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Original Research

The laryngeal twitch response – Can it avoid unnecessary two-stage thyroidectomy? – A retrospective cohort study

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ABSTRACT

Background: The objective of this study was to determine if the laryngeal twitch response, when compared to neuromonitoring, can predict postoperative vocal cord function and can thus be used in case of technical failure of the EMG-recording electrode.

Methods: A total of 640 nerves at risk were included in this study based on a prospective protocol. The laryngeal twitch response and the EMG-records were compared with the results of the postoperative laryngoscopy.

Results: Of the 640 nerves at risk, 582 showed a normal postoperative vocal cord function. A recurrent laryngeal nerve paralysis (no vocal fold movement) was observed in 39 cases and recurrent laryngeal nerve paresis (reduced vocal cord movement) was diagnosed in 19 cases. The overall negative predictive value (NPV) in final vagus nerve stimulation (V2) was 95.0% for the EMG-records and 94.8% for the laryngeal twitch response. When pareses were excluded, the NPV was 96.8% and 96.6% respectively. The positive predictive value (PPV) of vagus nerve stimulation lies between 51.4% and 57.1% excluding the pareses. It rises to values between 60.0% and 65.1% if they are included.

Conclusions: The laryngeal twitch response and the EMG-records show similar results, and the NPV is good in both. Thus, in case of technical failure or displacement of the EMG-recording electrode, the laryngeal twitch can be used in decision-making for or against a two-stage thyroidectomy.

1. Introduction

A recurrent laryngeal nerve injury remains a major complication in thyroid surgery [1–4]. Visual identification and careful dissection is still the gold standard to avoid recurrent nerve damage [5,6]. Over the last two decades, however, neuromonitoring has become a useful tool to facilitate the intraoperative localization of the recurrent nerve. Furthermore, the technological progress and improvement of intraoperative EMG-record interpretation allows an increasingly safe prediction of the nerve's function [5,7]. This has also led to the introduction of the principle of two-stage thyroidectomy to avoid bilateral recurrent laryngeal nerve palsy [3,8–10]. If a loss of signal occurs intraoperatively after removal of the first lobe, the surgery should be terminated. After recovery of the ipsilateral recurrent laryngeal nerve, the contralateral side can be operated to complete surgery [3,8–10].

While the negative predictive value (NPV) is good (well over 90% in the literature), i.e. an adequate vagus signal after initial lobar resection (V2) represents a normal vocal cord function, the positive predictive value (PPV) of around 60% in the current literature is generally poor and may result in unnecessary two-stage thyroidectomy [5,11]. If there is a technical failure or the tube electrode (a surface electrode positioned on the endotracheal tube used for recording the muscle-response potentials in intraoperative neuromonitoring) is misplaced, it is unable to assist in the prediction of the postoperative vocal cord function.

To investigate additional parameters for decision-making in proceeding to total thyroidectomy, in case of an uncertain nerve conduction after removal of the first thyroid lobe, we analyzed the PPV and NPV of the laryngeal twitch in this study.

The laryngeal twitch is defined by the palpable and impulse synchronous contraction of the cricoarytenoid posterior muscle when the vagus or recurrent laryngeal nerve is stimulated [12]. This phenomenon has been described before, but larger data sets for its reliability to predict postoperative vocal cord function are missing [12–15]. Nevertheless, Dralle et al. included the laryngeal twitch in their algorithm when assessing a loss of signal intraoperatively [16].

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The purpose of this study was to evaluate if the laryngeal twitch is representative in predicting postoperative vocal cord function when compared with the EMG-records. Furthermore, we investigated whether the laryngeal twitch can be used as a possible alternative in case of failure of the EMG-recording electrode, and whether it is reasonable to complete thyroidectomy relying on a positive and strong palpable laryngeal twitch.

2. Material and methods

In a prospective study, 388 patients undergoing thyroidectomy or hemithyroidectomy (i.e. lobectomy plus isthmusectomy), for benign and malign thyroid diseases between August 2015 and July 2016, were included. They routinely underwent preoperative laryngoscopy and patients with pre-existing vocal cord paresis or recurrent laryngeal nerve paralysis were excluded from the study. All patients had vagus and recurrent laryngeal nerve stimulation [5] using a stimulation hand probe, including EMG-record, as well as laryngeal palpation before and after removal of the thyroid lobe. On the first or second postoperative day all patients routinely underwent an ORL-examination for assessment of the vocal cord function. Only patients with a complete record were included.

For internal quality assurance, all surgeons routinely complete a prospective surgical protocol, i.e. prospective datasheet, immediately after thyroid surgery. This contains detailed information about the surgery, the EMG-records of the intraoperative neuromonitoring and the results of the laryngeal palpation.

The overall inpatient and outpatient data collected included age, gender, clinical diagnosis for indication, date of surgery, surgeon, the extent of the surgery, pre-and postoperative vocal cord function, the results of the laryngeal palpation, the type of EMG-electrode (needle or tube electrode) and the EMG-records of the intraoperative neuromonitoring. We used the avalanche neuromonitor for all procedures; the adhesive surface electrode, the stimulation hand probe and the needle electrodes were from Dr. Langer Medical.

After approval by the local ethical review board, we analyzed our prospective institutional database, which contains clinical, surgical, pathological and follow-up data of patients since January 1975. Details of data collection and processing have been published previously [6,17,18]. The work has been reported in line with the STROCSS criteria [19]. The research was registered under the UIN Number: researchregistry5066.

2.1. Laryngeal twitch palpation technique and study set-up

The laryngeal twitch or laryngeal palpation concerns the contraction of the laryngeal muscles, which is caused by the stimulation of the recurrent laryngeal nerve or the vagus nerve with the stimulation hand probe (which is also used in intermittent neuromonitoring). The stimulation current we used ranged from 1.0 to 2.5 mA. The technique of laryngeal palpation has been shown by Randolph et al. [12] Ideally one finger is inserted behind the larynx, but the laryngeal twitch is also noticeable on the sides or on the front when palpating the cricothyroid membrane. While the best muscle response can be achieved at the lateral or back side of the larynx, especially in patients with large goiters, this is often only possible after resection of the thyroid lobe.

The operative procedure was standardized. The initial vagus stimulation with the stimulation hand probe and a tube electrode was performed before the thyroid lobe was mobilized. A transcricoidal needle electrode was only used instead of the tube electrode in exceptional cases when there was a technical problem with the tube electrode or when the correct positioning of the tube electrode failed. If the needle electrode had to be used the cricothyroid membrane was punctured with the transcricoidal electrode at the lower border of the thyroid cartilage and inserted such that the position of the needle electrode was in the vocalis muscle. The recurrent laryngeal nerve was stimulated with the hand probe, when using the tube and the needle electrode, upon identification and was then dissected over its entire length to perform the removal of the thyroid lobe under complete vision of the nerve's integrity and also repeated neurostimulation. After lobar resection and bleeding control was completed, another stimulation of both the recurrent laryngeal nerve and vagus nerve was performed. Initial and final EMG-response was recorded, and in addition the laryngeal twitch response was carefully palpated and then documented immediately after surgery in the prospective protocol. If a loss of signal occurred intraoperatively, i.e. there was no vagus nerve signal in intermittent neuromonitoring after lobar resection, a two-stage thyroidectomy was performed at our hospital after all measures were taken to exclude and/or solve a possible equipment failure. The two-stage thyroidectomy is used in these cases to avoid the risk of a bilateral recurrent laryngeal nerve injury and is in agreement with current guidelines [16,20].

On the first or second postoperative day all patients who had undergone thyroid surgery also routinely underwent a laryngoscopy to determine if they had a recurrent laryngeal nerve injury. Patients who showed nerve injury at the end of surgery were examined with a fiberscope and an additional stroboscopy. Patients with a vocal cord hypomobility were diagnosed with a vocal cord paresis in the ORL-examination, whereas patients without any vocal fold movement were defined as having a vocal cord paralysis [21,22].

2.2. Statistics

The descriptive statistical analysis was performed with Microsoft Excel©. Negative predictive and positive predictive values as well as sensitivity and specificity were calculated.

A negative result was defined as a palpable muscle twitch or an EMG-record without a pathological finding. The absence of a palpable laryngeal twitch response or a pathological EMG-record was regarded as a positive result.

3. Results

A total of 388 patients, with 640 nerves at risk were included. Of these, 277 (71.4%) were females with a mean age of 54.3 years and 111 (28.6%) were males with a mean age of 58.5 years. The indication for surgery was a large endemic nodular goiter in 250 patients (64.4%), 65 patients (16.8%) had a malignant thyroid disease, 40 patients (10.3%) were diagnosed with Graves' disease, 14 patients (3.6%) had suspected nodules in hashimoto thyroiditis, 10 patients (2.6%) underwent surgery for a recurrent goiter and an intrathoracic goiter was present in 9 patients (2.3%). From the 640 nerves at risk, 177 (27.7%) belonged to males and 463 (72.3%) to females. The analysis will focus on the nerves at risk to allow comparison of the intermittent intraoperative neuromonitoring and the laryngeal twitch response.

A comparison was undertaken between the intraoperative findings of the intermittent neuromonitoring and the laryngeal twitch response in the vagus nerve and recurrent laryngeal nerve stimulation, taking into account the postoperative laryngoscopy results. A further selection was made by first including and then excluding patients with reduced vocal cord function. To make the comparison, we used both the positive predictive value, i.e. patients with a pathological intraoperative nerve function and a postoperatively confirmed recurrent laryngeal nerve injury, and the negative predictive value, i.e. patients with a normal intraoperative nerve function and normal postoperative ORL-examination.

3.1. Postoperative vocal cord function

A normal postoperative vocal cord function was confirmed by the ORL-examination in 90.9% (n = 582) of the nerves at risk. In 3% (n = 19) of the cases, a recurrent laryngeal nerve paresis was

Table 1
Comparison of intermittent neuromonitoring and laryngeal twitch response in vagus nerve monitoring.

	IONM Vagus incl. pareses	IONM Vagus excl. pareses	Twitch Vagus incl. pareses	Twitch Vagus excl. pareses
PPV	65.1%	57.1%	60.0%	51.4%
NPV	95.0%	96.8%	94.8%	96.6%
Sensitivity	48.3%	51.3%	46.6%	48.7%
Specificity	97.4%	97.4%	96.9%	96.9%

Table 2
Comparison of intermittent neuromonitoring and laryngeal twitch response in recurrent laryngeal nerve monitoring.

	IONM RLN incl. pareses	IONM RLN excl. pareses	Twitch RLN incl. pareses	Twitch RLN excl. pareses
PPV	66.7%	56.5%	62.2%	51.7%
NPV	93.8%	95.7%	94.2%	96.0%
Sensitivity	34.5%	33.3%	39.7%	38.5%
Specificity	98.3%	98.3%	97.6%	97.6%

diagnosed, whereas in 6.1% (n = 39) of the cases a recurrent laryngeal nerve paralysis was observed in the routinely performed postoperative ORL-examination on the first or second postoperative day.

3.2. Comparison of intermittent neuromonitoring and laryngeal twitch

The laryngeal twitch and the intermittent intraoperative neuromonitoring show similar results in the prediction of postoperative nerve function. The negative predictive values for both the vagus nerve and recurrent laryngeal nerve are over or equal to 93.8% (see Tables 1 and 2) in both techniques, indicating that intermittent neuromonitoring and the laryngeal twitch response are both safe to use for intraoperative prediction of postoperative normal vocal cord function. When excluding patients with vocal fold hypomobility, an even higher negative predictive value can be achieved.

Nevertheless, the positive predictive value for the prediction of an impaired postoperative nerve function is weak in both the intermittent neuromonitoring and in the laryngeal twitch response. The PPV for the vagus nerve stimulation, excluding vocal fold pareses, is 57.1% and 51.4% for the intermittent neuromonitoring and laryngeal twitch respectively. If the vocal fold pareses are included, the PPV rises to 65.1% and 60.0% respectively. Values for the recurrent laryngeal nerve are similar with a PPV of 56.1% and 51.7% excluding the vocal fold pareses, and a PPV of 66.7% and 62.2% including the vocal fold pareses.

Our results are also reflected in the sensitivity and specificity of the findings. We have achieved a high specificity, correctly identifying the patients during surgery, who will have normal postoperative vocal cord function. Values range between 96.9% and 98.3%. The sensitivity, however, is lower, ranging between 46.6% and 51.3% for vagus nerve monitoring and between 33.3% and 39.7% for recurrent laryngeal nerve monitoring.

The results of the descriptive statistics are shown in Tables 1 and 2. The raw numbers used for calculation are depicted in Table 3.

4. Discussion

The significance of recurrent laryngeal nerve identification and intraoperative neuromonitoring has already been shown by our working group and several other authors [5,23,24]. Intraoperative neuromonitoring is especially relevant in patients with thyroid carcinoma and a possible invasion of the recurrent laryngeal nerve as the nerve identification is essential if nerve shaving or dissection needs to be performed. A review by Dralle et al. assessing different studies about the validity of intraoperative recurrent laryngeal nerve monitoring, showed

Table 3
Overview of the raw numbers of the results for the laryngeal twitch response and intermittent intraoperative neuromonitoring for all nerves at risk.

	ORL normal	ORL paresis	ORL paralysis
Twitch RLN palpable	568	11	24
Twitch RLN not palpable	14	8	15
IONM RLN normal	572	12	26
IONM RLN not possible	10	7	13
Twitch Vagus palpable	564	11	20
Twitch Vagus not palpable	18	8	19
IONM Vagus normal	567	11	19
IONM Vagus not possible	15	8	20

that in neuromonitoring with EMG-record the negative predictive value and the specificity are very high, whereas the positive predictive value and sensitivity are subject to a wide fluctuation [11]. These findings by Dralle et al. [11] are largely in agreement with our findings. Alternative instruments to reliably assess the postoperative vocal cord function, such as the laryngeal twitch response, have rarely been discussed in the literature. Yet the laryngeal twitch can be useful in case of technical failure of the EMG-recording electrode or for financial reasons when cost-reduction is necessary. The cost-effectiveness of intraoperative neuromonitoring with EMG-record in patients undergoing thyroid surgery has already been documented [24–26].

There are few papers in the current literature about the laryngeal twitch. Randolph et al. for example, propose the laryngeal twitch as a good alternative or supplement to neuromonitoring with EMG-record [12]. However, as only one patient out of 449 patients with a total of 586 nerves at risk presented with a transient recurrent laryngeal nerve injury, no positive predictive value could be obtained from the data. In addition, it is not indicated in this paper if and in which timeslot after thyroidectomy, routine postoperative laryngoscopy took place. Overall, the laryngeal twitch response is presented as a safe method, first described by Riddell in 1970, for intraoperatively assessing anticipated vocal cord function [12,27]. The most recent paper on the laryngeal twitch, by Cha et al. suggests that laryngeal palpation can be used to predict postoperative vocal cord mobility in cases when intermittent neuromonitoring with EMG-record is unavailable [13]. Cavicchi et al. and Tomoda et al. have found that the results of the laryngeal palpation method and of intermittent neuromonitoring are similar and that the laryngeal twitch can safely be used for prediction of postoperative vocal cord function [14,15,28]. The papers by Cavicchi, Tomoda and Cha are consistent with our findings, since we can confirm the reliability of laryngeal palpation in predicting postoperative vocal cord function. A follow-up study by Cavicchi et al. reached the conclusion that neurostimulation with laryngeal palpation is preferable, when cost-effectiveness is taken into account, since there is no significant difference in the rate of recurrent laryngeal nerve injury between the two methods [14]. Loch-Wilkinson agree that compared to intermittent neuromonitoring, the laryngeal twitch response is less expensive. However, they reach the conclusion that the laryngeal palpation as a discontinuous monitoring method is neither useful nor beneficial [29].

A limitation of our study is its size. A larger prospective study assessing the usefulness and cost-effectiveness of the laryngeal twitch is warranted in future. This would also enable a direct comparison between those cases in which the laryngeal twitch and those in which neuromonitoring with EMG-record were able to correctly predict the outcome in the postoperative ORL-examination. A further limitation of this study is that our recurrent laryngeal nerve dysfunction rate appears higher than usual, largely because the protocols in patients with intraoperative loss of signal were complete, whereas other records were missing information on the laryngeal twitch and thus had to be excluded from this study. The permanent recurrent laryngeal nerve dysfunction rate of our surgical unit lies under 1%.

Laryngeal twitch response is highly useful for the intraoperative prediction of postoperative unimpaired vocal cord function and can supplement the assessment of intermittent neuromonitoring. Whether the laryngeal twitch will be able to replace EMG-records in the future is still unclear and further studies are needed. The laryngeal twitch offers considerable cost-reduction compared to the intermittent intraoperative neuromonitoring with EMG-records; this would be much appreciated in developing countries and would help them to routinely adopt intraoperative neuromonitoring. However, unlike the EMG-record the laryngeal twitch cannot be documented objectively in patients' records which might be of interest in malpractice claims [30]. Overall, both the laryngeal twitch and the EMG-records of intermittent neuromonitoring are comparable procedures. The laryngeal twitch is a reliable alternative in case of technical failure in the EMG-recording electrodes of the intermittent intraoperative neuromonitoring. Therefore, if a strong laryngeal twitch is palpable during surgery and the EMG-record shows no signal it is reasonable to continue surgery and avoid a two-stage thyroidectomy while also being more cost-effective. A prerequisite before surgery is to re-assess the indication in order to avoid unnecessary thyroidectomies when a hemithyroidectomy would also be feasible [4,31]. Neither intermittent neuromonitoring method can reliably predict a recurrent laryngeal nerve injury, which is also reflected in their positive predictive values. However, even if no laryngeal twitch is palpable or a loss of EMG signal occurs during surgery, this does not necessarily indicate a recurrent laryngeal nerve paralysis or paresis. Given the possibility of an early recovery of the recurrent laryngeal nerve after surgery, we assume that the PPV will never be reliable. In continuous intraoperative neuromonitoring, for example, a time span of 20 min is given to assess if an intraoperative recovery takes place and surgery may be continued. Furthermore, Dionigi et al. were able to show that on different postoperative days the nerve injury rate was different, and especially after the third postoperative day the injury rates were significantly reduced [32].

5. Conclusions

In conclusion, the laryngeal twitch can be useful as an alternative to intermittent neuromonitoring with EMG-record in case of its technical failure, although it has the disadvantage that it is not objectively documentable in patients' records. Overall, however, the laryngeal twitch can be helpful in decision-making for one-stage thyroidectomy if neuromonitoring fails and can possibly lead to the benefit of avoiding a two-stage procedure for the patient.

Ethical Approval

Ethical Approval was obtained by the "Ethikkommission der Stadt Wien" with the number EK_16_189_VK.

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Author contribution

All authors have made substantial contributions to study design, data collection, data analysis and writing.

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Data statement

Data will be made available on request.

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CRediT authorship contribution statement

Elisabeth Gschwandtner: Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Project administration, Data curation, Investigation. **Judith Netz:** Writing - original draft, Project administration, Data curation, Investigation. **Christian Passler:** Conceptualization, Methodology, Data curation, Investigation. **Ruth Bobak-Wieser:** Conceptualization, Data curation, Investigation. **Susanne Göbl:** Conceptualization, Data curation, Investigation. **Elisabeth Tatzgern:** Conceptualization, Data curation, Investigation. **Max Schneider:** Writing - original draft, Project administration, Data curation, Investigation. **Laura Handgriff:** Writing - original draft, Project administration, Data curation, Investigation. **Michael Hermann:** Conceptualization, Supervision, Writing - review & editing, Data curation, Investigation.

Declaration of competing interest

No conflicts of interest to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.11.001.

References

[1] A. Bergenfelz, S. Jansson, A. Kristoffersson, et al., Complications to thyroid surgery: results as reported in a database from a multicenter audit comprising 3,660 patients, Langenbeck's Arch. Surg. 393 (2008) 667–673.
[2] M.A. Cannizzaro, S. Lo Bianco, M.C. Picardo, D. Provenzano, A. Buffone, How to avoid and to manage post-operative complications in thyroid surgery, Updates Surg 69 (2017) 211–215.
[3] C. Christoforides, I. Papandrikos, G. Polyzois, N. Roukounakis, G. Dionigi, K. Vamvakidis, Two-stage thyroidectomy in the era of intraoperative neuromonitoring, Gland Surg. 6 (2017) 453–463.
[4] G. Conzo, G. Docimo, C. Mauriello, et al., The current status of lymph node dissection in the treatment of papillary thyroid cancer. A literature review, Clin. Ter. 164 (2013) e343–346.
[5] M. Hermann, C. Hellebart, M. Freissmuth, Neuromonitoring in thyroid surgery: prospective evaluation of intraoperative electrophysiological responses for the prediction of recurrent laryngeal nerve injury, Ann. Surg. 240 (2004) 9–17.
[6] M. Hermann, G. Alk, R. Roka, K. Glaser, M. Freissmuth, Laryngeal recurrent nerve injury in surgery for benign thyroid diseases: effect of nerve dissection and impact of individual surgeon in more than 27,000 nerves at risk, Ann. Surg. 235 (2002) 261–268.
[7] A. Bergenfelz, A.F. Salem, H. Jacobsson, E. Nordenstrom, M. Almquist, Risk of recurrent laryngeal nerve palsy in patients undergoing thyroidectomy with and without intraoperative nerve monitoring, Br. J. Surg. 103 (2016) 1828–1838.
[8] C.W. Wu, H. Sun, G. Zhang, et al., Staged thyroidectomy: a single institution perspective, Laryngoscope Investig Otolaryngol 3 (2018) 326–332.
[9] M. Melin, K. Schwarz, B.J. Lammers, P.E. Goretzki, IONM-guided goiter surgery leading to two-stage thyroidectomy–indication and results, Langenbeck's Arch. Surg. 398 (2013) 411–418.
[10] A. Anuwong, M. Lavazza, H.Y. Kim, et al., Recurrent laryngeal nerve management in thyroid surgery: consequences of routine visualization, application of intermittent, standardized and continuous nerve monitoring, Updates Surg 68 (2016) 331–341.
[11] H. Dralle, C. Sekulla, K. Lorenz, M. Brauckhoff, A. Machens, Intraoperative monitoring of the recurrent laryngeal nerve in thyroid surgery, World J. Surg. 32 (2008)

1358–1366.
[12] G.W. Randolph, J.B. Kobler, J. Wilkins, Recurrent laryngeal nerve identification and assessment during thyroid surgery: laryngeal palpation, World J. Surg. 28 (2004) 755–760.
[13] W. Cha, I. Cho, J.Y. Jang, J.K. Cho, S.G. Wang, J.H. Park, Supramaximal neurostimulation with laryngeal palpation to predict postoperative vocal fold mobility, The Laryngoscope 126 (2016) 2863–2868.
[14] O. Cavicchi, U. Caliceti, I.J. Fernandez, et al., Laryngeal neuromonitoring and neurostimulation versus neurostimulation alone in thyroid surgery: a randomized clinical trial, Head Neck 34 (2012) 141–145.
[15] O. Cavicchi, U. Caliceti, I.J. Fernandez, et al., The value of neurostimulation and intraoperative nerve monitoring of inferior laryngeal nerve in thyroid surgery, Otolaryngol. Head Neck Surg. 140 (2009) 866–870.
[16] H. Dralle, K. Lorenz, [Intraoperative neuromonitoring of thyroid gland operations: surgical standards and aspects of expert assessment], Chirurg 81 (2010) 612–619.
[17] J. Ott, M. Meusel, A. Schultheis, et al., The incidence of lymphocytic thyroid infiltration and Hashimoto's thyroiditis increased in patients operated for benign goiter over a 31-year period, Virchows Arch. 459 (2011) 277–281.
[18] E. Gschwandtner, R. Seemann, C. Bures, L. Preldzic, E. Szucsik, M. Hermann, How many parathyroid glands can be identified during thyroidectomy?: evidence-based data for medical experts, Eur. Surg. 50 (2018) 14–21.
[19] R.A. Agha, M.R. Borrelli, M. Vella-Baldacchino, R. Thavayogan, D.P. Orgill, The STROCSS statement: strengthening the reporting of cohort studies in surgery, Int. J. Surg. 46 (2017) 198–202.
[20] T.J. Musholt, A. Bockisch, T. Clerici, et al., [Update of the S2k guidelines: surgical treatment of benign thyroid diseases], Chirurg 89 (2018) 699–709.
[21] C.A. Rosen, T. Mau, M. Remacle, et al., Nomenclature proposal to describe vocal fold motion impairment, Eur. Arch. Oto-Rhino-Laryngol. 273 (2016) 1995–1999.
[22] A.D. Rubin, R.T. Sataloff, Vocal fold paresis and paralysis, Otolaryngol. Clin. N. Am. 40 (2007) 1109–1131 (viii-ix).
[23] H. Dralle, T.J. Musholt, J. Schabram, et al., German Association of Endocrine Surgeons practice guideline for the surgical management of malignant thyroid tumors, Langenbeck's Arch. Surg. 398 (2013) 347–375.
[24] R. Schneider, A. Machens, G.W. Randolph, D. Kamani, K. Lorenz, H. Dralle, Opportunities and challenges of intermittent and continuous intraoperative neural monitoring in thyroid surgery, Gland Surg. 6 (2017) 537–545.
[25] Z. Al-Qurayshi, E. Kandil, G.W. Randolph, Cost-effectiveness of intraoperative nerve monitoring in avoidance of bilateral recurrent laryngeal nerve injury in patients undergoing total thyroidectomy, Br. J. Surg. 104 (2017) 1523–1531.
[26] T. Wang, H.Y. Kim, C.W. Wu, et al., Analyzing cost-effectiveness of neural-monitoring in recurrent laryngeal nerve recovery course in thyroid surgery, Int. J. Surg. 48 (2017) 180–188.
[27] V. Riddell, Thyroidectomy: prevention of bilateral recurrent nerve palsy. Results of identification of the nerve over 23 consecutive years (1946-69) with a description of an additional safety measure, Br. J. Surg. 57 (1970) 1–11.
[28] C. Tomoda, Y. Hirokawa, T. Uruno, et al., Sensitivity and specificity of intraoperative recurrent laryngeal nerve stimulation test for predicting vocal cord palsy after thyroid surgery, World J. Surg. 30 (2006) 1230–1233.
[29] T.J. Loch-Wilkinson, P.L. Stalberg, S.B. Sidhu, M.S. Sywak, J.F. Wilkinson, L.W. Delbridge, Nerve stimulation in thyroid surgery: is it really useful? ANZ J. Surg. 77 (2007) 377–380.
[30] H. Dralle, K. Lorenz, A. Machens, Verdicts on malpractice claims after thyroid surgery: emerging trends and future directions, Head Neck 34 (2012) 1591–1596.
[31] G. Conzo, P.G. Calo, C. Gambardella, et al., Controversies in the surgical management of thyroid follicular neoplasms. Retrospective analysis of 721 patients, Int. J. Surg. 12 (1) (2014) S29–S34.
[32] G. Dionigi, L. Boni, F. Rovera, S. Rausei, P. Castelnuovo, R. Dionigi, Postoperative laryngoscopy in thyroid surgery: proper timing to detect recurrent laryngeal nerve injury, Langenbeck's Arch. Surg. 395 (2010) 327–331.