The nonrecurrent laryngeal nerve: A clinical anatomic mapping with regard to intraoperative neuromonitoring

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Background. We investigated the nonrecurrent inferior laryngeal nerve (nrILN), an important variant in the course of the inferior laryngeal nerve (ILN; 0.5–6.0%). Its importance was demonstrated in a clinical case as well as in cadaver specimens, and the pattern was identified with intraoperative neuromonitoring (IONM).

Methods. The ILN and the presence of an nrILN were investigated in 36 formaldehyde-embalmed specimens. Our anatomic findings showed differences in the anatomic course of the ILN and thus produced possible explanations for different IONM signals that would correlate with differences in the anatomic course of the ILN. Preoperative ultrasonographic evaluation of the brachiocephalic trunk and the recurrent laryngeal nerve were used for the exclusion or identification of an nrILN, respectively.

Results. We found 2 nrILNs (ascending, horizontal; 6%) in the anatomic specimens. These 2 specimens each showed an aberrant right subclavian artery (lusorial artery) and were, therefore, associated with the absence of a brachiocephalic trunk. The intraoperative case displayed a descending nrILN. Signals derived from the vagus nerve were positive if derived proximal to and negative if derived distal to the branching of an nrILN. By ultrasonographic identification of a normal brachiocephalic trunk, an nrILN could be excluded.

Conclusion. Surgeons need a working knowledge about nrILNs to avoid recurrent nerve palsy and should be familiar with all the possible course variations in the ILN when IONM signals are absent with vagal stimulation. Moreover, endocrine surgeons need to be able to interpret correctly negative as well as positive signals. Preoperative ultrasonography should ideally be performed, because the presence of a normal brachiocephalic trunk is a quick method to exclude or identify a nrILN. (Surgery 2016;160:161-8.)

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Recurrent laryngeal nerve palsy and hypoparathyroidism are the most common, important complications in thyroid and parathyroid surgery. Laryngeal nerve palsy limits a patient’s quality of life by either temporary or even permanent disorders of the voice and dyspnea. Temporary laryngeal nerve palsy usually disappears within 6 months; intraoperative neuromonitoring (IONM) may help to prevent this injury completely. At present, organizational support and helpful guidelines for IONM are being expanded continually. The International Neural Monitoring Group and German practice guidelines both recommend the use of IONM for all thyroid operations and not only for reinterventions. The American Academy of Otolaryngology–Head and Neck Surgery further emphasizes the usefulness of IONM for bilateral thyroid surgery, revisional operations, and in the setting of an existing RLN paralysis.

IONM can help to recognize anatomic variants such as a nonrecurrent inferior laryngeal nerve (nrILN) in thyroid surgery and reveals an ever greater number of patients with nrILNs. This incidence of nrILN seems to be considerably greater than expected or hitherto published.
in literature. Older publications report a prevalence rate between 0.6 and 0.8%, whereas a more recent study revealed a prevalence of at least 6.0%. This assessment supports the clinical relevance of this variation of the inferior laryngeal nerve (ILN). Our report presents the clinically relevant “mapping” by means of both anatomic specimens and a clinical case study using IONM to summarize the important anatomic facts of the nrILN.

SURGICAL ANATOMY

The Zuckerkandl tubercle. The Zuckerkandl tubercle is a posterior extension of the thyroid gland, which in the majority of cases arises dorsal to the fusion of the medial and lateral thyroid anlagen. Thus, it can serve as an intraoperative anatomic landmark to locate the RLN. In 93% of all cases, the RLN is found medial to the Zuckerkandl tubercle and in 7% lateral to the Zuckerkandl tubercle. In 63–80% of patients, the Zuckerkandl tubercle was found and classified as to size: size I: <0.5 cm, size II: 0.5–1 cm, and size III: >1 cm. All other patients had no recognizable tubercle. In addition, the anatomic variability of the nerves in relation to the inferior thyroid artery in the area of the lower thyroid pole must be kept in mind.

Parathyroid glands. The RLN lies dorsal to the lower and ventral to the upper parathyroid glands when these glands assume their normal positions after their descent from the third (lower parathyroid gland) and fourth (upper parathyroid gland) pharyngeal pouches.

Nonrecurrent inferior laryngeal nerve, lusorial artery. When an aberrant right subclavian artery arises as the last branch of the aortic arch (then named a lusorial artery), the right ILN does not take a corresponding “recurrent” course; in this situation, a nrILN occurs on the right side, and the lusorial artery, branching off from the aortic arch on the left side, takes either a retroesophageal (80%), interesophageotrichal (15%), or pretracheal course (5%) (Fig 1). Symptoms of swallowing disorders in patients with a small nodular goiter can be signs of esophageal compression caused by a lusorial artery and not the thyroid and should alert the clinician to the possibility of a right nrILN.

There are 3 major relevant variations in the course of a nrILN—concerning its branching off from the vagus nerve—that have to be considered (Fig 2, A): 1) the nrILN branches off cranial to the cricothyroid joint (articulatio cricothyroidea); 2) the nrILN branches off at the level of the cricothyroid joint; horizontal course; and 3) the nrILN branches off at the level of the inferior thyroid artery: ascending course. The extremely rare variant of a left nrILN is found only in cases of situs inversus totalis, as described twice by Henry et al in 1988. Finally, a fifth, very rare variant exists: a forked ILN; this variant involves either a recurrent or nonrecurrent ramification of different size and can occur both with or without a lusorial artery. With IONM, a corresponding signal indicative of these variants can be registered. Variations in the anatomic course of a right nrILN present an additional intraoperative challenge and lead to different signals derived from the vagus nerve during IONM (Fig 2, A and B).
Vagus nerve. The intraoperative localization and identification of the vagus may be difficult, because its anatomic position can vary (Fig 3).20 The vagus nerve may be found dorsal to and course between the common carotid artery and the internal jugular vein (73%), only dorsal to the common carotid artery (15%), only dorsal to the internal jugular vein (8%), or ventral to both the common carotid artery and the internal jugular vein (4%).

MATERIAL AND METHODS

Cadaver dissection. During our dissection course for medical students (winter term 2013/14), 36 cadavers were examined comprehensively for nrILNs. The body donors had given their informed written consent for their use for scientific and educational purposes by the Division of Clinical and Functional Anatomy of the Medical University of Innsbruck.21,22 Because of the immediate anonymization of the cadavers, no certificate of nonobjection was needed. All cadavers were preserved with an arterial injection of a formaldehyde-phenol solution and further immersion in phenolic acid in water for 1–3 months.22 The possibility of this solution causing preservation artifacts is minimal.23,24

Clinical case. Our clinical case was a male patient who underwent a total thyroidectomy at the Department of General and Endocrine Surgery. Written informed consent was obtained before surgery.

Clinical use of IONM. For IONM, we used the AVALANCHE XT System (Dr Langer Medical GmbH, Waldkirch, Germany). The anesthetist positioned the ET tube (Dr Langer Medical GmbH) with its adherent electrode at the level of the vocal cords.

At the beginning of the operation, the vagus nerve was exposed and stimulated at mid-carotid level with 1 mA. The latency period and the action potential of the nerve were recorded by the
tracheal electrode. An adequate signal (both a visual and an audible signaling by the AVALANCHE XT System) implied an intact, normal course of the RLN. Technical defects were excluded by successful stimulation of the contralateral vagus nerve.

During the thyroidectomy, the blood vessels and nerves were dissected free, and IONM was used to indicate whether the RLN was present in the connective tissue bundle. After stimulation of the respective bundle, the lack of an IONM signaling indicated that the RLN was not included in the bundle which, therefore, could be transected.

After removal of the ipsilateral thyroid lobe, a successful restimulation of the vagus nerve was essential, because, to avoid serious bilateral nerve palsy, only in case of this stimulation being unimpaired was the contralateral side operated on.

In our clinical case of a descending nrILN, no deducible IONM signal could be recorded when the vagus was stimulated caudal to the branching off of the descending nrILN (Fig 4). The dissection of the upper thyroid pole posed a special challenge, because of the missing intraoperative monitoring signal, and the surgeon needed to work with increased care and sensitivity to protect the nerve. Therefore, it was imperative that the dissection of the right upper pole was performed from medial-dorsal (from behind) to avoid nerve injury or transection of the nerve (Figs 4 and 5).

A right common carotid artery lying very close to the thyroid gland again suggested the presence of an nrILN (Fig 5). Because the right vagus nerve could not be stimulated in its typical mid-carotid position within the carotid sheath (Fig 3) and a technical defect could be excluded, the surgeon therefore, had to look for an nrILN (Fig 6).

**Anatomic variants.** In 36 cadavers, we found 2 right nrILNs (6%), one ascending and one horizontal in an 85-year-old woman and a 80-year-old man, who had both died from right heart failure.

**Ascending nrILN.** The ascending nrILN branched off from the vagus nerve approximately at the level where the inferior thyroid artery arose from the common carotid artery. Coming from the caudal direction cranially, the ascending nrILN crossed dorsal to the vertebral artery and the common carotid artery ventral to the inferior thyroid artery and then entered the larynx. The lusorial artery had a typical retroesophageal course. Because of the absence of a

**Fig 3.** Possible locations of the vagus nerve within the carotid sheath. Right neck. In 73% of all cases, the vagus nerve was dorsal and coursed between both the common carotid artery and the internal jugular vein, in 15% dorsal to the common carotid artery only, in 8% dorsal to the internal jugular vein only, and in 4% ventral to the common carotid artery and the internal jugular vein. *jiu*, internal jugular vein; *cca*, common carotid artery; *t*, trachea; *es*, esophagus.

**Fig 4.** Descending nrILN. Intraoperative image of a descending nrILN on the right side. The clamp retracts the right thyroid lobe medially, and the IONM revealed no endotracheal signal despite appropriate stimulation of the proximal and distal vagus nerve, indicating a nonrecurrent inferior laryngeal nerve. The stimulation electrode of the IONM (AVALANCHE XT System) stimulates the nonrecurrent inferior laryngeal nerve (descending). *tg*, thyroid gland; right lobe; *n*, nonrecurrent inferior laryngeal nerve (descending); *e*, stimulation electrode.
brachiocephalic trunk, we could visualize a common carotid artery coursing near the trachea and lying very close to the thyroid gland (Figs 1 and 2, A).

Horizontal nrILN. In the male cadaver, the right nrILN branched off from the vagus nerve at the level of the cricothyroid joint. Once again, the right common carotid artery coursed very close to the trachea and the thyroid gland, and a Galen anastomosis could be seen on the right side, ie, internal branch of the superior laryngeal nerve anastomosed with the horizontal nrILN within the wall of the larynx (Fig 7).

**Descending nrILN.** Our intraoperative case presented a right nrILN with a descending course. The branching off from the vagus nerve occurred cranial to the cricothyroid joint (Figs 4 and 5). Vagus stimulation caudal to the respective branching off of the nrILN from the vagus nerve was not recorded by the endotracheal electrodes at level 1 (descending nrILN [n_desc]), level 2 (horizontal nrILN [n_hor]), and level 3 (ascending nrILN [n_asc]) (Fig 2, A and B).

**DISCUSSION**

Anatomic knowledge concerning the presence of an nrILN is a basic requirement to avoid injury to this nerve, which can lead to temporary or permanent laryngeal palsy. Our anatomic findings seem to be consistent with a greater incidence of an nrILN than reported by Donatini et al. All the nrILNs we identified associated with the existence of a lusorial artery. In 1985, Lippert and Papst investigated 22,271 cases and found 312 lusorial arteries (1.4%). Because a lusorial artery is reported to occur in only 1–1.4% of subjects, there is a large discrepancy in our data and those of Donatini, Bergman, and Marty et al, who give no data regarding the prevalence of a nrILN. They only concentrated on the frequency of arterial variations. In our work with 36 cadavers, the number of lusorial arteries and, consequently, of nrILNs, seems to be greater than hitherto stated in literature, although further studies including a greater number of subjects will be needed to better define the true incidence of a nrILN. Moreover, there are also several possible biases, such as ethnicity or sex. Age should not be among them.

Our study, although advocating the use of IONM, nonetheless underlines the necessity not to trust solely in this technical support device, because the danger of being lulled into a false sense of security is great. Surgeons must always be on the alert, looking out for possible traps and pitfalls, and they need to be aware of the potential existence of an nrILN with all its possible course variants to avoid injury to the ILN. Surgeons who use IONM must be able to interpret negative vagal stimulation signals correctly, including the possibility of a technical defect.
The following potential reasons for the lack of a vagus signal from the vagus include the following:

a) Presence of an nrILN (descending, horizontal, or ascending) (Fig 2): Stimulation of the vagus nerve distal to the separation of the nrILN will not result in an action potential or waveform from a vocal fold electrode).

b) An atypical position of the vagus nerve within the carotid sheath in relation to the common carotid artery and internal jugular vein (Fig 3): with this anatomic variant, the vagus nerve is not situated in its typical position between and dorsal to the common carotid artery and the internal jugular vein (73%) but only dorsal to the common carotid artery (15%), dorsal to the internal jugular vein (8%), or ventral to both the common carotid artery and the internal jugular vein (4%).

Intraoperatively, the vagus nerve must be located and/or uncovered with special care until a correspondingly clear signal from the tracheal electrodes can be achieved. To open the sheath and uncover the vagus nerve is not necessary routinely, but we recommend it. A vagus signal also can be obtained by just pointing the probe at the general sheath area and by gently touching it with 1–3 mA, but the possibility of the vagus nerve being positioned atypically must be kept in mind if no signal is obtained (Fig 3).

Continuous intraoperative neuromonitoring via continuous vagus nerve stimulation can be performed with electrode applications on the vagus nerve (eg, electrodes that are J-shaped and positioned around the vagus nerve). After exclusion of an nrILN, this approach allows monitoring of the functional integrity of the ILN throughout the entire operation, providing real-time monitoring of potential injury of the ILN. Continuous intraoperative neuromonitoring can help to signal reliably imminent nerve injury and allows immediate corrective action, thereby potentially decreasing the risk of injury of the ILN.

To exclude an nrILN that is always accompanied by a lusorial artery, each patient and especially patients undergoing reoperation should undergo routinely a preoperative, cervical duplex-ultrasonography examination. Other techniques, such as digital subtraction angiography, angiocomputed tomography, or angiomagnetic resonance imaging, are possible alternatives. These techniques are expensive, time-consuming, and involve exposure to radiation or iodine. Because of the cost-effectiveness, convenience, and high rate of detection, we agree with Gong et al.,29 who suggest performing an ultrasonography to rule out a nrILN without an additional, unnecessary chest-X-ray to avoid radiation exposure.

To evaluate the vascular anatomy, we maintain that duplex ultrasonography of the neck should be considered as part of the routine preoperative diagnostics for each patient undergoing an operation on the thyroid or parathyroid gland (Fig 8). Preoperatively, surgeons can determine which patients may have a nrILN by following the right common carotid artery down to its origin, which is visible in nearly all patients by hyperextension of the neck and some angling of the probe. A brachiocephalic trunk bifurcating into the right
subclavian artery and the right common carotid artery excludes the presence of an nrILN. If this bifurcation of the brachiocephalic trunk cannot be seen, an nrILN is very likely (Fig 9).

Moreover, other techniques can be carried out intraoperatively; if an nrILN is suspected, the surgeon should not rely on the patient history to exclude the presence of a lusorial artery without the help of imaging. Clinical symptoms such as swallowing disorders caused by a retro-esophageal course of the lusorial artery only occur in approximately 30% of all patients. Dysphagia can result from a lusorial artery or a small goiter, both of which may cause esophageal compression and should prompt the surgeon to obtain a diagnostic imaging procedure, preferably ultrasonography, to look for an nrILN.

IONM can be a reliable test in recognizing anatomic variants of the ILN. The lack of a positive signal with vagal stimulation during IONM should alert the surgeon to the possibility of a nrILN (ascending, horizontal, or descending).

Stimulation of the proximal and distal vagus nerve may help to eliminate technical problems (ie, electrode position or system malfunction) or nerve variants or to indicate the presence of a nrILN. Moreover, we believe that each patient and especially patients undergoing re-operation should receive a preoperative, cervical duplex-ultrasonography routinely to evaluate the vascular anatomy, because the presentation of a normal brachiocephalic trunk is a very easy and quick method to exclude or identify an nrILN.

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REFERENCES