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The Mechanisms of Recurrent Laryngeal Nerve Injury During Thyroidectomy and The Impact of Continuous Intraoperative Nerve Monitoring on Surgical Strategy

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ABSTRACT:

The mechanisms of recurrent laryngeal nerve injury during thyroidectomy and the impact of continuous intraoperative nerve monitoring on surgical strategy

Objective: To evaluate the mechanisms of recurrent laryngeal nerve (RLN) injury during thyroidectomy and the impact of continuous intraoperative nerve monitoring (C-IONM) on surgical strategy.

Material and Methods: The data of 364 consecutive patients who underwent total or hemithyroidectomy between June 2014 and January 2016 were evaluated prospectively. All patients underwent thyroidectomy by using C-IONM. The mechanisms of RLN injury and the outcomes of the patients with combined events (CE) and loss of signal (LOS) were evaluated.

Results: Combined events (CE) occurred in 6 (1.6%) of these 364 patients. The reduced electromyographic (EMG) amplitude and prolonged latency recovered in all patients intraoperatively by the reversal of the medial traction maneuver. Loss of signal (LOS) occurred in 7(1.9%) patients. The mechanisms of LOS was ligation of the anterior branch of the nerve in 1 (14.3%) patient and traction in 4(57%) patients. The probable mechanism of LOS was traction or transection in 2 (28.6%) patients in whom LOS occurred during the dissection of the intrathoracic portion of large substernal goiter. Of these 7 patients, LOS recovered intraoperatively after 20 minutes of waiting in 1(14.3%) patient. In the remaining 6 (85.7%) patients, unilateral vocal cord paralysis (VCP) was verified on the postoperative laryngoscopic examination. The overall temporary and permanent unilateral VCP rates were 1.6% (n=6) and 0.8% (n=3), respectively in these 364 patients. No bilateral VCP was recorded. Continuous intraoperative nerve monitoring (C-IONM) prevented bilateral VCP in 1 (0.3%) patient.

Conclusion: The major advantage of C-IONM is to alert the surgeon for imminent RLN injury. Combined event (CE) is a pathognomonic sign of impending nerve injury that may progress to LOS. This situation enables the surgeon to adverse (reverse) the surgical maneuver before permanent damage to the nerve sets in. Continuous intraoperative nerve monitoring (C-IONM) can also immediately spot RLN injury during thyroidectomy. This property of C-IONM gives the surgeon the opportunity for an early corrective action to release the affected nerve promptly. In case of permanent LOS, staged thyroidectomy could be planned to prevent bilateral VCP.

Keywords: Continuous intraoperative neuromonitoring, Thyroid surgery, IONM, C-IONM, recurrent laryngeal nerve injury, vocal cord palsy, loss of signal

ÖZET:

Tiroidektomi esnasında rekürren laringeal sinirin yaralanma mekanizmaları ve devamlı intraoperatif sinir monitorizasyonunun cerrahi strateji üzerine etkisi

Amaç: Tiroidektomi esnasında rekürren laringeal sinirin (RLN) yaralanma mekanizmalarını ve devamlı intraoperatif sinir monitorizasyonunun (D-İONM) cerrahi strateji üzerine etkisini değerlendirmek

Gereç ve Yöntemler: Haziran 2014-Ocak 2016 arası total veya hemitiroidektomi yapılan ardışık 364 hastanın verileri prospektif olarak değerlendirildi. Tüm hastalar D-İONM kullanılarak ameliyat edildi. RLN yaralanma mekanizmaları, kombine olaylar (KO) ve sinyal kayıpları (SK) değerlendirildi.

Bulgular: Üç yüz altmış dört hastanın 6'sında (%1.6) KO gelişti. Elektromiyografideki (EMG) amplitüd azalması ve latensdeki artış medial manevraya dönülmesinden sonra tüm hastalarda düzeldi. Yedi hastada (%1.9) SK saptandı. SK'nın mekanizması; 1 hastada (%14.3) sinir ön dalının bağlanması, 4 hastada (%57.0) ise gerilmeydi. İntratorasik büyük guatrı olan 2 hastada (%28,6) ise SK'nın muhtemel mekanizması aşırı gerilme veya transeksiyon olarak değerlendirildi. Bu yedi hastanın 1 tanesinde (%14.3) SK ameliyat esnasında 20 dakika bekleme sonrası düzeldi. Kalan 6 hastanın (%85.7) ise ameliyat sonrası yapılan laringoskopik muayenelerinde vokal kord paralizisi (VKP) saptandı. Tüm hasta grubunda tek taraflı geçici ve kalıcı VKP oranı sırasıyla %1.6 (n=6) ve %0.8 olarak saptandı. Hiçbir hastada kalıcı VKP saptanmadı. D-İONM, bir hastada (%0.3) bilateral VKP'yi önledi.

Sonuç: D-İONM'nin en büyük avantajı RLN hasarı durumunda cerrahı anında uyarmasıdır. KO gelişebilecek SK'nı gösteren patognomonik bir bulgudur. Bu durumda cerrah ters yöne doğru bir manevra yaparak kalıcı hasar gelişmesini önler. D-İONM ayrıca tiroidektomi esnasında RLN yaralanmasını anında gösterir. Böylece cerrah etkilenen sinir bölgesine yönelik rahatlatıcı bir harekette bulunabilir. Kalıcı SK'da ise bilateral SK'yı önlemek için aşamalı tiroidektomi planlanabilir.

Anahtar kelimeler: Devamlı intraoperatif sinir monitorizasyonu, tiroid cerrahisi, İONM, D-İONM, rekürren laringeal sinir yaralanması, vokal kord hasarı, sinyal kaybı

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INTRODUCTİON

Recurrent laryngeal nerve (RLN) injury is a serious complication of thyroid surgery which can deteriorate the quality of life (1). The temporary vocal cord palsy (VCP) is more common (2-5.1%) than permanent RLN injury (0.6-1%) during thyroid surgery (2-5). However, RLN injury rates increase up to 10.8% in neck re-explorations (6). Dissection and the identification of the RLN is considered as the gold standard method to prevent RLN injury during thyroid surgery (7,8). Although the visualization of the nerve shows the structural integrity, it does not reveal any information about the functional integrity of the nerve and postoperative vocal cord function. Several studies showed that stretching of the nerve rather than its transection is the leading source of RLN injury during thyroidectomy (9-12). The use of intermittent intraoperative nerve monitoring (I-IONM) which includes stimulation of the RLN and the vagus nerve has become a standard method to evaluate nerve function. A standardized approach was introduced, including vagal nerve and RLN stimulation before and after the resection of the both thyroid lobes (13,14). Intermittent intraoperative nerve monitoring (I-IONM) helps to identify the nerve, maps its course and diagnoses the loss of signal (LOS). Intermittent intraoperative nerve monitoring (I-IONM) also has advantages over visual protection especially in patients who have a large goiter, locally-advanced thyroid cancer or in patients with previous thyroid surgery in predicting postoperative nerve function (15). However, I-IONM shows the functional integrity of the RLN limited to the time interval of direct nerve stimulation.

The main advantage of continuous intraoperative nerve monitoring (CIONM) to I-IONM is the real-time surveillance of RLN function during thyroid mobilization and RLN dissection. Continuous intraoperative nerve monitoring (CIONM) allows instant evaluation of a decrease in the amplitude or increase in the latency by the surgeon which also allows aborting a surgical maneuver thus to prevent nerve damage (16).

In this study, we evaluated the mechanisms of combined event (CE) (decrease in the amplitude and simultaneous increase in the latency) and loss of signal during thyroid surgery and the outcome of vocal cord functions in patients in whom C-IONM was used during thyroid surgery.

MATERIAL AND METHOD

The data of 371 consecutive patients who underwent total thyroidectomy or hemithyroidectomy between June 2014 and January 2016 were evaluated prospectively. Patients who had vocal cord paralysis on the preoperative vocal cord examination due to nerve injury sustained during a previous operation (n=5, 1.3%), or in whom intentional resection of the RLN was performed due to locally invasive thyroid cancer (n=2, 0.5%) were excluded. A total of 364 patients and 658 nerves which were at risk were included in the study. The laryngoscopic examinations of the vocal cords were performed prior to operation and within the three days following the operation. In case of VCP detected on early postoperative vocal cord examination, further laryngoscopic examinations were performed on 3rd, 6th and 12th months postoperatively.

Surgical Technique

Anesthesia preparations and methods used during the surgery were recorded in compliance with the recommendations of the International Intraoperative Monitoring Study Group (13). Following the Kocher incision and opening the midline, the vagus nerve was identified within the carotid sheath and an original EMG signal was obtained from the vagus nerve (V1) with the hand probe before the identification of RLN. The alternative lateral approach was employed especially in revision procedures. After recording the V1 with the hand probe, the vagus was dissected gently and the S-shaped vagus probe was positioned. For continuous stimulation of the vagus nerve, an EMG amplifier and pulse generator were used (1mA, 200µs, 3Hz frequency). Continuous intraoperative nerve monitoring (CIONM) was performed using an S-shaped vagus probe and bipolar hand probe in all patients (Dr. Langer Medical GmbH, Avalanche SI). If the basal signal was under 50 mA, repositioning of the endotracheal tube was performed.

After the signal exceeded 50 mA, it was recorded (V1) and dissection was initiated.

The signal was obtained from the RLN, which was first identified at the tracheoesophageal groove and was recorded as R1. Recurrent laryngeal nerve (RLN) was then dissected by a caudocranial approach during its entire course and any anatomical variations were recorded. After completion of lobectomy and hemostasis, the signal was obtained by stimulating the most proximally exposed portion of RLN (R2) which was dissected completely from Berry's ligament and the vagus nerve (V2).

During the interpretation of C-IONM recordings, a CE was defined as greater than 50% decrease in amplitude along with greater than 10% increase in latency regarding baseline values, demonstrating clinically important EMG thresholds which were indicative of impending nerve injury (11). The diagnosis of LOS implies the complete loss of neural stimulation response with amplitude ≤100 μV, as defined by the International Neuromonitoring Study Group (INMSG) (13).

RESULTS

The mean age of the patients was 46.3±16 years with female/male ratio of 4/1(291/73). Of these 364 patients, 294 (81%) underwent total thyroidectomy and 70 (19%) underwent hemithyroidectomy. Central lymph node dissection additional to total thyroidectomy was performed in 30 patients.

Of these 364 patients, a CE occurred during the medial traction of the either right or left lobe in 6 (1.6%) patients. In these 6 patients, reduced signal values recovered after reversing the medial traction maneuver. Postoperative laryngoscopy revealed normal vocal cord functions in these 6 patients.

Unilateral LOS occurred in a total of 7 (1.9%) patients. The mechanisms of LOS were summarized in Table-1. In one of these 7 patients, LOS occurred due to the ligation of the anterior branch of a bifurcated RLN which was mistaken for a vessel during the dissection of the nerve at the site of the Berry's ligament. In this patient, the knot was untied immediately when LOS was encountered. Postoperative early vocal cord examination revealed unilateral VCP in this patient. Vocal cord functions were found to be normal by laryngoscopic examination on the 3rd postoperative month. In 4 of 7 patients with LOS, LOS occurred due to the medial traction of the thyroid lobe. Of these 4 patients, LOS occurred during the surgery of the dominant side in 2 patients and during the surgery of the opposite side after the lobectomy was completed in the dominant side in the remaining 2 patients. The medial traction maneuver was reversed in all patients after the LOS occurred. Of the two patients in whom LOS occurred during the surgery of the dominant side, the reduced values improved after a period of 20 minutes in one patient and total thyroidectomy was completed. The postoperative laryngoscopic examination showed that both vocal cords were normal in this patient. In the remaining 1 patient, the reduced amplitude didn't show an improvement after 20 minutes of waiting and staged thyroidectomy was planned. Postoperative laryngoscopy revealed unilateral VCP which was found to recover on the 3rd month postoperatively and the patient underwent surgery for the opposite side. In the 2 patients in whom LOS occurred during the surgery of the opposite side after the lobectomy

Table-1: The mechanisms and the outcomes of patients with LOS

LOS	Mechanism	Temporary	Permanent	Recovery
Patient 1	Ligation	✓	-	Postoperative 3rd month
Patient 2	Traction	✓	-	Intraoperatively
Patient 3	Traction	✓	-	Postoperative 3rd month
Patient 4	Traction	-	✓	-
Patient 5	Traction	✓	-	Postoperative 3rd month
Patient 6	Transection ?*	-	✓	-
Patient 7	Transection ?*	-	✓	-

*LOS occurred during the dissection of the intra-thoracic portion of the huge substernal goiter.

was completed on the dominant side, the reduced amplitudes didn't improve after 20 minutes of waiting. Postoperative laryngoscopic examination revealed unilateral VCP in both patients. During the follow-up, vocal cord function recovered in 1 patient on the postoperative 3rd month, however, permanent VCP occurred in the remaining patient. In 2 patients with substernal goiter, LOS occurred during the dissection of the mediastinal portion of a large intrathoracic goiter via sternotomy. The mechanism of LOS was probably due to RLN injury at the intrathoracic segment of the nerve. Permanent VCP developed in these 2 (28.6%) patients.

Of the 7 patients in whom LOS was encountered during C-IONM, permanent unilateral VCP developed in 3 (42%). The overall temporary and permanent unilateral nerve injury rates were 1.6% (n=6) and 0.8% (n=3) in these 364 patients, respectively. No bilateral VCP was recorded.

DISCUSSION

Iatrogenic RLN injury during thyroid surgery is the main reason for postoperative VCP. Visual identification of the RLN during thyroid operations has been considered as the gold standard of RLN treatment by many studies (7,8). There are several injury mechanisms that cause RLN dysfunction, including transection, clamping, stretching, electro-thermal injury, ligature entrapment or ischemia. Chiang FY et al. (2) showed that excessive stretching of the RLN at the region of Berry's ligament while traction of the thyroid lobe plays a major role in the occurrence of RLN paralysis during thyroidectomy.

Intraoperative neuromonitoring helps to identify and localize the RLN and also helps to recognize anatomical variations of the nerve, as well as to predict postoperative vocal cord function (13,17,18). The major advantage of I-IONM is to reduce the risk of bilateral RLN injury by staging the thyroidectomy if RLN injury occurred during the mobilization of the dominant side (19). However, I-IONM has relevant limitations. Assessment of RLN functional integrity is limited to the short time interval of direct nerve stimulation and the integrity of the laryngeal nerve is assessed only at the site of direct nerve stimulation which may produce a false negative (normal) signal in patients with a proximal nerve injury (13). Standardized IONM technique with vagal nerve (VN) stimulation recognizes any RLN lesions, even the most proximal but again in an intermittent manner in I-IONM.

To overcome these limitations, C-IONM has been proposed (20-23). C-IONM comprises automatic periodic stimulation (APS) of the vagus nerve which shows the changes in electromyographical (EMG) amplitude during surgery. C-IONM also gives visual and acoustic feedback to the surgeon of the current RLN conductivity, which allows continuous evaluation of the RLN (20-23). The major advantage of C-IONM is to detect imminent and/or increasing RLN injury intraoperatively. In case of a reduction in the amplitude and increase in the latency, the surgeon may react early intraoperatively to RLN stress, and RLN injury may become reversible. Theoretically, the surgeon can avoid an eventual further injury of RLN and the nerve is restored by relieving the pressure and damage earlier.

There are several studies in the literature that show the superiority of the C-IONM to visual identification alone and I-IONM (20,21,22,24,26-28). In a study of Schneider et al. (29) the final outcome of RLN dysfunction was significantly improved by C-IONM. The authors compared the VCP rates in 965 nerves dissected by using I-IONM with the rate in 1,314 nerves dissected by using C-IONM. They found that the rate of permanent VCP could be diminished from 0.4% to 0% (p=0.019) with the use of C-IONM.

In our study, C-IONM provided to avoid further RLN injury in 6 (1.6%) patients in whom CE occurred during the medial traction of the thyroid lobe. The reduced amplitudes improved in all of these 6 (1.6%) patients after relieving the stress on the nerve by reversing the surgical maneuver. Of the 7 patients in whom LOS occurred during the surgery, the use of C-IONM prevented permanent vocal cord paralysis in 2 (28.6%) patients. In these 2 patients, the mechanism of LOS was traction of the nerve in one of the patients. In this patient, the reduced amplitudes recovered after waiting for 20 minutes intraoperatively by reversing the surgical maneuver. In the remaining patient, LOS occurred after a ligation of the anterior branch of the RLN which was mistaken for a vessel. In this patient, the knot was quickly untied and vocal cord paralysis recovered 3 months after the operation. C-IONM prevented bilateral vocal cord paralysis risk in 1 (14.3%) of 7 patients with LOS, in whom staged thyroidectomy was performed after the recovery of the paralyzed vocal cord function on the 3rd month.

One of the controversial topics related with C-IONM is the local and cardiac complications. In the study of Terris DJ et al. (30) in 2015, the authors mentioned hemodynamic instability and reversible vagal neuropraxia in two patients and they reported C-IONM as an unsafe and invasive method. In the study of Brauckhoff K et al., the authors concluded that the C-IONM may, however, be limited in its utility by system malfunction, direct harm to the vagus nerve, and particularly, inability to indicate RLN lesions ahead in time (31). Beside these two reports, there are several clinical data showing no evidence of adverse effects related to dissection of vagal nerve or cardiac complications related to C-IONM (21,25,27,29,32-35).

The other controversial topic related with C-IONM is proceeding the contralateral lobectomy in patients with LOS which occurred during the lobectomy of the dominant side. In a study of Sitges-Serra A. et al. (36), the authors reported that upon detection of unilateral LOS during surgery in 16 patients, the signal returned in 15 of the 16 after waiting for an average of 20.2 (10-35) minutes. Based on these results, Sitges-Serra A. argued that after especially unilateral LOS, two-stage surgery increases complications and costs in the first three months. However, contrary to the general consensus, two-stage thyroidectomy reduces the risk of bilateral paralysis (37-40). In a study of Peter E. Goretzki et al. (40), IONM's sensitivity to detect a damage was determined as 93% and the specificity as 77% for patients who are visually healthy but developed temporary vocal cord paralysis after surgery. Bilateral vocal cord paralysis did not develop in patients whose surgery strategy had been changed.

CONCLUSION

The major advantage of C-IONM is to alert the surgeon for imminent RLN injury. Combined event is a pathognomonic sign of impending nerve injury that may progress to LOS. This situation enables the surgeon to reverse the surgical maneuver before permanent damage to the nerve sets in. C-IONM can also immediately spot RLN injury during thyroidectomy. This property of C-IONM gives the surgeon the opportunity for an early corrective action to release the affected nerve promptly. In case of permanent LOS, staged thyroidectomy could be planned to prevent bilateral VCP.

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