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ORIGINAL RESEARCH

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Optimization of electromyographic endotracheal tube electrode position by UEScope for monitored thyroidectomy

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Abstract

Objective: Proper position of an electromyographic (EMG) endotracheal tube within the larynx plays a key role in functional electrophysiologic intraoperative neural monitoring (IONM) in thyroid surgery. The purpose of this study was to determine the feasibility of a portable video-assisted intubation device (UEScope) to verify the optimal placement of an EMG tube.

Methods: A retrospective study enrolled 40 consecutive patients who underwent monitored thyroidectomies. After positioning the patient for surgery, an anesthesiologist performed tracheal intubation with UEScope and checked the position of the tube at the proper depth without rotation to the vocal cords. The main outcome measured was the proper EMG tube position, free from further adjustment. The secondary outcomes assessed were the percentage of available initial vagal stimulation (V1) signals.

Results: All tracheal intubations were successful at first attempt. Proper EMG tube placement without position adjustment was found in 97.5% of the patients. Tube withdrawal was required in a male patient. All patients obtained detectable V1 signals; the lowest and median V1 amplitude was 485 and 767 μV as a reference value, respectively.

Conclusion: The UEScope is a valuable and reliable tool for placing an EMG tube and confirming its position during monitored thyroidectomy. In addition, further tube adjustment might be waived in most cases when the anesthesiologist placed the

I-Cheng Lu and Che-Wei Wu contributed equally to this work.

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EMG tube after patient positioning for surgery. Routine use of video-assisted intubation devices is highly recommended.
Level of Evidence: 4.

KEYWORDS
electromyography (EMG) tube, intraoperative neural monitoring (IONM), recurrent laryngeal nerve (RLN), thyroidectomy, UEScope

1 | INTRODUCTION

Recurrent laryngeal nerve (RLN) and external branch of the superior laryngeal nerve (EBSLN) dysfunctions remain significant sources of morbidity after thyroid surgery. Intraoperative neuromonitoring (IONM) of the RLN and EBSLN is a useful adjunct technique in thyroid surgery and has gained widespread acceptance in the international community[1-9] Electromyographic (EMG) endotracheal tube (ET) surface recording electrode systems are now used worldwide for IONM-assisted thyroidectomy. Accurately positioning the EMG ET is a key step in successful IONM.[10,11] For high-quality signals, the electrodes embedded in the EMG tube must have good contact with the vocal cords. A mispositioned EMG tube can cause a false decrease or false loss of EMG signals. False signals may be difficult to distinguish from those caused by true RLN injuries and may impair surgical decision-making.[12]

Although IONM is successful in 95% of patients, it requires a complex and time-consuming protocol. The conventional procedure is to use direct laryngoscopy to place the EMG tube and then use flexible laryngofiberscopy to verify the surface electrode positions.[13,14] Chang et al simplified the procedure for EMG tube placement by using an intubating stylet (Trachway) rather than direct laryngoscopy.[15] However, a laryngofiberscopic examination was still required to confirm the surface electrode positions.

The UE video laryngoscope (UEScope) is a portable video laryngoscope device with a moderate blade curvature, a wide-angle adjustable screen, and an effective anti-fogging design. Simulated and actual applications of the UEScope in various clinical scenarios have shown that it improves visualization of the glottis, allows both anesthesia and surgical operating room personnel full visualization, and increases the success rate of intubation.[16,17]

To our knowledge, the use of a UEScope for EMG tube placement in patients undergoing monitored thyroidectomy has not been reported yet. We hypothesized that the UEScope would enable guidance of the EMG tube placement and the videoscopic verification of the surface electrodes, simultaneously. Herein, we demonstrate a simple technique for UEScope-guided EMG tube placement and confirmation of the surface electrode position without laryngofiberscopy.

2 | MATERIALS AND METHODS

After obtaining approval from the institutional review board of the Kaohsiung Medical University Hospital (KMUHIRB-E(II)-20190156), perioperative records of 40 consecutive patients who underwent monitored thyroidectomy by an experienced thyroid surgeon, between August 2017 and July 2018, were reviewed. All tracheal intubations were performed and anesthesia care was given by an experienced anesthesiologist. The neural monitoring setup and anesthesia protocol followed international guidelines. Anesthesia was induced by lidocaine (1 mg/kg), fentanyl (1 mcg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg). When maximum neuromuscular blockade was achieved, tracheal intubation with an EMG ET was performed as follows. All patients underwent a standard neural monitoring protocol for thyroidectomy.[18,19]

2.1 | Preparation of the UEScope and loading an EMG tube with the stylet

A donut head pad was used to extend the neck (Figure 1A), and standard physical monitoring was performed before anesthesia. A reinforced EMG ET (internal diameter [ID] 6.0 and 7.0 mm; Medtronic, Jacksonville, Florida) was chosen for both male and female patients. A UEScope stylet was preloaded within the EMG tube and kept 1 cm distal to the tip of the tube (Figure 1B). The stylet length was adjusted according to the length of the EMG tube. The flexible EMG tube was matched to the stylet curve. The LCD screen was powered on at the beginning of the anesthesia induction procedure (Figure 1C). A size 4 blade (length 10 cm) was used. (Figure 1D). The pre-warm light source prevented the lens of the blade from fogging when placed in the oral cavity during tracheal intubation.

2.2 | EMG tube placement and electrode position confirmation by UEScope

The initial steps of EMG tube placement were similar to those of conventional laryngoscopy. The UEScope (UE Medical Devices, Newton, Massachusetts) was placed from the midline of the oral cavity to enable a full view of the vocal cords. The blade was gently adjusted until the glottic opening appeared in the upper center of the LCD screen (Figure 2A). The records of the laryngeal view were classified as full and restricted with or without anterior laryngeal pressure. A complete visualization of laryngeal inlet was defined as "complete" view (Figure 2B). A visualization of partial glottic structures (arytenoid cartilage or posterior commissure) was defined as" restricted" view

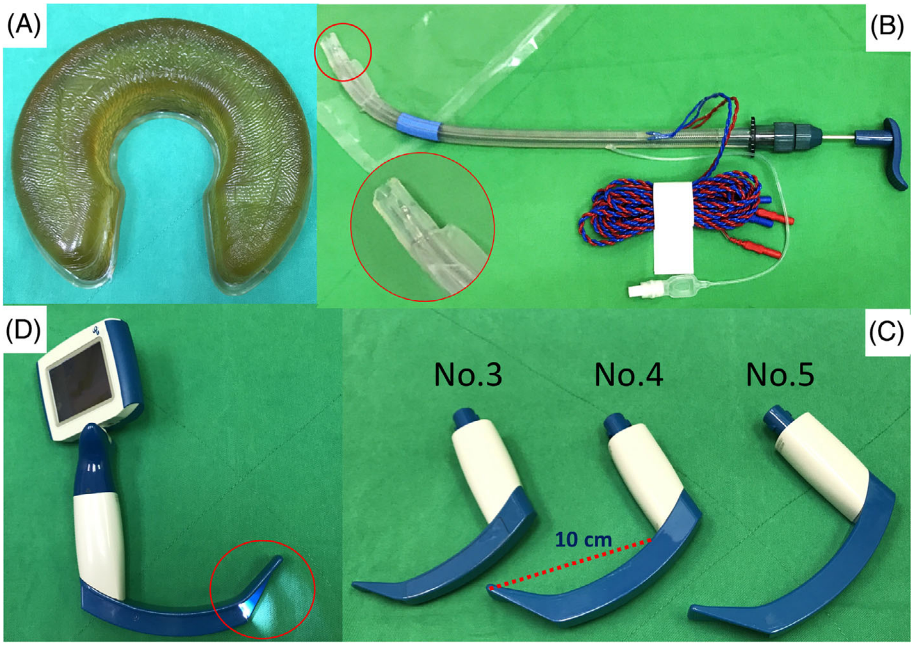

FIGURE 1 Preparation of the patient for electromyographic (EMG) tube placement. A, A donut pad is used to extend the neck before intubation. B, The UEScope stylet is loaded with an appropriate EMG tube such that it is 1 cm distal to the tip of the EMG tube (inset). C, Local heat from a light source prevents fogging of the camera lens. D, Three UEScope blades are designed for adult patients, of which size 4 is most commonly used

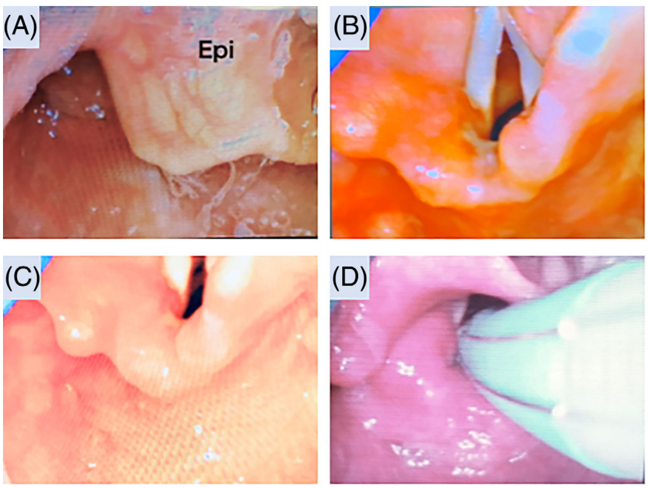

FIGURE 2 The procedures of endotracheal intubation with an electromyographic (EMG) tube and surface electrode alignment adjustment under the UEScope. A, Identify epiglottis (Epi) as an initial landmark. B, Typical "complete" laryngeal view of a full glottic inlet visualization. C, A "restricted" laryngeal view of posterior glottic structures visualization (partial vocal cords and arytenoid cartilage). D, Well contact between surface electrodes and vocal cords are kept at the proper depth

(Figure 2C). The advance of an EMG tracheal tube was guided by video image when the surface electrodes were in proper alignment with the true cords. End-tidal CO_2 waveforms and values were confirmed using standard monitoring. Proper tube depth and invisible tube rotation were visually verified using video (Figure 2D) (Video S1). The tube was then fixed at the right mouth angle during neck extension. The intubation attempt was recorded and difficult intubation was defined as more than three try attempts or shift to any other device such as fiberoptic bronchoscopy or optical stylet (Trachway). The position of the surface electrodes was not rechecked using fiberoptic endoscopy.

2.3 | Intraoperative neural monitoring setup

Standard protocols for general anesthesia and equipment setup were used for IONM of the RLN.[3] The channel leads from the surface electrodes of the EMG tube were connected to the neural monitoring system (NIM-Response 3.0, Medtronic, Jacksonville, Florida). The NIM-Response stimulus settings were as follows: time window, 50 ms; amplitude scale, 0.2 mV/division; duration, 100 μs; and frequency, 4 Hz. The threshold for the event capture was 100 μV. A standardized neural monitoring protocol was strictly followed, and the highest EMG signal amplitude was recorded at the initial (V1) and final (V2) vagus nerve stimulation. Preoperative and postoperative video recording of vocal cord mobility was performed by flexible laryngofibrescopy. When vocal cord dysfunction was noted, regular follow-up was conducted until recovery. Vocal cord palsy was defined as permanent if it persisted for 6 months after thyroid surgery.

2.4 | Outcome measurements and statistical analysis

The main outcome measured was proper EMG tube position, free from further adjustment, during the entire operation. The secondary outcomes assessed were the percentage of available V1 signal and V1 amplitudes higher than 500 μV. Medical records included demographic data, anesthesia and operation parameters, EMG tracheal tube depth, intubation-related airway trauma (dental, pharyngeal, and laryngeal), and monitoring troubleshooting events. Data were presented as mean with SD. Statistical

TABLE 1 Patient characteristics

	Female (n = 28)	Male (n = 12)	*P*
Age (y/o)	51.5 ± 12.7	58.9 ± 6.9	.07
Height (cm)	157.4 ± 5.3	169.1 ± 6.8	<.01
Weight (kg)	62.3 ± 13.0	71.7 ± 14.7	.05
ASA I/II/III (n)[a]	2/19/7	0/7/5	.42
Operation total thyroidectomy/lobectomy (n)	21/7	8/4	0.87
Laryngeal view			
Complete/restricted	26/2	26/2	.99
EMG tube depth (cm)	20.7 ± 0.9	21.2 ± 1.2	.2
V1 amplitude >500 μV (n)	25 (89%)	11 (92%)	.97
V1 amplitude (μV)	980 ± 493	781 ± 224	.19
V2 amplitude (μV)	993 ± 439	950 ± 365	.77

[a]Physical status classification system from the American Society of Anesthesiologists.[7]

analysis of continuous variables was carried out by the 2-sample *t* test. Categorical parameters were analyzed with the chi-square test or Fisher exact test. All statistical tests were 2-tailed, and a *P* value less than .05 was considered statistically significant.

3 | RESULTS

The patient characteristics are shown in Table 1. In our experience, this method simplifies intubation and enables a full view of the glottis in most patients. UEScope provided complete laryngeal view in 92.5% (37/40) and partial laryngeal view in 7.5% (3/40) of the patients during tracheal intubation. In all 40 consecutive patients, the tracheal intubations with EMG tubes were successful in the first attempt. None of them was labeled as difficult intubation. Adjustment of the EMG tube position during the surgery was not required in 97.5% cases (39 of 40 patients). The EMG tube depth ranged from 18 to 22 cm in female patients and 19 to 23 cm in male patients. Tube withdrawal was required in a male patient with a body height of 170.4 cm after the surgeon found, using the IONM mapping technique, that the tube was too deep. The EMG tube was then fixed at the right mouth angle, at a length of 23 cm.

All patients obtained a detectable V1 signal; the lowest V1 amplitude of 485 μV was considered as a reference value. A V1 amplitude greater than 500 μV was obtained in 90% of the cases (36 of 40 patients). The overall averaged values for V1 and V2 amplitudes were 920 ± 437 and 979 ± 413 μV, respectively. The procedure time was less than 10 minutes from anesthesia induction to confirmation of EMG tube position. No intubation-related airway injuries occurred and no monitoring troubleshooting was required during thyroid surgery. There was no temporary or permanent vocal palsy in all 40 patients.

4 | DISCUSSION

The UEScope have shown to improve visualization of the glottis, allows both anesthesia and surgical operating room personnel full visualization, and increases the success rate of intubation in various clinical scenarios. This study is the first to demonstrate a simple and effective technique for UEScope-guided EMG tube placement and confirmation of the surface electrode position without laryngofiberscopy. Our result shows that UEscope could provide 100% successful tracheal intubation at first attempt. Furthermore, proper EMG tube placement without position adjustment was found in 97.5% of the patients. Tube withdrawal was required in only one patient. With the improvement of the EMG tube electrode placement, we believe IONM will be implemented more optimally, to the ultimate benefit of the thyroid surgical patients.

Postoperative dysphonia remains a major cause of morbidity after thyroid surgery. One major change in the past decade is the widespread use of IONM to identify the RLN, adjunct to the standard practice of visual identification.[1-9] With the application of IONM, the surgeon can qualify and quantify the real-time functional status of the RLN based on the evoked laryngeal EMG response via electrical RLN or vagus nerve stimulation. At times, there may be a partial or total loss of nerve conduction to stimulation indicating RLN stress or injury; the surgeon can also evaluate the surgical maneuver that produced the impending or actual RLN injury. By elucidating the mechanism of RLN injury and surgical pitfalls, IONM can help surgeons improve surgical techniques, predict recovery outcomes, and plan intra- and postoperative management.[2,3,12,20-25] EMG endotracheal tube-based surface electrodes are predominantly used for neural monitoring during thyroidectomy because of their simplicity, utility, non-invasiveness, and safety.[19,26]

However, their major limitation is the need to maintain constant contact between the electrodes and the vocal cords during surgery to obtain a high-quality recording.[12-14,27] A mispositioned tube can cause false negative or decreased EMG signals that may result in inappropriate surgical decisions, and the verification or readjustment of the EMG tube position can be complicated and time-consuming. This study demonstrated a simple method of using a UEScope to place the EMG tube (Figures 1 and 2, Video S1) and to confirm the surface electrode position, rendering the blind and potentially dangerous intraoperative ET repositioning, or repeat intraoperative laryngofiberscope-based repositioning unnecessary.

In this study, neck extension before anesthesia induction has applied routinely to prevent possible EMG tube displacement caused by patient positioning. In one male patient, repositioning was done by the surgeon due to inadequate neck extension. The reason of deep position might be associated with neck extension after tracheal intubation and an EMG tube fixation.[14] Fortunately, the IONM system worked well and EMG signal was not influenced in this case.

Several studies have discussed the use of video-assisted airway devices for EMG tube placement instead of traditional direct laryngoscopy.[13,14] For example, the GlideScope video-assisted laryngoscope enable tracheal intubation under video guidance. Berkow et al reported that the GlideScope enabled optimal EMG tube positioning during monitored thyroidectomy.[27] Kanotra et al reported a high success rate in using the GlideScope to place EMG tubes in 250 surgical procedures.[28] The advantages of the UEScope are similar to those of GlideScope. Both tools enable the surgeon and the anesthesiologist to collaborate in the placement of EMG tubes and verification of surface electrode positions. However, an advantage of UEScope over GlideScope is that the UEScope stylet fits through the EMG tube whereas a standard stylet has to be bent to be used with the GlideScope.

The use of UEScope for EMG tube placement in monitored thyroidectomy has some limitations. First, the inherent curvature and size of the blade may make oral insertion difficult in patients with a limited mouth opening. Second, the deep insertion of the blade enables clear visualization of the glottis, but reduces the visual field on the video screen. This can be avoided by a gradual midline insertion of the blade with simultaneous observation of tube movement and glottic anatomy. A final limitation is that the UEScope does not allow rechecking of the tube displacement after fixation. Cherng et al proposed middle-mouth fixation to reduce the rotation of the EMG tube in a manikin study.[29]

In addition to the recent development of video-assisted airway devices for EMG tube placement, alternative recording electrode systems that can circumvent the factors affecting ET-based neural monitoring accuracy have been investigated recently. Recent experimental and clinical studies have confirmed the hypothesis that needle or adhesive surface recording electrodes on the thyroid cartilage (transcartilage and percutaneous)[28-32] or overlying neck skin (transcutaneous)[33,34] can function like the ET-based electrodes and enable access to the EMG response of the vocal fold muscles which originates from the inner surface of the thyroid cartilage. A recent large series case-control study by Türk et al[32] reports that the thyroid cartilage needle electrodes not only record significantly higher EMG signals but also cost 20 times cheaper than the EMG tube electrodes. These findings show that these thyroid cartilage or neck skin electrodes have potential applications in future electrode designs and have the potential to be used as a complementary quantitative tool for IONM in thyroid surgery.

This study has some limitations. First, the study design was a retrospective cohort rather than a prospective randomized controlled. The study aim was to demonstrate a simple and effective technique for UEScope-guided EMG tube placement for monitored thyroid surgery. Since video laryngoscope and optical stylet devices have been proven to show better intubation outcomes than conventional direct laryngoscopy and became the routine method in our institution, we did not collect patients using conventional method as control group and perform a power analysis for the study. Furthermore, we could not exclude a bias resulted from experienced anesthesiologist who performed all intubation. Since learning curve of each device is mandatory, the different level of experience might influence the successful intubation. Therefore, future prospective randomized controlled studies with comparison of different intubation method and experience level will be required to verify the outcomes of this study. Finally, the effectiveness of this method is limited to IONM signal via EMG tube incorporated with surface electrodes. When thyroid cartilage needle or adhesive electrodes are used, the use of UEScope for alignment will become unnecessary.

In conclusion, UEScope is a valuable and reliable tool for placing an EMG tube and confirming its position during monitored thyroidectomy. It also allows the surgeon and the anesthesiologist to simultaneously confirm optimal EMG tube placement. Therefore, it can help ensure maximum, sustained contact between the surface electrodes and the vocal cords during the surgery and thus prevent RLN or EBSLN injury that could lead to postoperative complications.

CONFLICT OF INTEREST

The authors have no financial interests or other conflict of interests to declare.

AUTHOR CONTRIBUTIONS

Jui-Mei Huang, I-Cheng Lu: Conception and design of study; **Che-Wei Wu, Sheng-Hua Wu, Chun-Dan Hsu, Yi-Wei Kuo**: Administrative support of study; **Tzu-Yen Huang**: Collection and assembly of data; **All authors**: Analysis and interpretation of data, preparation of manuscript, and final approval of manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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