Electromyographic endotracheal tube placement during thyroid surgery in neuromonitoring of recurrent laryngeal nerve

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Abstract Intraoperative neuromonitoring (IONM) is widely used in thyroid surgery. This study aimed to investigate the influence of neck extension on electromyographic (EMG) endotracheal tube displacement and to determine the necessity of routinely checking the final electrode position after the patient had been fully positioned. A consecutive 220 patients undergoing thyroidectomy were enrolled. All patients were intubated with the EMG endotracheal tube under direct laryngoscopy. The electrode position and tube displacement were routinely checked and measured by laryngofiberscopy before and after patient positioning. The
Introduction

Intraoperative neuromonitoring (IONM) has gained widespread acceptance as an adjunct to prevent recurrent laryngeal nerve (RLN) injury during thyroid surgeries [1–8]. Several neuromonitoring systems have been developed in the past three decades, but the system of endotracheal tube–based surface electrodes has become popular because of its essential advantages, including ease of setup and use, noninvasive nature, and the capacity as a surface electrode to contact larger areas of the target muscle and summate electromyography (EMG). IONM can be applied to localize and identify the RLN, to elucidate the mechanism of RLN injury during the operation [6,7], and to predict the outcome of vocal function after resection of thyroid. However, until now, monitor dysfunction has been continuously reported at rates ranging from 3% to 23% [9–13].

Monitor dysfunction will give misleading information and, conversely, increase the risk of nerve injury. It also results in a low rate of positive predictive value [13–17] when IONM is used to predict the outcome of vocal function. Some studies reported that malpositioning of EMG endotracheal tube was the main cause of monitor dysfunction [11,12]. Dionigi et al. [11] reported that 15 patients (10%) needed further tube adjustment intraoperatively because of nonoptimal contact of endotracheal surface electrodes to vocal cords. In our previous study [12], we also experienced six cases (5.6%) of monitor dysfunction among our 106 patients, and all were caused by the malpositioning of electrodes. These results suggest that the electrode position can be displaced and not detected when the patient’s neck is changed from the neutral position for tracheal intubation to full extension for thyroid surgery. If severe displacement of EMG endotracheal tube occurs, poor contact between the electrodes and true vocal cords will result in monitor dysfunction. This study aimed to investigate the influence of neck extension on EMG endotracheal tube displacement and to determine the necessity of routine verification of proper position of electrodes after the patient is fully positioned.

Materials and methods

The study was approved by the local Institutional Review Board and the ClinicalTrials.gov (http://www.clinicaltrials.gov, identifier: NCT00629746). Written informed consent was obtained from each patient. Patients were informed that they were to be intubated with an EMG endotracheal tube for the neuromonitoring system, potentially, to aid in the localization and identification of the target nerves during the operation. There was no financial or professional association between the authors and the commercial company whose nerve-monitoring product was used.

From September 2007 to October 2009, 220 consecutive patients who underwent thyroid surgeries for various diseases and who were all treated by the same surgeon (F.-Y. Chiang) were enrolled. There were 97 total lobectomies and 123 total thyroidectomies. Ten nerves were excluded from this study (8 nerves with preoperative palsy and 2 nerves with intentional transection because of cancer invasion). Thus, in all, 333 nerves were at risk in this study.

The patient’s head and neck were kept at neutral position during tracheal intubation. After induction of anesthesia with 2 μg/kg fentanyl (Janssen-Cilag, Taiwan) and 5 mg/kg thiamyal (Shinlin Sinseng, Taiwan), quantitative monitoring of the neuromuscular blockade with the TOF-GUARD system (Organon Teknika, Turnhout, Belgium) was established. After a stabilization phase for the relaxometry of 60 seconds, all patients were given a standard dose of muscle relaxant. When maximal neuromuscular blockade was achieved, a Medtronic Xomed nerve integrity monitor standard
reinforced EMG endotracheal tube [Metronic Jacksonville, FL. Internal diameter (ID) = 6.0 mm for women and ID = 7.0 mm for men] was inserted under direct laryngoscopy by the same anesthesiologist. To ensure the correct position of electrodes and to measure the displacement of EMG endotracheal tube, we routinely put three marks (2 transverse lines and 1 vertical line) on the posterior surface of the tube (Fig. 1). The first transverse line was 5 mm lower than the upper margin of the exposed surface electrodes, and the second transverse line was 10 mm distal to the first line. The vertical line (15 mm from the first transverse line) was put on the posterior midline of the tube. After the EMG endotracheal tube was intubated and the patient’s neck was still in neutral position, a laryngofiberoscope (Olympus ENF XP 4.5 mm; Olympus, Tokyo, Japan) was inserted through the nasal route to examine and adjust the electrode position. Initially, we placed the first transverse line at the level of inter-arytenoid bar and the vertical line at midline position without rotation, which was regarded as the ideal position of electrodes (Fig. 2). In Group I (n = 110), the endotracheal tube was taped and fixed at the right mouth angle before full neck extension. In Group II (n = 110), the endotracheal tube was disconnected from the circuit tube and was not taped during positioning (the disconnection time was less than 30 seconds). After the patient’s neck was placed at full extension, the laryngofiberoscope was reinserted to check and measure the displacement between the first transverse line and the inter-arytenoid bar. If displacement of the tube occurred, it was returned to the original position. Then, the EMG tube was taped to the right mouth angle, and the circuit tubes were placed on the holder (Fig. 3). During the operation, standardized IONM procedures [18] were used to test vagus nerve and RLN in each patient. The procedures included the following: (1) vagal stimulation (V1 signal); (2) RLN localization (L signal); (3) RLN stimulation before dissection (R1 signal); (4) RLN stimulation after dissection (R2 signal); and (5) vagal stimulation after complete hemostasis (V2 signal).

Results

The rates of upward, downward, and no displacement of the endotracheal tube were 89.1% (98/110), 4.5% (5/110), and 6.4% (7/110) in Group I, and 75.4% (83/110), 6.4% (7/110), and 18.2% (20/110) in Group II. The range of tube displacement after neck extension was 16 mm upward and 4 mm downward in Group I, and 12 mm upward and 5 mm downward in Group II (Fig. 4). The rate of tube displacement greater than 10 mm was 12.7% (14/110) in Group I and 3.6% (4/110) in Group II.

Successful monitoring was achieved in all patients after ensuring that the final electrode position was the optimal position routinely, and no patient needed to have the EMG endotracheal tube readjusted intraoperatively. Only two nerves experienced loss of signal intraoperatively, and both nerves developed temporary cord palsy. The RLN palsy rate was 0.6%; no permanent palsy occurred. The mean EMG amplitudes from different stimulating steps (V1, L, R1, R2, and V2 signals) are shown in Table 1.

Discussion

From the results of this study, we found that severe displacement of EMG endotracheal tube occurred after neck extension whether or not the tube was fixed, although less displacement was found in patients whose tubes were not taped during neck extension. The rate of tube
displacement greater than 10 mm was 12.7% in Group I and 3.6% in Group II. The endotracheal tube displacement ranged from 16 mm upward to 5 mm downward. The results suggest that the electrodes of EMG endotracheal tube may have poor contact with the true vocal cord after neck extension, typically in those cases in which the tube had been taped before neck extension. Several studies [19,20] also reported changes in endotracheal tube position during head and neck position change. In the study by Yep et al. [19], a range of endotracheal tube displacements from 33 mm upward to 21 mm downward after neck extension was reported. Therefore, ensuring proper electrode position after the neck is fully positioned is the key to successful IONM, but it is seldom discussed in the literature.

In our previous study [12], the mean depth of the Nerve Integrity Monitor EMG endotracheal tube (21 ± 1 cm for men and 20 ± 1 cm for women) was a useful reference value in detecting the malposition of electrodes and adjusting the depth of tube during the operation. However, these data are only useful for Asian patients. Randolph [21] advocated that the presence of respiratory variation on both channels after patient positioning always guarantees proper endotracheal tube position and subsequent problem-free monitoring. However, the presence of respiratory variation can be hindered by the use of muscle relaxant for induction or by deeper anesthesia.

In this study, we routinely put three marks (2 transverse lines and 1 vertical line) on the posterior surface of the tube (Fig. 1). We found that the marks were very useful to ensure proper positioning of electrodes during laryngofiberoptic examination. As the first transverse line was placed at the level of interarytenoid bar, the true vocal cord would be located at the middle of the exposed electrodes. The vertical line is useful and helpful not only to detect the rotation of the tube, but also to judge the depth of the tube if the tube depth is suspected to be too deep intraoperatively. There are several potential advantages with this tube placement procedure: (1) the electrodes are ensured to be placed at the optimal position before the beginning of operation, and some upward or downward displacement of the tube caused by the intraoperative manipulation on trachea would not result in malposition; (2) the procedure ensures that the electrodes are placed at the midline position; besides tube depth error, tube rotation can also result in monitor dysfunction or a false weakened signal; and (3) it provided a higher magnitude of EMG amplitude that would be useful for RLN localization, detecting a true weakened signal and predicting the outcome of vocal function. The EMG amplitude detected by endotracheal tube–based system is an inconstant parameter because it changes under different circumstances, typically in the case of tube rotation or

Figure 3. The holder provides good support and fixation of the EMG endotracheal tube and the circuit tubes. It is very useful to prevent tube rotation and upward or downward displacements during the operation.

Figure 4. The plots depict the range of the electromyographic endotracheal tube displacement in Groups I and II. The range of tube displacement after neck extension was from 16 mm upward to 4 mm downward in Group I and from 12 mm upward to 5 mm downward in Group II. The rate of tube displacement greater than 10 mm was 12.7% in Group I and 3.6% in Group II. ETT = endotracheal tube.
suboptimal positioning of electrodes that was caused by manipulation on the trachea. Using this setup procedure, we never experienced monitoring dysfunction and we obtained stable amplitudes during the whole operation. The mean EMG amplitudes from different stimulating steps ($V_1$, $L$, $R_1$, $R_2$, and $V_2$ signals) were $874 \pm 492 \mu V$; $1,033 \pm 514 \mu V$; $1,172 \pm 570 \mu V$; $1,184 \pm 584 \mu V$; and $901 \pm 499 \mu V$, respectively. All RLNs were successfully localized and identified at the tracheoesophageal groove. Two nerves (0.6%) experienced loss of signal after dissection of RLN and both developed temporary palsy.

Besides the malpositioning of EMG endotracheal tube, there are still some pitfalls, such as misuse of neuromuscular blocking agents, defective equipment, improper setup of wires, and others, which will cause monitor dysfunction and lead to false IONM results. Therefore, ensuring a functional IONM at the beginning of thyroid surgery is also a necessary step. Dralle et al. [5] emphasized that vagal stimulation can easily uncover most kinds of artifacts. In this study, we routinely perform vagal stimulation before RLN identification. If EMG signal is obtained from vagal stimulation, it means that the monitoring system is working and the RLN is running in a normal pathway. We detected two non-RLNs at the earlier stage of operation because of negative response from vagal stimulation, and the non-RLNs were localized and identified at the upper tracheoesophageal groove.

Monitoring dysfunction significantly affected the positive predictive values (ranging from 10% to 90%) for the prediction of postoperative RLN palsy [14–19]. The low and highly variable positive predictive value has limited the value of IONM. Furthermore, false-positive results (for patients with signal loss intraoperatively but normal vocal function postoperatively) may influence the surgeon's decision regarding the extent of thyroidectomy and may cause the patient to receive an unnecessary second operation. If verification of proper electrode position after patient positioning and vagal stimulation before RLN identification are routinely performed, the positive predictive value is expected to rise.

To prevent the occurrence of monitor dysfunction, we recommend that IONM should be a teamwork between the surgeon and the anesthesiologist. A highly collaborative anesthesiology team can assist in (1) correct placement of the EMG endotracheal tube, (2) re-ensuring proper positioning of electrodes after patient positioning or during the operation, and (3) carefully delivering neuromuscular blocking agents, thus avoiding repeated use.

In conclusion, EMG endotracheal tube placement is the most important part during the setup of IONM. Verification of proper electrode position after patient positioning is the key to functional IONM during the thyroid surgery. Checking the final electrode position routinely with laryngofiberoscopy is a simple procedure. It takes only a few minutes and guarantees a problem-free IONM during the whole operation.

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### References


