightwand intubation with a 6.5-cm bent length were much better than those with an 8.5-cm bent length. In regard to ΔBL-TMD, the success rates were satisfying when the ΔBL-TMD ranged from −1.1 to 2.9 cm (table 6). However, the success rate dropped remarkably with a 3- to 3.9-cm ΔBL-TMD and even more when the ΔBL-TMD exceeded 4 cm. Such a large ΔBL-TMD was found in group A with an 8.5-cm bent length in our study design. These findings are compatible with our hypothesis that the bent length should be approximated to individual's TMD for a successful lightwand intubation.

In a review by Davis *et al.*,[6] a technique of deliberate esophageal insertion followed by slow withdraw with anterior direction of the wand is described to help lightwand intubation. We used this technique frequently in this study. However, it is difficult to redirect the tip of the lightwand into the glottic opening in some patients with a short TMD when the 8.5-cm bent length is used. We speculated that the withdrawal of the wand is limited by the space in the oral cavity, and the ΔBL-TMD in these patients is too large to be overcome by withdrawing the wand (fig. 3). We believe that this withdrawal technique is useful in patients with a large epiglottis hindering direct transillumination, but the bent length should also be decided first to keep the ΔBL-TMD in an acceptable range. However, there were 14 patients who were intubated successfully with a bent length shorter than their TMD (table 6). The possible explanation is that the shortness of the bent length is not enough to cause significant influence on the success rate of lightwand intubation, and/or the intubator could push the ETT-LW against the tongue to overcome this small shortness.

Although the suggested bent length range did not cover the entire distribution of TMD in our patients, we do not think it is appropriate to expand or change the suggested range according to our measured TMD because there might be ethnic differences in the distribution of TMD and also because successful lightwand intubation could be performed in a range of ΔBL-TMD. A larger suggested range would only cause more confusion in choosing the bent length in a given patient. Choosing a bent length close to the patient's TMD could be a more practical way. Further investigation should be performed to ascertain these circumstances.

Another finding of this study is that the occurrence of postoperative sore throat showed a significant increase in patients who received more than one lightwand attempt (table 5). Intuitively, the rocking motion of light-

Table 5. Numbers of Patients with Postoperative Sore Throat and Hoarseness

	Group A		Group B		Patients Receiving Two Lightwand Attempts
Bent length	6.5 cm only	8.5 cm only	6.5 cm only	8.5 cm only	—
Patients, n*	65	52	53	54	16
Sore throat	13	18	12	11	15†
Hoarseness	2	4	3	2	2

* Forty-nine patients had been anesthetized longer than 4 h and/or sent to the intensive care unit postoperatively, and they were excluded from the analysis of postoperative complications. † Significantly different from the occurrence of sore throat in patients who received only one lightwand attempt ($P < 0.005$).

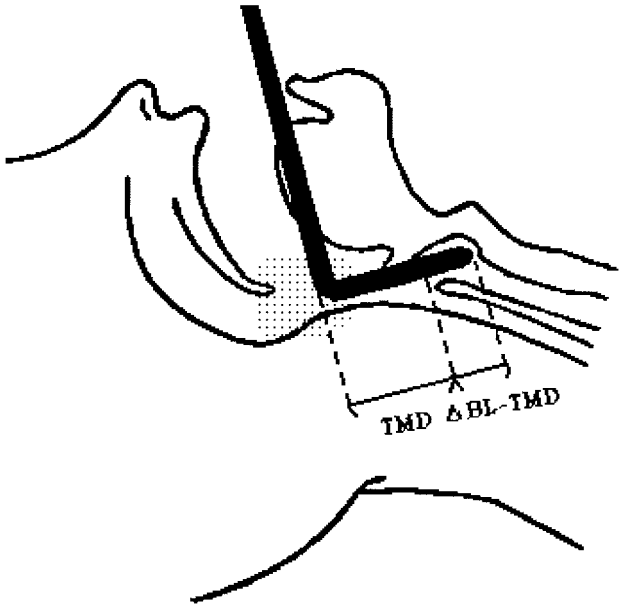

Fig. 3. A schematic drawing of the estimated distance from the tongue base to the opening of glottis. We assume that our measured thyroid prominence–to–mandibular angle distance (TMD) could represent this estimated distance. The bent length should be longer than the estimated distance to allow some part of the endotracheal tube–lightwand entering the trachea. The intubator should use the available space in the oral cavity (dotted area) to turn the tip of the lightwand into the trachea. It would be more difficult to succeed with either a large difference between the bent length and the TMD (ΔBL-TMD) or a narrow space in the oral cavity.

wand intubation could injure the mucosa of the pharynx/larynx, especially in patients who received an uneven attempt or multiple attempts. Repeated attempts with an inappropriate bent length might only waste time and could result in more complications. In this study, applying a more appropriate bent length is helpful for a successful lightwand intubation. Among the 19 patients with failed attempts, 17 patients were successfully intubated during the second attempt (the bent length was shifted from 8.5 to 6.5 cm, thereby decreasing the ΔBL-TMD in these patients). There were only two patients who were not intubated after two lightwand attempts. One had an omega-shaped epiglottis; the fissure of the glottis was small in the other patient. In either case, changing the bent length is not guaranteed to achieve successful lightwand intubation. Another direct-view intubation technique is more suitable in these situations.

There were several drawbacks in this study. First, most patients with a TMD of 5.5 cm or less were female (148 of 158), whereas patients with a TMD of greater than 5.5 cm were more often male (71 of 131). We could not avoid the sex bias in this study design since the distribution of TMD in our patient group showed that patients with a TMD of 5.5 cm or less were predominately female. Nevertheless, we do not think the influence of bent length could be explained by sex only (*e.g.*, long bent length for men and short bent length for women) since there is no significant difference in success rate between the 6.5- and 8.5-cm bent lengths among female patients with a TMD of greater than 5.5 cm. Second, most failures in this study were due to a search time of more than 25 s rather then due to esophageal intubation. This is an arbitrary definition of failure. However, the chance of success after 25 s is low, and even with success, the long search time is also a reflection of an inappropriate bent length if a much shorter search time could be achieved with a different bent length. Third, it may be inconvenient to use a ⊓-shaped ruler to measure the TMD on every patient. For clinical practice, we recommend "eyeballing" the patient's TMD to try to approximate the bent length closer to the TMD.

In conclusion, this is the first clinical study to demonstrate the influence of bent length on the success rate of lightwand intubation. Our results suggest that a bent length close to the individual's TMD should be chosen. The suggested bent length range (6.5–8.5 cm) is suitable for patients with a TMD of greater than 5.5 cm. However, in patients with a TMD of 5.5 cm or less, the large discrepancy between the upper limit of the suggested bent length and this short TMD would cause difficulty in lightwand intubation. It is more suitable to choose the 6.5-cm bent length than the 8.5-cm bent length to intubate patients with a TMD of 5.5 cm or less.

Table 6. Success Rate of Lightwand Intubation in Relation with Different ΔBL-TMD

	Group A		Group B		
ΔBL-TMD	6.5 cm	8.5 cm	6.5 cm	8.5 cm	Overall Success Rate, %
−1.1 ∼ −0.1 cm	0	0	14	0	100
0.0 ∼ 0.9 cm	0	0	52	0	100
1.0 ∼ 1.9 cm	72 (1)	0	0	19	98.9
2.0 ∼ 2.9 cm	8	0	0	46 (1)	98.1
3.0 ∼ 3.9 cm	0	67 (11)	0	0	83.6*
4.0 ∼ 4.5 cm	0	11 (6)	0	0	45.5†

Values are the number of the patients, and the values in parentheses refer to the failures of first lightwand attempt.

* Significantly different from the success rates of the ΔBL-TMD between −1.1 and 2.9 cm ($P < 0.002$). † Significantly different from the success rates of the ΔBL-TMD between −1.1 and 2.9 cm ($P < 0.001$) and that of the ΔBL-TMD between 3.0 ∼ 3.9 cm ($P < 0.02$).

ΔBL-TMD = difference between bent length and patient's thyroid prominence-to-mandibular angle distance.

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