European Archives of Oto-Rhino-Laryngology (2019) 276:1109–1115
https://doi.org/10.1007/s00405-019-05360-5

LARYNGOLOGY

Ultrasonography-guided electromagnetic needle tracking in laryngeal electromyography

Kathleen Klinge[1] · Orlando Guntinas-Lichius[2] · Anne Naumann[1] · Andreas H. Mueller[1]

Received: 3 December 2018 / Accepted: 22 February 2019 / Published online: 5 March 2019

Abstract

Purpose The clinical evaluation of vocal fold movement disorders should contain the electromyography of the laryngeal muscles (LEMG). The most challenging point in LEMG is the right positioning of the EMG needle in the small target muscles. As the results of the EMG have great influence in the decision of treatment it is important to confirm the results of this examination. Anatomical structures of the larynx should be identified with laryngeal ultrasonography and the ultrasonography (US)-guided electromagnetic needle tracking should guide the LEMG needle to the target muscle.

Methods The thyroarytenoid (TA) and cricothyroid (CT) muscles had been evaluated in 19 patients (20 examinations). The US-guided transcutaneous LEMG using electromagnetic needle tracking was performed by one ENT doctor and all examinations had been video monitored. The videos were analyzed for the accuracy rate and the visibility of the important laryngeal structures.

Results The laryngeal structures were identified in all the cases using laryngeal ultrasonography. The examination times of the US-guided LEMG were acceptable (8 min, 32 s). The US-guided LEMG was feasible in 56 (36 TA, 20 CT) examinations. The TA and CT could be visualized successfully but in 17 examinations (30%) the signal was not stable. We could still reach the target muscles in more than 50% of these cases.

Conclusion US-guided electromagnetic needle tracking in LEMG helps to determine the exact position of the laryngeal structures. With further technical improvement of the stability of the electromagnetic needle tracking signal the US-guided electromagnetic needle tracking of the target muscles in the larynx could help to improve the accuracy of the transcutaneous LEMG.

Keywords Laryngeal ultrasonography · Laryngeal electromyography · Electromagnetic needle tracking · Laryngeal ultrasound

Introduction

Laryngeal electromyography (LEMG) is not a new examination in the laryngeal field but it has not been used widely for various reasons. In the last few years it has become more popular again to guide botulinum toxin injections, to assume the prognosis of a vocal fold paralysis and to plan their further treatment looking into the options of laryngeal pacing [1] and reinnervation [2]. It is considered as a cost effective and objective method to diagnose the laryngeal movement disorders including vocal fold paralysis, vocal fold paresis and other neuromuscular disorders [3, 4]. LEMG is not pain-free and for this reason it is considered as an often uncomfortable examination for the patient. Furthermore, the target muscles are small and sometimes not easy to detect with the needle especially in anatomical difficult patients due to obesity, former surgery or radiation. These are the main reasons why LEMG requires a lot of technical skills to perform the examination in a reasonable time. The decisions that are taken due to this examination are widely important for the patient whereas you want to have the most secure information out of the LEMG as possible. Our aim was to find out if US-guided electromagnetic needle tracking as a painless,

✉ Kathleen Klinge
kathleenklinge@gmx.de

[1] Department of Otorhinolaryngology/Plastic Surgery, SRH Wald-Klinikum Gera gGmbH, Strasse des Friedens 122, 07548 Gera, Germany

[2] Department of Otorhinolaryngology, Jena University Hospital, Jena, Germany

well tolerated and radiation free guidance method can facilitate the LEMG needle placement to the target muscle.

Methods and materials

Ethics and consent

The local ethics committee at the Friedrich-Schiller University, Jena approved this study. The patients gave their informed consent.

Subjects

From June 2016 to December 2017, 23 adult patients who attended our voice clinic had been evaluated (3 had to be excluded after successful examination due incomplete data sets). 19 (mean age 63 years) patients had been enrolled into the study finally (one patient presented twice, 20 examinations). 56 evaluations of the thyroarytenoid (TA) and cricothyroid (CT) muscles had been evaluated. The US-guided LEMG was performed by one ENT doctor (K.K.).

Equipment

The LEMG has been performed with the four-channel EMG machine (Neuropack M1, Nihon Kohden, Tokyo, Japan), multi-channel recordings including channels for a respiratory belt, a thermistor to register nasal breathing and a microphone (Atmos, Lenzkirch, Germany) to record vocal maneuvers. Further, we used 23 gauge needle electrodes (75 mm length), Neuroline Concentric, Ambu (Ambu, Ballerup, Denkmark) and the eZMagL Long Needle Magnetiser from ezono (ezono AG, Jena, Germany). The US-guided electromagnetic needle tracking has been realised by the ezono 4000 machine with the L3-12 NGS linear transducer (ezono AG, Jena, Germany) and it was videomonitored by a sony camera, Sony HDR-SR11 60 GB Camcorder (Sony, Tokio, Japan).

Setting

All enrolled study patients that presented to our voice clinic had been assessed by taking a detailed clinical history and we performed a videolaryngostroboscopy. After evaluating the condition of the patient a voice analysis had been completed. Once the patient had been evaluated as suitable for the study an informed consent was achieved. The LEMG was performed with the US-guided electromagnetic needle tracking including the muscles of interest according to the diagnostic findings.

The patient was positioned in a chair, upright position and the cables of the EMG-machine were connected (multi-channel recordings including channels for a respiratory belt, a thermistor to register nasal breathing and a microphone).

In the next step, we prepared the US and the electromagnetic needle tracking. We first started to evaluate the neck of the patient and the anatomical structures of the larynx (thyroid cartilage, cricoid cartilage, arytenoid cartilages, trachea, thyroid, the cricothyroid muscle, the thyroarytenoid muscle). After identifying the position of the laryngeal structures we have given the patient a local anesthetic (lidocaine, 2%) into the area of the cricothyroid membrane and into the trachea to reduce discomfort for the patient during examination.

The EMG-needle needed to be magnetized and the electromagnetic needle tracking signal was seen on the screen. The muscle (CT, TA) was focused with the US and the needle was put into place according to the electromagnetic needle tracking signal. The TA was evaluated first before exploring the CT.

We used the transverse/midline and transverse/oblique approach as described by Park [5] to evaluate the TA. The TA was found with the US signal in the transverse/midline approach and the transducer was shifted then laterally along the thyroid cartilage parallel to the TA of the desired side. Concerning the US-guided electromagnetic needle tracking we used an in-plane mode to demonstrate the penetration of the needle [6]. The tracking signal was awaited and the needle was inserted through the cricothyroid membrane. Once it had penetrated the CT membrane the needle was angled 30 degree laterally and 10 degree superiorly to reach the TA. This method of needle insertion is following the guidelines by Volk et al. [7] Additional corrections of the position of the needle needed to be done if the needle had not reached the correct position. Once the needle reached the target muscle and appeared in the US in plane two solid parallel lines could be seen on the US screen and the needle tip was estimated within the square box, marked in green color to make the in plane mode visible (Fig. 1). The patient was asked to perform different maneuvers such as high pitched phonation, like the vocal “eee”, and deep breathing.

After evaluating the TA we were looking into the CT. Concerning the US we used again the method described by Park [5]. The CT muscle was first investigated in the transverse/midline approach. Once the CT was identified we followed the structure of the muscle and fulfilled a turning of the ultrasound probe 15°–20° in parallel with the muscle (transverse/oblique approach). The navigation was activated and the EMG-needle was approximately angled 70°–80° to the ultrasound probe. This kind of US procedure has been classified as an out of plane mode [6]. Once the needle had reached the target muscle (CT) the two solid parallel lines appeared and the tip of the needle was estimated within the square box in green color to ensure that the needle tip was under the US beam (Fig. 2). The patient is asked again to

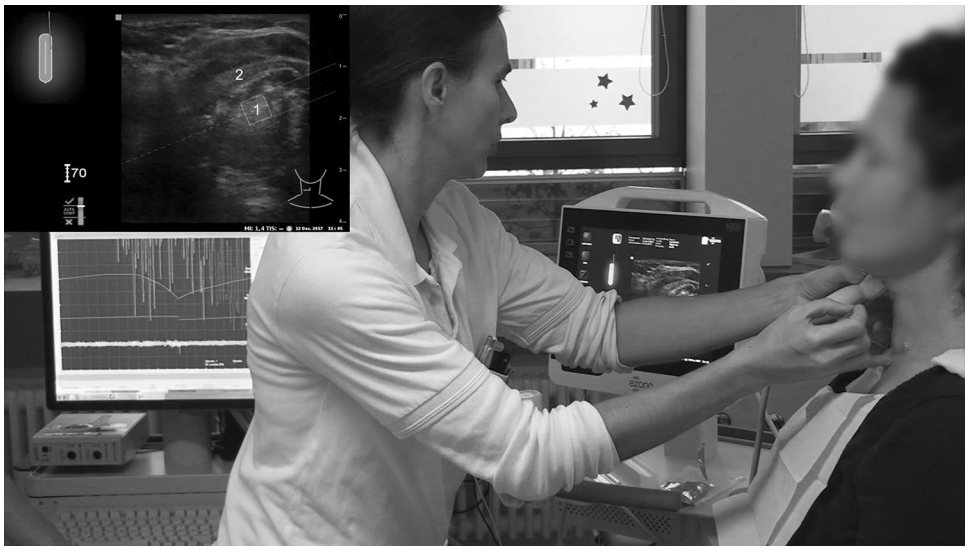

Fig. 1 Position US-guided thyroarytenoid muscle (TA), 1 TA muscle, 2 thyroid cartilage

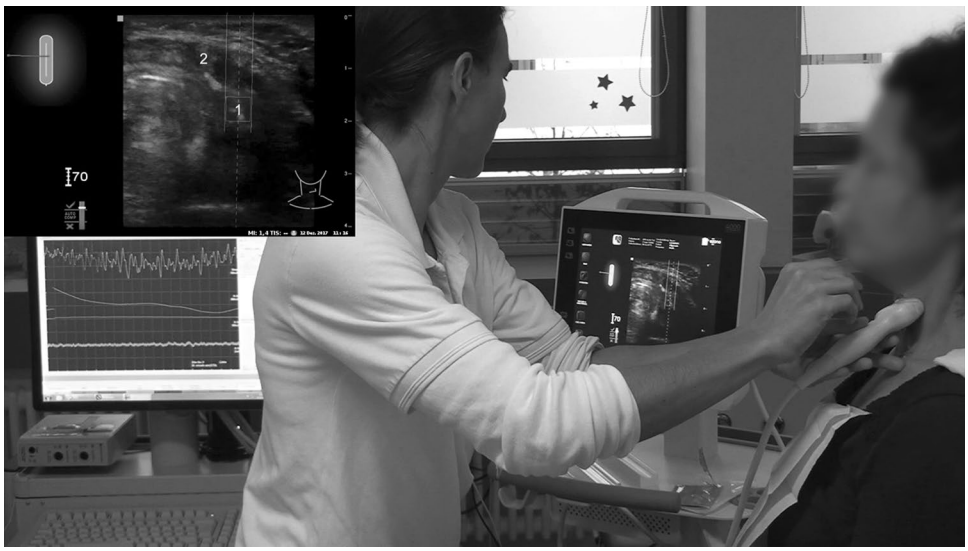

Fig. 2 Position US-guided cricothyroid muscle (CT), 1 CT muscle, 2 strap muscles

phonate with a glissando from dark "ee" to a high pitched "eee" once the needle has reached the target position. Forced breathing in inspiration was evaluated as well and a swallowing maneuver.

For completion of the LEMG examination the posterior cricoarytenoid muscle was monitored if necessary but was not part of the study as this muscle is difficult to demonstrate by US.

The whole procedure was videomonitored and afterwards it had been cut into the relevant parts of the examination (US of the laryngeal structures and each muscle from the time the probe had been set onto the skin to visualize the target muscle to the time the probe was taken off the skin). The videos had been evaluated by the examiner first and the ultrasound videos had been evaluated alone without seeing the complete video by a second medical doctor with a special interest in ultrasound (A.N.). In the next step, the videos had been reevaluated again by a third doctor with high knowledge in LEMG (A.M.).

We evaluated the US-guided LEMG of the TA as an in-plane procedure and counted the needle position as correct when in the video monitored examination the needle reached the target muscle and the two solid parallel lines appeared in the green color to mark the in plane mode. The green square to mark the needle tip needed to be in the target muscle and the LEMG signal typical for the TA needed to be seen and heard by the EMG-machine.

The CT was evaluated in the same manner except that this was an out of plane procedure.

Results

Patient's characteristics

The 56 EMG-evaluations of the TA (36) and CT muscles (20) that had been included into the study arose from 20 patient presentations (whereas one patient presented twice). 10 patients were female and 9 patients were male. The youngest patient was 33 years old and oldest patient 79 years old (mean age 63 years).

23 patients presented in total but 3 patients had to be excluded (because of a disturbing noise in the EMG machine, no separately recording of the US signal and interruption of the US signal).

The cause of the dysphonia the patients presented with had been very heterogenic. 8 patients presented with a recurrent nerve paresis after a surgical intervention, 2 patients had a recurrent nerve paresis due to tumors, 3 patients had an idiopathic nerve paresis, one patient presented with a recurrent nerve paresis due to an endoscopy and one patient due to an inflammation, one patient after an apoplectic insult. 3 patients presented with a laryngeal dystonia.

Concerning the stroboscopy findings we have seen 14 paresis (9 right sided, 4 left sided, 1 bilaterally). Furthermore, we found 2 patients with a reduced vocal fold motility, 3 inadequate glottic closure and one patient with a bilaterally vocal fold tremor. The LEMG findings are demonstrated in Table 1.

US of the laryngeal structures

In all patients the required laryngeal landmarks (thyroid cartilage, cricoid cartilage, arytenoid cartilages, trachea, thyroid and the target muscles) could be identified (data not shown). The quality of the US depended mostly on the age of the patient, the number and timing of the operating procedures prior to the examination and the sex of the patient. Female young patients with no operations prior to the examination presented the best quality of the US scans.

Examination times

The mean US examination time was 1.41 min (fastest examination 0.28 min and slowest examination 3.45 min). The time for each muscle to be visualized with the needle tracking and during the LEMG and the total time for the whole examination with the US-guided LEMG for each muscle is presented in Table 2. The evaluated times of the examination show that even for the US-guided LEMG for 4 muscles we reached an acceptable average time of 8 min and 32 s.

Results of the US-guided LEMG

We achieved a total number of 56 (100%, 36 TA, 20 CT) examinations from which we reached in 31 (55%) examinations (21 TA and 10 CT) the target muscle and had an adequate LEMG signal (Table 3). 13 (23%) attempts of US-guided LEMG did not reach the target muscle (TA/CT muscle) and in 12 (22%) cases it was unsure to detect if the needle reached the target position. This was mainly due to a loss of the electromagnetic needle tracking signal. We stated 39 (70%) of all examinations with a stable quality of the ezono navigation signal but in 17 (30%) of the cases the signal was not stable, got lost during the examination or was only intermittently apparent.

Discussion

Scanning the neck for lymph nodes and the thyroid gland is an integral part of head and neck US in the clinical setting but laryngeal US is not used that often. Just recently it was suggested that it could be used for the examination of the laryngeal regions [4, 8, 9]. But there had been studies in the past as well and already at this time it was found that the visualization of the larynx had its limitations due to ossification of the thyroid cartilage especially in older men and due to air [10, 11]. Recently Woo [12] suggested a lateral approach of the larynx which improved the visualization of the larynx a lot and this method had been used in this study and was performed in the way Park [5] has described it in the transverse midline/transverse oblique approach. Using this technique we could visualize all the required structures (thyroid cartilage, cricoid cartilage, arytenoid cartilages, trachea, thyroid, the cricothyroid muscle, the thyroarytenoid muscle) in the larynx during all examinations.

As far as we are aware of the duration of a LEMG examination has not been reported in the literature yet. Although we know that we did not have any comparable data in healthy patients we can estimate our examination times that we can achieve in a normal setting. Reaching the time of the US examination itself (mean time 1.41 min, fastest examination 0.28 min and slowest examination 3.45 min) we think we stayed in an acceptable range, which did not prolong the examination relevantly. But there are no existing data in the literature and the LEMG is a very examiner depending examination concerning the examination time. In some cases of difficult anatomy (due to obesity, former radiation or surgery, male patients) it might have even shortened it because we saved relevant time by identifying the laryngeal structures easily due to US where we would have needed a lot more time for palpation and failed attempts.

Concerning the initial question, if we could reach the target muscle with US guidance we must state that we only

Table 1 Clinical characteristics of the patients (sex, age, cause of the paresis) and results of laryngostroboscopy and the LEMG

No.	Sex	Age	Cause	Laryngotroboscopy	LEMG (laryngeal electromyography)
1	Female	72	Apoplectic insult 2014	Right vocal fold paresis, paramedian position	Strongly reduced recruitment pattern RTA[a], RCT[b], RPCA[c]
2	Female	69	Thyroid surgery 07/2016, parkinsons disease	Inadequate glottic closure, decreased vibratory amplitude bilaterally	Normal recruitment pattern RTA[a], LTA[d], single fibre activity RCT[b], LCT[e]
3	Female	33	Neck dissection, left 8/2016	Left vocal fold paresis, paramedian position	Single fiber activity LCT[e]
4	Female	77	Thyroid surgery 9/2016	Left vocal fold paresis, median position	Mildly reduced recruitment pattern LTA[d]
5	Male	77	Laryngeal dystonia	Inadaequate glottic closure, tremor right arytenoid cartilage	Overall slightly reduced recruitment, but no difference in the side
6	Male	79	Laryngeal dystonia	Inadaequate glottic closure, false vocal fold squeezing	Mildly reduced recruitment pattern RTA[a], single fibre actvitiy LTA[d], mildly reduced activity pattern LCT[e]
7	Male	62	Endoscopy 11/2016	Bilateral vocal fold paresis, bilaterally lateral position	Strongly reduced recruitment pattern RTA [a] and LTA[d]
8	Male	75	Idiopathic	Reduced motility left vocal fold	Mildly reduced recruitment pattern LTA[d]
9	Female	53	Encephalitis, meningoradiculitis (9/2016), myasthenia gravis	Right vocal fold paresis, paramedian position	Strongly reduced recruitment pattern RTA[a], mildly reduced recruitment pattern RCT[b]
10	Male	76	Aortic aneurysm operation, 2016	Left vocal fold paresis, paramedian position	Mildly reduced recruitment pattern LTA[d]
11	Male	63	Bronchial carcinoma, right side	Right vocal fold paresis, paramedian position	Mildly reduced recruitment pattern LTA[d]
12	Female	55	Cervical spine operation, 2017	Right vocal fold paresis, paramedian position	Strongly reduced recruitment pattern RPCA[c]
13	Female	52	Thyroid surgery, 2017	Right vocal fold paresis, paramedian position	Single fiber activity RTA[a]
14	Female	59	Laryngeal Dystonia, vocal tremor	Bilateral tremor vocal folds	Overall slightly reduced recruitment in all muscles, complex repetitive discharges
15	Male	67	Idiopathic	Right vocal fold paresis, paramedian position	Mildly reduced recruitment pattern RTA[a], stronlgy reduced recruitment pattern RPCA[c]
16	Female	53	Encephalitis, meningoradiculitis (9/2016), myasthenia gravis	Right vocal fold paresis, paramedian position	Mildly reduced recruitment pattern RTA[a]
17	Male	62	Idiopathic	Right vocal fold paresis, paramedian position	Mildly reduced recruitment pattern RTA[a]
18	Female	38	Thyroid surgery 2017	Left vocal fold paresis, paramedian position	Mildly reduced recruitment pattern LTA[d], strongly reduced recruitment pattern LCT[e]
19	Female	68	Cervical spine operations, 2005, 2006, 06/2017, 10/2017, thyroid surgery 1975	Reduced motility right vocal fold	Strongly reduced recruitment pattern RTA[a]
20	Male	72	Carcinoma of the cardia, resection of the esophagus 2016	Right vocal fold paresis, lateral position	Strongly reduced recruitment pattern RTA[a]

[a]RTA right thyroarytenoid muscle

[b]RCT right cricothyroid muscle

[c]RPCA right posterior cricoarytenoid muscle

[d]LTA left thyroarytenoid muscle

[e]LCT left cricothyroid muscle

reached in 31 (55%) examinations (21 TA and 10 CT) the target muscle and had an adequate LEMG signal. This is not an optimal result but we could proof in more than half of the procedures in a secure manner to have reached the target position. This is a beginning using a new method. Reasons for failure to detect the target muscle were mainly due to loss of signal but as well due to a misaligned needle, which may have caused misinterpretation of the position of the needle tip. The loss of signal (17 examinations, 30%, of the cases) was very variable and occurred sometimes early and in some cases late during the examination, where we had 8 examinations we still could reached the target position

Table 2 Times of the US-guided LEMG for the thyroarytenoid muscle (TA) and the cricothyroid muscle (CT), total time in minutes

TA right ultrasound	TA right LEMG	TA right total time
0.42 min	1.11 min	1.53 min
TA left Ultrasound	TA left LEMG	TA left total time
1.07 min	1.11 min	2.18 min
CT right Ultrasound	CT right LEMG	CT right total time
1.24 min	0.52 min	2.16 min
CT left Ultrasound	CT left LEMG	CT left total time
0.57 min	1.08 min	2.05 min

although in the later examination the signal had got lost. But in 9 examinations the failed target muscles were due to signal loss.

Each needle manufacturer uses a slightly different amount of iron in their needles, resulting in a slightly different magnetic signature [6]. Although the needle profile was tested by ezono there might exist other needles more suitable for the examinations. So magnetization might have been one problem and while using the in plane mode for the TA muscle with less magnetization points at the end of the probe this might have been a problem.

The other problem we observed was an examination with a good quality EMG signal which indicated to have reached the target muscles but in the later evaluation of the video we must state that we can not proof to have reached the target point. This might be as a misaligned needle problem where the target muscle was reached in reality but could not be sufficiently visualized in the US. The flexibility of the needle also needs to be taken into account. The other probable explanation in some cases could have been a muscle signal from a strap muscle in tensed patients misinterpreted as a TA-signal and a truly wrong needle position.

A last problem that needs to be mentioned is the moving larynx, which makes this examination difficult as the US-guided electromagnetic needle tracking was not designed for this procedure. But the movement itself is a problem that exists without US guidance, too.

Conclusion

US of the larynx helps beginners and advanced clinicians for orientation in the laryngeal structures. Identification is quick, safe, easy applicable and well tolerated. US-guided electromagnetic needle tracking in transcutaneous LEMG is a new approach to this well-established examination that can potentially shorten the examination time in difficult anatomy and give proof of the needle position when in the correct place. Failures in needle placements need to be improved by optimize equipment and apply the learned aspects in needle guidance to reduce missed target muscles.

Finally, to give more relevant data, a prospective randomized analysis of this new method including a control group and designed for a higher number of patients needs to be realized in the future to confirm the prognosis of a benefit due to US-guided electromagnetic needle tracking in transcutaneous LEMG.

Table 3 Evaluation of the target muscles (thyoarytenoid muscle, TA and cricothyroid muscle, CT) which could be reached via US-guided electromagnetic needle tracking (EMT) in LEMG

	TAR[a]	TAR %[a]	TAL[b]	TAL %[b]	CTR[c]	CTR %[c]	CTL[d]	CTL%[d]	Total	Total %
Examinations	19	100	17	100	12	100	8	100	56	100
Muscle reached, EMT[e] + LEMG signal	11	58	10	59	5	42	5	63	31	55
Muscle not reached	6	32	4	23	2	16	1	12	13	23
Unsure	2	10	3	18	5	42	2	25	12	22
Good quality of EMT signal[e]	14	74	13	76	6	50	6	75	39	70
EMT signal disturbance[e]	5	26	4	24	6	50	2	25	17	30

[a]TAR right thyroarytenoid muscle

[b]TAL left thyroarytenoid muscle

[c]CTR right cricothyroid muscle

[d]CTL left cricothyroid muscle

[e]EMT electromagnetic needle tracking

Funding The Company eZono AG Jena (Spitzweidenweg 30, D-07743 Jena, Germany) provided the ultrasound scanner with the prototype needle guidance system for the time the trial was running. No further funding was secured for this study.

Compliance with ethical standards

Conflict of interest The company eZono AG Jena provided a prototype of the ultrasound machine for the time of the study and was otherwise not involved in the study design, execution, and analysis.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The local ethics committee at the Friedrich-Schiller University, Jena approved this study.

Informed consent The patients gave their informed consent.

References

1. Mueller AH (2011) Laryngeal pacing for bilateral vocal fold immobility. Curr Opin Otolaryngol Head Neck Surg 19:439–443
2. Marina MB, Marie JP, Birchall MA (2011) Laryngeal reinnervation for bilateral vocal fold paralysis. Curr Opin Otolaryngol Head Neck Surg 19:434–438
3. Kim HT (2003) Lagryngeal electromyography. Korean J Otolaryngol-Head Neck Surg 46:453–456
4. Sataloff RT, Praneetcatakul P, Heuer RJ, Hawksshaw MJ, Heman-Ackah YD, Schneider SM, Mandel S (2010) Laryngeal electromyography: clinical application. J Voice 24:228–234
5. Park HS, Jung SY, Yoo JH, Park HJ, Lee CH, Kim HS, Chung SM (2016) Clinical Usefulness of ultrasonography-guided laryngeal electromyography. J Voice 30(1):100–103
6. Gadsden J et al (2015) Evaluation of the eZono 4000 with eZGuide for ultrasound-guided procedures. Expert Rev Med Devices 12(3):251–261
7. Volk GF, Hagen R, Pototschnig C, Friedrich G, Nawka T, Arens C, Mueller A, Foerster G, Finkensieper M, Lang-Roth R, Sittel C, Storck C, Grosheva M, Kotby MN, Klingner CM, Guntinas-Lichius O (2012) Laryngeal electromyography: a proposal for guidelines of the European Laryngological Society. Eur Arch Otorhinolaryngol 269(10):2227–2245
8. Cheng SP, Lee JJ, Liu TP, Lee KS, Liu CL (2012) Preoperative ultrasonography assessment of vocal cord movement during thyroid and parathyroid surgery. World J Surg 36:2509–2515
9. Seo HG, Jang HJ, Oh BM, Kim W, Han TR (2014) Use of ultrasonography to locate laryngeal structures for laryngeal electromyography. PM R 6:522–527
10. Garel C, Legrand I, Elmaleh M, Contenvin PH, Hassan M (1990) Laryngeal ultrasonography in infants and children: anatomical correlation with fetal preparations. Pediatr Radiol 20:241–244
11. Wong KP, Woo JW, Youn YK, Chow FC, Lee KE, Lang BH (2014) The importance of sonographic landmarks by transcutaneous laryngeal ultrasonography in post-thyroidecomtomy vocal cord assessment. Surgery 156(6):1590–1596
12. Woo JW, Suh H, Song RY, Lee JH, Yu HW, Kim SJ, Chai YJ, Chou JY, Lee KE (2016) A noval lateral-approach laryngeal ultrasonography for vocal cord evaluation. Surgery 159(1):52–56