The Importance of Mapping Vagus and Laryngeal Nerves Monitoring During Thyroid Surgery

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ABSTRACT

Objective: To determine the location of thyroid-related nerves by nerve monitoring and demonstrate the usefulness of Nerve Integrity Monitor in thyroid surgery.

Study Design: Descriptive study.

Place and Duration of Study: Department of General Surgery, University of Health Sciences, Istanbul Training and Research Hospital, Turkey, from February 2017 to January 2020.

Methodology: Patients, who underwent thyroid surgery, were evaluated for age, gender, preoperative diagnosis, type of surgery, histopathological result, postoperative hoarseness, and postoperative vocal cord examinations. The vagus nerve, recurrent laryngeal nerve (RLN), and superior laryngeal nerve (SLN) were mapped by nerve monitoring.

Results: A total of 328 patients were included in this study. On both sides, the vagus nerve was most often located in the posterior of the internal carotid artery and internal jugular vein and less frequently anterior to this vein. A total of 303 right RLNs and 305 left RLNs were verified. The SLN was visualised or motor activity was verified by nerve monitoring on the right side in 181 patients and on the left side in 179 patients. The SLN's location was classified most frequently as type I and least frequently as type IIb on the right and left sides.

Conclusion: The reported variations, the experience of the surgeon, and these anatomical markers cannot be adequate in preventing nerve injuries. Furthermore, the variations can be identified more clearly peroperatively with the use of nerve monitoring.

Key Words: *Laryngeal nerves, Nerve mapping, Nerve monitoring, Nervus vagus, Thyroid surgery, Zuckerkandl tubercles.*

How to cite this article: Dogan S, Sari S, Ulusan K, Uzum G, Idiz UO. The Importance of Mapping Vagus and Laryngeal Nerves Monitoring During Thyroid Surgery. *J Coll Physicians Surg Pak* 2022; **32(10)**:1326-1329.

INTRODUCTION

Thyroidectomy is the gold standard surgical procedure for treating most of the thyroid disorders. However, serious life-threatening complications such as bleeding, nerve injury or hypoparathyroidism can be observed. To date, many technological improvements are implemented to decrease complication rates. One of the most important improvements was intraoperative nerve monitoring (IONM) which was first used in late 1960s.[1,2] Although, visualisation of recurrent laryngeal nerve (RLN) may reduce nerve injury rates, the use of IONM helps to ensure that the integrity of the nerve is preserved. However, the role and benefits of IONM are not significantly proven widely. Some studies have reported that the usefulness of IONM is still controversial.[3] Studies are ongoing to reduce the complication rates.

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Received: May 22, 2021; Revised: February 14, 2022; Accepted: March 05, 2022
DOI: https://doi.org/10.29271/jcpsp.2022.10.1326

In addition to visualisation of RLN and the use of IONM, mapping of the thyroid nerves may also help to reduce complication rates. Considering that anatomical locations of the nerves can vary according to geographical locations

The aim of this study was to map the thyroid-related nerves by nerve monitoring and assess the contribution of the nerve monitoring device to the safety of thyroid surgery.

METHODOLOGY

An institutional prospectively maintained database was used for this retrospective study. Ethical approval was obtained from the local human Ethics Committee of the institution. The study included patients underwent thyroid surgery in the General Surgery Clinic of University of Health Sciences, Istanbul Training and Research Hospital, Turkey, between February 2017 and January 2020. All operations were performed by one surgeon. Pregnant women and patients who had previous neck surgery, oesophagal cancer, nasopharyngeal cancer, laryngeal cancer, or neck radiotherapy were excluded from the study. Patients' age, gender, preoperative diagnosis, type of surgery, histopathological result, postoperative hoarseness, and postoperative vocal cord examinations were also evaluated. The vagus nerve, recurrent nerve, and SLN were also mapped by nerve monitoring.

Central and lateral neck dissections and/or standard thyroidectomy techniques were applied to the patients. Neuromuscular blocking agents were not used during operations to prevent intraoperative nerve monitoring (IONM). The authors monitored the electromyographic (EMG) activity of thyroarytenoid muscles using endotracheal tube monitoring systems. Nerve monitoring was performed intermittently. The stimulation current was set to 1.5 mA, and a disposable probe was used.

First, an EMG signal was obtained from the vagus nerve. Recurrent laryngeal nerve dissection was initiated after receiving an EMG signal from the vagus nerve, which confirmed the correctness of the endotracheal tube placement. The event threshold was set at 100 mV. The path of the RLN in the thyroid lobe was followed with monitoring support until the point of the trachea. After complete hemostasis of the operative field, the last tests for the vagus nerve and RLN were done. With the help of monitoring, The authors noted the course of RLNs in relation to the trachea, oesophagus, and thyroid artery; the number of branches and branching points in relation to the thyroid artery, Berry ligament, and the Zuckerkandl tubercle; course of the SLN according to the Cernea classification; and the location of the vagus nerve in the carotid sheath.

The data obtained from the patients were analysed in SPSS-21.0 (IBM). Descriptive data were shown as mean and standard deviation. Categorical data were given as numbers and percentages.

Table I: Nervus vagus placement according to ICA and IJV.

Nervus Vagus placement	Right (n= 298) n (%)	Left (n =300) n (%)
Middle posterior ICA and IJV	264 (88)	249 (83)
Posterior ICA	23 (8)	20 (7)
Posterior IJV	2 (1)	4 (1)
Middle anterior ICA and IJV	6 (2)	19 (6)
Anterior ICA	2 (0.6)	7 (2.3)
Anterior IJV	1 (0.3)	1 (0.3)

(ICA=internal carotid artery, IJV=internal jugular vein).

RESULTS

A total of 328 patients enrolled in this study with a mean age of 47.07 ± 12.8. Seventy one (21.6%) were male and 257 (78.4%) were females. There were 280 (85.4%) patients who underwent bilateral total thyroidectomy, 25 (7.6%) patients who had left hemithyroidectomy, and 23 (7%) patients with right hemithyroidectomy.

In all patients, the vagus nerve was monitored, and its location in the carotid sheath is shown in Table I. On both sides, the vagus nerve was most often located in the middle posterior of the internal carotid artery and internal jugular vein and anterior aspect of this vein. The RLN was observed and monitored in all patients in the study.

A total of 303 right RLNs and 305 left RLNs were verified. Table II shows the course of the recurrent laryngeal nerve, the number of extralaryngeal branches and branching points, the location according to the thyroid artery, its relationship with the Berry ligament, and the location of the nerve according to the Zuckerkandl tubercle. The left RLNs were located in the tracheoesophageal fissure in 251 (82.3%) patients, and the right RLNs were located in the anterolateral trachea in 172 (57%) patients. The SLN was visualised or motor activity was verified by nerve monitoring on the right side in 181(59.7%) patients and on the left side in 179(58.7%) patients. The distribution of the SLNs verified is given according to the Cernea classification in Table III.

RLN injury occurred in one of 303 patients who underwent right thyroidectomy and one of 305 patients who underwent left thyroidectomy. RLN injury rate was 0.3% (2/608) whereas there was no SLN injury.

DISCUSSION

In this study, the authors determined the location of thyroid-related nerves by nerve monitoring and demonstrated the usefulness of the Nerve Integrity Monitor (NIM) in thyroid surgery.

For many years, surgeons have used some anatomical landmarks to prevent complications, such as the tracheoesophageal fissure, Berry ligament, and inferior thyroid artery.[4,5] In a study published in 1995 by Cernea *et al.*, 584 SLNs and RLNs of 404 patients who underwent thyroid surgery were examined by nerve monitoring. The locations of the external branches of 324 right SLNs were examined in this study according to the Cernea classification.[6] Locations in 70.7% were type I, 17.9% were type IIa, and 8% were type IIb. In the external branches of the 260 left SLNs examined, the corresponding rates were reported as 72.3% for type I, 15.7% for type IIa, and 6.53% for type IIb.[7] In the present study using intraoperative nerve monitoring, the results were similar as the SLN's location was classified most frequently as type I and least frequently as type IIb on both right and left sides.

In a study by Shao *et al.*, 1699 right RLNs of 2404 patients were examined, and the non-recurrent rate was found to be 0.9%.[8] In this study, the non-recurrent rate was found to be 0.3%.

The course of RLN has been reported to be in the tracheoesophagal fissure.[9,10] Ardito *et al*. reported that 61.4% of the right RLNs were located in the tracheoesophageal fissure, 37.8% were located in the lateral trachea, and 0.6% were located in the anterolateral trachea. Furthermore, 67.3% of the left RLNs were located in the tracheoesophagal fissure, 31% were located in the lateral trachea, and 1.6% were located in the anterolateral trachea.[11] Conversely, in this study, 30% of the right RLNs were located in the tracheoesophageal fissure, 6% were located in the lateral trachea, and 57% were located in the anterolateral trachea. Moreover, 82.3% of the left RLNs were located in the tracheoesophageal fissure, 4.6% were located in the lateral of trachea, and 4% were located in the anterolateral trachea. A possible reason for this discrepancy could be that the anterior surface of the oesophagus was not specified as a location site in their classification whereas it was uncovered during nerve monitoring in this study.

Table II: Relationship of recurrent laryngeal nerve with anatomical structures.

Recurrent laryngeal nerve		Right (n=303) n (%)	Left (n=305) n (%)
Course	Tracheaoesophageal groove	92 (30)	251 (82.3)
	Periesophageal	18 (6)	28 (9.1)
	Lateral trachea	19 (6)	14 (4.6)
	Anterolateral trachea	173 (57)	12 (4)
	Non-recurrent	1 (0.3)	0 (0)
Number of branches	Single	277 (91)	264 (86.6)
	Double	24 (8)	32 (10.4)
	Multiple	2 (0.6)	9 (3)
In relation to the thyroid artery	Anterior	115 (38)	134 (44)
	Posterior	137 (45)	130 (42.6)
	Between branches	51 (17)	41 (13.4
Branching point	Lateral to thyroid artery	9 (35)	21 (51.2)
	Medial to thyroid artery	7 (27)	13 (31.7)
	Crossing point with thyroid artery	5 (19)	6 (14.6)
	Larenks Access	5 (19)	1 (2.4)
In relation to ligament of Berry	Superficial	113 (37)	129 (42.3)
	Deep	118 (39)	116 (38)
	Between ligament fibers	72 (24)	60 (19.7)
Zuckerkandl Tubercle size	None	157 (52)	188 (61.6)
	0.5 cm- 1 cm	79 (26)	61 (20)
	>1 cm	67 (22)	56 (18.4)
In relation to Zuckerkandl Tubercle	Anterior	93 (63.7)	75 (64.1)
	Posterior	53 (36.3)	42 (35.9)

Table III: Cernea classification of EBSLN.

External branch of the superior laryngeal nerve	Right (n:181) n (%)	Left (n:179) n (%)
Cernea I	114 (63)	110 (61.4)
Cernea IIa	58 (32)	54 (30.2)
Cernea IIb	9 (5)	15 (8.4)

Different rates have been reported when examining the location of the RLN in relation to the inferior thyroid artery. Ardito *et al.* reported that on the right side, 12% of the RLNs were located anterior to the artery, 61% were located posterior to the artery, and 27% were located between the artery branches. On the left side, 1.9% of the RLNs were located anterior to the artery, 77.4% were located behind the artery branches, and 20.5% passed between the artery branches.[11] There was a marked difference in this series as 38% of the RLNs on the right were located anterior to the thyroid artery, 45% were located posterior to the artery, and 17% were located between the inferior artery branches. Whereas on the left, 44% of the RLNs were located anterior to the artery, 42.6% were located posterior to the artery, and 13.4% passed between the artery branches.

The location of the RLNs vary significantly. However, it has been reported in the literature that RLNs are generally located on the surface of the Berry ligament.[12-14] A meta-analysis and cadaveric study by Henry *et al.* examined the relation between RLNs and the Berry ligament. A total of 2470 nerves were evaluated, and it was reported that RLNs were usually located over the Berry ligament (78.2%), and less frequently deep into the Berry ligament (14.8%) and between the fibers (7%).[12] In this study, RLNs were located deep within and on the surface of the Berry ligament in similar rates, and they progressed between the ligament fibers less frequently, but the rate was higher than in the literature. This may be a possible reason for this could be geographical differences.

A cadaver-based study, conducted by Henry *et al.* also examined the relationship between the RLNs and the Zuckerkandl tubercle, which is used as an anatomical marker during neck surgery. It was identified that Zuckerkandl tubercles were found in 38.9% of the subjects on the right side and on the left side in 30.6% of them. In this study, 64.2% of the tubercles on the right side of the neck were smaller than 10 mm, and 72.7% of tubercles on the left side were smaller than 10 mm. RLNs were reported to be located posterior to the Zuckerkandl tubercle on the right and left sides (71.4% and 72.7% respectively).[15] This study is in conformity with the literature as the size of the Zuckerkandl tubercle was smaller than 10 mm, but in contrast to the literature, RLNs were located anterior to the Zuckerkandl tubercle. Again, that may be a possible reason for this could be geographical differences.

Non-recurrent RLN is present in approximately 1% of patients, and in these cases, it turns directly to the trachea after leaving the vagus nerve.[16] The reported SLN injury rates are 3-40%, while the RLN's temporary damage rate is 0-7.1%, and the permanent damage rate is 0-11%. In this study, the RLN injury rate was 0.3% while there was no SLN injury. Compared with the literature, the RLN rate is low. The variations can be identified more clearly peroperatively with the use of nerve monitoring, and nerve injury rates can be reduced.

Although this study is a strength since all operations were performed by a single surgeon and the sample size is large, this study has some weaknesses. This study is based on a specific geographical region and may not reflect other parts of the world. Additionally, it is required further research to investigate the effect of mapping on complications of thyroid surgery.

CONCLUSION

Nerve mapping variations in nerve anatomy can be identified more clearly peroperatively with the use of the NIM device. This helps in reducing the rate of nerve injuries.

ETHICAL APPROVAL:
Ethical approval was obtained from the local human Ethics Committee of the institution.

PATIENTS' CONSENT:
Since it was designed as a retrospective study, the data were collected from the hospital archive after approval of the Ethics Committee.

COMPETING INTEREST:
The authors declared no competing interest.

AUTHORS' CONTRIBUTION:
SD: Design of the work.
SD, SS, KU, GU: Acquisition of data.
SD, SS, UOI: Analysis and interpretation of data.
SD, KU, GU: Drafting.
SS, UOI: Important intellectual content.
All the authors have approved the final version of the manuscript to be published.

REFERENCES

1. Shedd DP, Durham C. Electrical identification of the recurrent laryngeal nerve. I. Response of the canine larynx to electrical stimulation of the recurrent laryngeal nerve. *Ann Surg* 1966; **163(1)**:47–50. doi: 10.1097/00000658-196601000-00006.
2. Flisberg K, Lindholm T. Electrical stimulation of the human recurrent laryngeal nerve during thyroid operation. *Acta Otolaryngol Suppl* 1969; **263**:63-7. doi: 10.3109/0001648 7009131523.
3. Lin HS, Terris DJ. An update on the status of nerve monitoring for thyroid/parathyroid surgery. *Curr Opin Oncol* 2017; **29(1)**:14-9. doi: 10.1097/CCO.0000000000000334
4. Thomas AM, Fahim DK, Gemechu JM. Anatomical variations of the recurrent laryngeal nerve and ımplications for ınjury prevention during surgical procedures of the neck. *Diagnostics (Basel)* 2020; **10(9)**:670. doi: 10.3390/diagnostics10090670.
5. Freitas CAF, Paroni AF, Santos AN, Silva RJSD, Souza RO, Silva TFD, e+t al. Can the Zuckerkandl tubercle assist in the location of the inferior laryngeal nerve during thyroidectomies? *Rev Col Bras Cir* 2019; **46(4)**:e2249. doi: 10.1590/0100-6991e-20192249.
6. Cernea CR, Nishio S, Hojaij FC. Identification of the external branch of the superior laryngeal nerve (EBSLN) in large goiters. *Am J Otolaryngol* 1995; **16(5)**:307-11. doi: 10.1016/0196-0709(95)90058-6.
7. Pradeep PV, Jayashree B, Harshita SS. A closer look at laryngeal nerves during thyroid surgery: A descriptive study of 584 nerves. *Anat Res Int* 2012; **2012**:1-6. doi: 10.1155/2012/490390.
8. Shao T, Qiu W, Yang W. Anatomical variations of the recurrent laryngeal nerve in Chinese patients: A prospective study of 2,404 patients. *Sci Rep* 2016; **6**:25475-25479. doi: 10.1038/srep25475.
9. Berry J. Suspensory ligaments of the thyroid gland. Ireland: Proceedings of anatomy society of great britain, 1887; p4.
10. Herr MJ, Macy Cottrell J, Kahl M, Weiman DS. Comprehensive comparison of right and left recurrent laryngeal nerves in the tracheoesophageal groove. *Innovations (Phila)* 2021; **16(2)**:148-51. doi: 10.1177/1556984520976583.
11. Ardito G, Revelli L, D'Alatri L, Lerro V, Guidi ML, Ardito F. Revisited anatomy of the recurrent laryngeal nerves. *Am J Surg* 2004; **187(2)**:249-53. doi: 10.1016/j.amjsurg.2003.11.001.
12. Henry BM, Sanna B, Graves MJ, Sanna S, Vikse J, Tomaszewska IM, *et al*. The reliability of the tracheoesophageal groove and the ligament of berry as landmarks for ıdentifying the recurrent laryngeal nerve: A cadaveric study and meta-analysis. *Biomed Res Int* 2017; **2017**:4357591-4357602.
13. Asgharpour E, Maranillo E, Sañudo J, Pascual-Font A, Rodriguez-Niedenführ M, Valderrama FJ, *et al*. Recurrent laryngeal nerve landmarks revisited. *Head Neck* 2012; **34(9)**:1240-6. doi: 10.1002/hed.21882.
14. Lee E, Lee K, Yu HW, Kim SJ, Chai YJ, Choi JY, *et al*. Comparison of recurrent laryngeal nerve ıdentification time in the lower central triangle during thyroid surgery using neurophysiological mapping and monitoring. *Medicina (Kaunas)* 2021; **57(8)**:748. doi: 10.3390/medicina57080748.
15. Henry BM, Sanna B ,Vikse J, Graves MJ, Spulber A, Witkowski C, *et al*. Zuckerkandl's tubercle and its relationship to the recurrent laryngeal nerve: A cadaveric dissection and meta-analysis. *Auris Nasus Larynx* 2017; **44(6)**:639-47. doi: 10.1016/j.anl.2017.03.013.
16. Surgical anatomy of the thyroid gland. Available from: www.uptodate.com/contents/surgical-anatomy-of-the-thyroid-gland?search=surgical%20anatomy%20of%20thyroid%20gland&source=search_result&selectedTitle=1~150&usage_type=default&display_rank=1. [09 June 2021].