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HOW I DO IT

Diagnosis of recurrent laryngeal nerve paralysis following esophagectomy by evaluating movement of the vocal cords and arytenoid cartilages using ultrasonography

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Abstract

Advancements in thoracoscopic surgery have provided us with a deeper anatomical understanding of recurrent laryngeal nerve paralysis (RLNP), which is likely to occur after lymph node dissection. Taking a novel approach to researching the diagnosis of RLNP, we evaluated movement of the vocal cords and arytenoid cartilages using ultrasonography in patients who underwent thoracoscopic esophagectomy. RLNP occurred in six of the 24 patient cohort. The rate of hoarseness and difficulty in discharging sputum was significantly higher in the paralyzed group than in the non-paralyzed group. The diagnostic accuracy of RLNP by ultrasonography had a sensitivity of 83.3% (5/6), a specificity of 88.8% (16/18), a false positive rate of 5.6% (1/18), and a false negative rate of 0% (0/6). Although it is not completely accurate, our findings indicate that ultrasonography is quite effective for diagnosing RLNP, more so in combination with clinical symptoms. Ultrasonography may also be effective for identifying patients who are amenable to laryngoscopy for diagnosing RLNP, or for evaluating the recovery status of nerve paralysis.

Keywords Esophagectomy · Recurrent laryngeal nerve paralysis · Vocal cords · Arytenoid cartilages · Ultrasonography

Introduction

The magnifying effect of thoracoscopy has provided us with a deeper understanding of the anatomical structure of the recurrent laryngeal nerve and its surroundings. The rate of recurrent laryngeal nerve paralysis (RLNP) has been reported to be significantly higher following thoracoscopic esophagectomy than thoracotomy [1]. To prevent RLNP, we need to not only prevent nerve cutting and compression and traction, but also thermal damage to the nerve caused by surgical devices [2].

Laryngoscopy is primarily used to diagnose RLNP by evaluating movement of the vocal cords. However, laryngoscopy can be invasive and painful for patients, and it takes time and effort to complete the examination [3]. In comparison, ultrasonography is non-invasive for patients and medically economical, and it can be performed by clinicians who are not specialized in the cervical region [4]. The diagnostic accuracy for RLNP by evaluating movement of the vocal cords using ultrasonography has previously been reported to be about 50%, mainly after thyroid surgery [5, 6]. Even though there are very few reports on the use of ultrasonography for diagnostic purposes following esophagectomy, it is important to evaluate RLNP following lymph node dissection in the area surrounding the recurrent laryngeal nerve in the thoracic cavity, separate to the thyroid surgery area. This study therefore makes a significant contribution to the literature by examining the effectiveness of using ultrasonography to diagnose RLNP, by not only detecting movement of the vocal cords, but also with the high luminance of ultrasonographic images of the arytenoid cartilages.

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Materials and methods

We examined movement of the vocal cords and arytenoid cartilages in 24 patients who underwent thoracoscopic esophagectomy with lymph node dissection of the superior mediastinal for thoracic esophageal cancer at our facility from February 2019 to February 2020. Movement of the arytenoid cartilage was evaluated only in cases where movement of the vocal cords could not be evaluated. Diagnosis of RLNP by evaluating any movement of the vocal cords and arytenoid cartilages by ultrasonography was performed 3 days after surgery, and the laryngoscopy was performed by an otolaryngologist on the day following the ultrasonography to confirm the diagnosis. While paresis indicates weak vocal cord movement due to partial interruption of the nerve impulse, paralysis results in no movement of the vocal cords due to total interruption. Patients' clinical data were reviewed and research findings were analyzed retrospectively. The treatment strategy and surgery, including lymph node dissection, were performed in accordance with the Esophageal Cancer Practice Guidelines [7] and Esophageal Cancer Criteria [8]. This study was approved by the review board of Nagoya City University (NO. 60-18-0008). Written informed consent was waived because of the retrospective design.

Ultrasonography

LOGIQ Q6 (GE Healthcare Japan Co., Ltd.) was used for diagnosing RLNP. A linear type probe (9L-probe) with superior capabilities to visualize superficial organs was used with a frequency of 8 MHz. Two surgeons who were not involved in the esophagectomy and postoperative treatment course, and who do not specialize in the cervical area performed the ultrasonography. The patients were examined in a reclining position of approximately 60 degrees with their neck tilted slightly backward (Fig. 1).

The 9L-probe was placed vertically and axially on the laryngeal prominence of the thyroid cartilage, and vocal cords movement was observed in the visual field including the arytenoid cartilages. The patients were asked to make several small utterances of "Ah, Ah, Ah" to observe the abduction and adduction movements on the vocal cords and arytenoid cartilages during the same respiratory cycle. Similar to laryngoscopy, we conducted on-site diagnosis of RLNP using ultrasonography and did not perform ex-post image analysis.

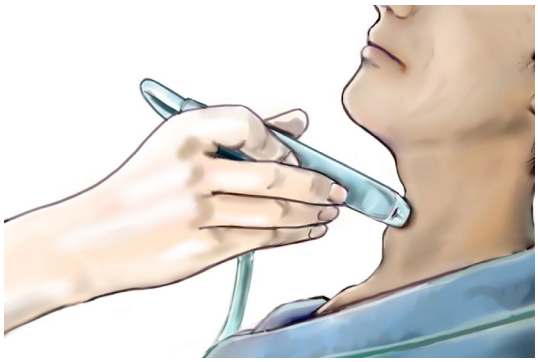

Fig. 1 Ultrasonography of the vocal cords and arytenoid cartilages

Statistical analysis

All statistical analyzes were performed using EZR (Saitama Medical Center, Saitama Medical University). The Mann–Whitney *U* test was used to analyze continuous variables and Fisher's exact test was used to analyze categorical variables. p value < 0.05 was judged to be statistically significant.

Results

Patient characteristics and clinical variables are shown in Table 1. Based on the results of laryngoscopy evaluation, the 24 patients were grouped into two groups: six patients diagnosed with RLNP in the "paralyzed group" and 18 patients with no indication of RLNP in the "non-paralyzed group". Five of the six patients in the Paralyzed group had unilateral RLNP (four paralysis, 1 paresis) and the other patient had paralysis of one vocal cord and paresis of the other vocal cord. The paralyzed group had more days from surgery to soft diet (10.5 vs. 7.0, $p = 0.027$). Considering clinical symptoms, hoarseness and sputum discharge difficulty was significantly higher in the Paralyzed group than in the Non-paralyzed group (Hoarseness: 6 vs. 3, $p < 0.001$, discharging sputum: 5 vs. 3, $p < 0.01$). The accuracy of this study is shown in Table 2. Vocal cord movement could be evaluated by ultrasonography in four patients in the Paralyzed group and 13 patients in the Non-paralyzed group. In addition, we were able to evaluate arytenoid cartilage movement in one patient in the Paralyzed group and four patients in the Non-paralyzed group by ultrasonography. There was one case in both groups, in which neither movement of the vocal cords or the arytenoid cartilages could be detected by ultrasonography. There was one patient in the Non-paralyzed group who

Table 1 Demographic and clinical characteristics of patients

Variables	Paralyzed ($n=6$)	Non-paralyzed ($n=18$)	p
Gender			
Male/Female	5/1	15/3	1
Age (years)	71.5 (58.0–75.0)	70.0 (48.0–82.0)	0.92
BMI[a] (kg/m2)	23.02 (16.58–26.58)	19.97 (14.75–26.37)	0.25
ASA[b] score			
1/2/3	3/3/0	4/13/1	0.49
Pre-surgical serum albumin value (g/L)	3.75 (2.90–4.50)	3.85 (2.20–4.30)	0.74
Location			
Ut[c]/Mt[d]/Lt[e]	1/3/2	2/10/6	1
pStage			
0/I/II/III/IVa	1/0/1/3/1	2/2/7/7/0	0.40
pT Stage			
1a/1b/2/3/4a	1/0/3/2/0	2/3/5/7/1	0.83
pN Stage			
0/1/2/3/4	1/1/2/1/1	8/6/3/1/0	0.25
Pathological type			1
Squamous cell carcinoma	6	17	
Others	0	1	
Reconstruction route			1
Retro-sternal	6	17	
Antethoracic	0	1	
Reconstruction organ			1
Gastric tube	6	17	
Free jejunum graft	0	1	
Days from surgery to soft diet (days)	10.5 (7.0–55.0)	7.0 (7.0–8.0)	0.027
Postoperative hospital stays (days)	37.0 (18.0–64.0)	19.5 (14.0–82.0)	0.081
Subjective hoarseness	6 (100%)	3 (16.7%)	<0.001
Difficulty in sputum expectoration	5 (83.3%)	3 (16.7%)	<0.01
Fever ($\geq$37.5 degrees)	1 (16.7%)	2 (11.1%)	1
Pneumonia ($\geq$Grade II)	1 (16.7%)	1 (5.6%)	0.45

BMI[a] body mass index

ASA[b] American Society of Anesthesiologists

Ut[c] upper thoracic esophagus

Mt[d] middle thoracic esophagus

Lt[e] lower thoracic esophagus

Table 2 Results of ultrasonography

Characteristic	Paralyzed ($n=6$)	Non-paralyzed ($n=18$)
RLNP[a] positive in ultrasonography	5	1
Evaluation by vocal cord movement	4	1
Evaluation by arytenoid cartilage movement	1	0
RLNP negative in ultrasonography	0	16
Evaluation by vocal cord movement	0	12
Evaluation by arytenoid cartilage movement	0	4
Non-evaluable	1 (16.7%)	1 (5.6%)

RLNP[a] recurrent laryngeal nerve paralysis

was erroneously determined to have RLNP by the initial ultrasonography, but was subsequently shown not to have RLNP in the laryngoscopy results. The diagnostic method for RLNP using ultrasonography had a sensitivity of 83.3% (5/6), a specificity of 88.8% (16/18), a false positive rate of 5.6% (1/18), and a false negative rate of 0% (0/6).

Axial image of ultrasonography

Figures 2a, b show abduction and adduction movements of bilateral vocal cords and arytenoid cartilages in one of the patients in the Non-paralyzed group. Figures 2c, d, and supplemental video data 1a show one case in the Paralyzed group in which the vocal cords were detected due to abduction and adduction movements only on the healthy vocal cord (right side). More specifically for this case (Fig. 2c, d), the ultrasonography performed just before discharge (42 days after surgery) showed that the nerve paralysis had improved (left side), although not completely (supplemental video 1b]. Figures 2e, f show one case in the paralyzed group in which only arytenoid cartilages could be detected and abduction and adduction movements on the healthy arytenoid cartilage (right) were observed. The anatomical schema of the cervical ultrasonography is shown in Fig. 2g.

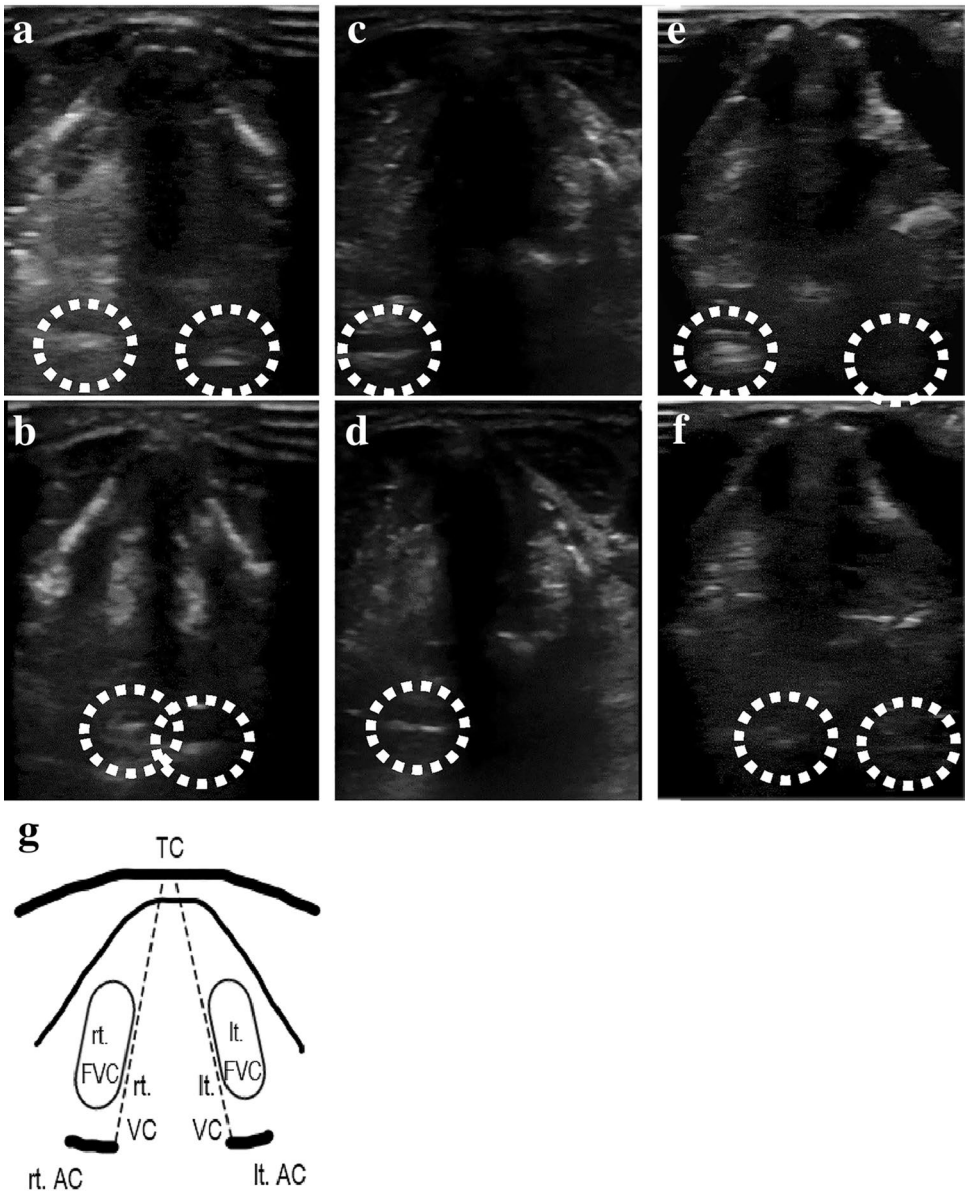

Fig. 2 Abduction and adduction movement of the vocal cords and arytenoid cartilage. The dotted circles indicate the arytenoid cartilage. **a** Abduction of the vocal cords and arytenoid cartilages and (**b**) adduction in healthy patient. **c** Abduction and (**d**) adduction of the right vocal cord and arytenoid cartilage, which is the healthy side of a patient with left RLNP. **e** Abduction and (**f**) adduction of the right arytenoid cartilage in the left RLNP patient, whose vocal cords could not be detected. **g** Schema of the ultrasound image

Discussion

In our examination of the ultrasonography results, the thyroid cartilage is detected in black. When thyroid cartilage is ossified, the permeability of ultrasonography is attenuated, making it difficult to obtain clear imaging information of the deeper parts of anatomy. Elderly patients, males, and patients of taller height are considered as low observable factors of vocal cord movement by ultrasonography [5]. In the present study, vocal cord movement could not be detected in seven of the 24 patients using ultrasonography. In these cases, abductor and adductor action on the arytenoid cartilages were evaluated as alternative methods for diagnosing RLNP. There were only two cases that we could not detect either the vocal cords or the arytenoid cartilages using ultrasonography. The reason for the patient in the Non-paralyzed group was due to the fact that he suffered from postoperative cervical subcutaneous emphysema. And the reason we could not detect any movement in the patient in the Paralyzed group was because the brightness of the ultrasonography through the thyroid cartilage was too high due to the fact that the patient was an elderly man over 70 years old. This patient also had a thick and short neck, making it difficult to determine the proper position for placing the ultrasonic probe. Although no such patient was found in our study, hematomas and inflammatory changes under the wound may impair the field of view for ultrasonography. In the first case evaluated in this study, the patient was initially misdiagnosed with RLNP using ultrasonography, but subsequent laryngoscopy indicated normal movement of one of the vocal cords (false positive). This misdiagnosis was attributable to the fact that the patient was an elderly man over 70 years old with a short neck and hoarseness, and he was able to make only a few vocalizations due to postoperative fatigue. After this first case, the procedure using ultrasonography became more stable as the number of cases increased, and we could diagnose RLNP with relatively high sensitivity and specificity. Although low observable factors of vocal cord movement by ultrasonography have been reported, patient conditions that are prone to misdiagnosis need to be investigated by examining more cases.

There are several points to consider for evaluation of movement of the vocal cords and arytenoid cartilages using ultrasonography. First, since the vocal cords are anatomically located in a substantially horizontal position, the ultrasonic probe should be applied perpendicular to the thyroid cartilage. Second, we need to be mindful that vocal cord detection can be difficult depending on the skill of the examiner and the condition of the patient undergoing the examination. In such cases, we should focus on observing movement of the arytenoid cartilages without committing too much time and resources looking for vocal cord movement. In some cases, even movement of the arytenoid cartilage cannot be confirmed by ultrasonography. In addition, we need to know that the paralyzed vocal cord may passively move slightly due to movement of the cricoarytenoid joint by the cricothyroid muscles of the superior laryngeal nerve innervation without paralysis.

A lateral ultrasonography for observing the arytenoid cartilage has previously been reported with a higher degree of diagnostic accuracy for RLNP than the vertical method used in this study [9]. The lateral method requires finding the left and right arytenoid cartilages that move up and down, alternatingly. Since paralyzed arytenoid cartilage do not move, it is difficult to detect arytenoid cartilage and evaluate its movement. Furthermore, the examiner is unable to determine the relative degree of paralysis of the arytenoid cartilage by comparing movement of the left and right arytenoid cartilages simultaneously. As a result, the examiner must be an expert in cervical clinics or a person who is accustomed to using cervical ultrasonography. Our method is comparatively easier for clinicians to use. The learning curve for using the procedure has been shown to stabilize over 10–20 trials [4]. However, we also acknowledge that the accuracy of this ultrasonography procedure depends on the patient's condition, and that certain cases cannot be evaluated correctly.

At present, laryngoscopy is recommended for the reliable diagnosis of postoperative RLNP in cases other than in the esophageal cancer area [6, 10]. However, it is possible to limit the use of laryngoscopy to patients whose vocal cords and arytenoid cartilages cannot be detected by ultrasonography and have clinical symptoms such as hoarseness. As an alternative to overcome these limitations, ultrasonography can be an effective diagnostic tool for RLNP not only immediately after esophageal surgery, but also during the recovery period for RLNP, which has a reported median duration of 6 months.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10388-021-00830-4.

Compliance with ethical standards

Ethical statement All procedures followed were in compliance with the ethical standards of the Responsible Commission on Human Experimentation (institutional and national) and the Helsinki Declaration of 1964 and later versions.

Informed consent Informed consent or its alternatives were obtained from all patients to be included in the study.

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