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Impact on swallowing functions of arytenoid adduction in patients with unilateral vocal fold paralysis

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ABSTRACT

Objective: Although the pathophysiology of swallowing dysfunction in patients with unilateral vocal fold paralysis (UVFP) remains uncertain, glottal insufficiency is known to be a possible major cause, and other factors due to vagus nerve or recurrent laryngeal nerve damage may contribute to dysphagia or aspiration. This study aimed to evaluate the effect of arytenoid adduction (AA) surgery on the swallowing functions of UVFP patients and to investigate the important role of glottic closure during swallowing.
Methods: We prospectively analyzed the data of thirteen patients with UVFP who underwent AA in combination with medialization laryngoplasty (ML) for improving voice quality. The subjects received a series of examinations for not only voice function but also swallowing function and cough strength both preoperatively and approximately 6 months after surgery. The evaluations of voice function included the Voice Handicap Index and aerodynamic measures; the evaluations of swallowing function included the Eating Assessment Tool-10, liquid aspiration, a videofluorographic examination of swallowing study, and high-resolution manometry; and the evaluation of cough strength included the measurement of cough peak flow. All measurements before and after surgery were statistically compared and examined.
Results: Considerable improvements in voice measures were observed after the procedure, as sufficient glottic closure was achieved during phonation and swallowing. In terms of swallowing evaluation, there were significant differences in the subjective assessment methods after the operation. Additionally, our intervention improved two cases of aspiration according to abnormal findings on the videofluorographic examination of swallowing. There was a significant difference in cough peak flow, with all participants having better values after surgery. High-resolution manometry revealed no significant differences between pre- and postsurgery in any parameters at the level of the mesopharynx or upper esophageal sphincter.
Conclusion: The findings of our study suggest an important effect on the dysphagia of UVFP patients who undergo AA combined with ML. In addition, we revealed improvements in swallowing by strengthening incomplete glottic closure; thus, we consider that sufficient glottic closure must play an important role in swallowing function in patients with UVFP.

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1. Introduction

Unilateral vocal fold paralysis (UVFP) results from damage to the recurrent laryngeal nerve or vagus nerve as a consequence of iatrogenic injury, malignant tumor, inflammation, cervical trauma, intubation, or idiopathic causes. Incomplete glottal closure caused by UVFP can lead to symptoms of breathiness, poor cough reflex, dysphagia and aspiration, which eventually impact quality of life (QoL). Impaired phonation with UVFP has been thoroughly studied, whereas the symptoms of dysphagia and aspiration have been less well investigated. Based on functional endoscopic evaluation of swallowing (FEES), Leder et al. reported an incidence of aspiration in UVFP of 40% (45 of 112 patients) [1]. In a total of 415 patients with UVFP, Schiedermayer et al. found a dysphagia prevalence of 55% according to symptoms and of 19% according to a videofluoroscopic examination of swallowing study (VFSS) or FEES [2]. A systemic review by Zhou et al. indicated that the prevalence of symptomatic dysphagia among patients with UVFP ranges from 55.6% to 69.0%, as assessed using self-reporting and clinical evaluation, whereas the aspiration rate by VFSS or FEES was 20.0% to 50.0% [3]. When considering “dysphagia”, it is necessary to be aware of whether it refers to a symptom, such as the patient’s complaint, or a sign, such as objective findings of abnormal swallowing. Notably, UVFP cases with a sensation of a change in swallowing are not necessarily evaluated as abnormal by objective examination. The reason for the wide range of aspiration rates in studies may be attributed to differences in the health status of the patient, underlying disease, etiology, severity of vocal fold paralysis, duration since onset, and the use of different evaluation methods.

Regarding mechanism of swallowing impairment in UVFP patients, glottal insufficiency is likely one of the main causes. However, patients with unilateral recurrent laryngeal nerve or vagus nerve damage not only exhibit ipsilateral vocal fold paralysis but also supraglottic and pharyngeal abnormalities that might cause aspiration, such as reduced laryngeal elevation, weak pharyngeal stripping waves, and pharyngeal retention [4–6]. According to Tabaee et al., the pathophysiology of dysphagia in patients with UVFP is multifactorial, with decreased sensation by FEES via sensory testing [7].

Several types of interventional options have been developed for the treatment of dysphonia with UVFP, including medialization laryngoplasty (ML), injection laryngoplasty (IL), arytenoid adduction (AA), and laryngeal reinnervation. Among these interventions, AA is an excellent technique that can medialize and close a large posterior glottic gap; it can also correct vocal fold height mismatches by adducting and rotating the arytenoid cartilage in UVFP [8–11]. To compensate for atrophy or bowing of the membranous portion, AA in combination with ML has been recently recommended by several surgeons [8–11]. Slavit et al. concluded that the AA procedure can correct a large posterior glottic gap and that AA combined with ML is an effective technique in patients with marked vocal cord bowing [9]. McCulloch et al. reported major improvements in multiple voice parameters in patients who underwent ML and ML-AA [10]. Mortensen et al. reported that AA is able to correct the physiology of an incompetent larynx better than ML alone [11]. We also reported excellent postoperative improvement in multidimensional phonatory parameters after AA combined with ML in UVFP patients [12]. Although these surgical procedures have been developed and performed to improve phonation, there are few detailed reports on the effects on swallowing function in patients with UVFP. Indeed, despite reports of swallowing function after surgical intervention, including IL or ML [13–16], there are few studies of changes in swallowing function after AA.

In this study, we aimed to evaluate the effect of AA on the swallowing functions of UVFP patients using multiple measures of phonation and swallowing and to investigate the important role of glottic closure during swallowing.

2. Materials and methods

2.1. Participants

This was a prospective observational study. Between February 1st, 2018, and September 30th, 2019, we prospectively recruited patients with UVFP who were referred to Tohoku University Hospital for complaints of severe dysphonia and were eligible for laryngeal framework surgery for improving voice quality. In each case, the diagnosis of UVFP and the side of paralysis were confirmed by transnasal flexible fiberscopy. All assessments were carried out by the same two ear, nose, and throat (ENT) surgeons and one speech and language therapist (SLT). Exclusion criteria were as follows: younger than 20 years old; pregnancy; a history of laryngeal surgery, vocal fold injection, vagus nerve palsy due to central lesions; or cardiac or respiratory failure. None of the patients underwent speech and swallowing rehabilitation by SLT at our hospital. Clinical data, including age, sex, etiologic factors, side of paralysis, duration since onset, swallowing function, voice function, and cough strength, were collected. Subjects received a series of all measurements, both preoperatively and at approximately 6 months after surgery.

2.2. Surgery

AA combined with ML was performed by a single surgeon. The technique was carried out using a previously published method [10,17] with some modifications as follows. The patient received total intravenous anesthesia without intubation [18]. First, the affected side of the sternohyoid muscle was cut, then the thyroid cartilage lamina was exposed. By using a small hook, the posterior edge of the thyroid cartilage was retracted and rotated anteriorly, while a part of the thyropharyngeal muscle was removed. After the muscular process of the arytenoid cartilage was exposed, nylon threads were sutured on the muscular process to perform AA. Neither the cricoarytenoid nor cricothyroid joint was released. Two threads were pulled toward the lateral cricoarytenoid muscle and fixed at the cricothyroid ligament. Next, a window for ML was created at the vocal fold level on the thyroid cartilage lamina. We preserved the inner perichondrium and retained the cartilage window. Gore-Tex® was fashioned into a single

7- to 8-mm-wide ribbon, pushed over the cartilage piece, and placed into the subperichondrial space beneath the window while assessing the patient's vocal quality during the operation.

2.3. Examination of voice function

2.3.1. The Voice Handicap Index (VHI)

The VHI is a 30–item self–administered questionnaire that was developed by Jacobson et al. to quantify a patient's perception of disability resulting from voice disorder [19]. A Japanese version of VHI [20] was used in our study, with the score ranging from 0 to 120.

2.3.2. Aerodynamic measures

Maximum Phonation Time (MPT), mean airflow rate (MFR) and subglottal pressure (SGP) were measured using Phonatory Analyzer PA–1000 (Minato Medical Science Co., Ltd., Osaka, Japan). Patients were instructed to phonate the vowel /a:/ at a comfortable pitch and loudness while keeping a mouthpiece around the lips and wearing a nose clip.

2.4. Examinations of swallowing function

2.4.1. The eating assessment tool-10 (EAT-10)

Subjective swallowing impairment was determined using the validated EAT-10, which was originally developed as an outcome measure by Belafsky et al. [21] to assess a patient's self-evaluation of being at risk for dysphagia. Items are scored on a 5-point scale (0 = no problem to 4 = severe problem), and item scores are summed to provide a total score ranging from 0 to 40. Belafsky et al. [21] first suggested that a score of 3 or more indicates that a patient is at risk of swallowing problems and requires further evaluation.

2.4.2. Liquid aspiration

Participants were simply asked subjectively if they had liquid aspiration in their daily diets.

2.4.3. Videofluorographic examination of swallowing study (VFSS)

To evaluate swallowing function objectively, VFSS was performed with UVFP patients in a sitting position to allow a lateral view using an oral intake of 3-mL liquid contrast medium. Each assessment was performed 3 times, with the worst score of the 3 measurements being used for analysis. The findings were rated using the PAS developed by Rosenbek et al. [22]. The ratings were performed by one SLT and one ENT surgeon, both of whom were experienced in the radiographic evaluation of swallowing disorders. In this study, we defined a PAS score of 6 or higher as abnormal.

2.4.4. High-resolution manometry (HRM)

HRM studies were performed with a 32-channel solid-state catheter system and circumferential sensors at 1-cm intervals (InSight G3, Sandhill Scientific Inc., CO, USA). Using HRM, we can measure rapidly changing pressures along the entire length of the pharynx. The results are shown as the pressure topography and pressure waveform (Fig. 1a, 1b). The areas of interest are from the mesopharynx and the upper esophageal sphincter (UES). Referring to previous reports [23–26], pressure variables were measured from three spatial regions: the velopharynx, the mesopharynx, and the UES. The velopharynx was defined as the region of swallow-related pressure change just proximal to the area of continuous nasal cavity quiescence extending approximately two centimeters. The UES region was defined as the point of stable high pressure just proximal to the baseline low esophageal pressure zone [24]. The mesopharynx was defined as the area of swallow-related pressure change with a high-pressure zone identified approximately midway between the velopharynx and the UES. The velopharynx, where the soft palate and associated lateral and posterior pharyngeal wall contraction protect the nasal airway from regurgitation of bolus material [27], is not innervated by the recurrent laryngeal nerve. We excluded evaluation of the velopharynx in our study because the effect on velopharyngeal kinematics by UVFP is considered to be minimal.

Participants underwent transnasal placement of the manometric catheter in a natural supine position. Topical 2% viscous lidocaine hydrochloride was applied with a cotton-tipped applicator to the nose and the tip of the catheter to ease insertion, and the catheter was passed through the nose, the pharynx, and into the upper esophagus and fixed in place by taping it at the nostril. Once the catheter was positioned within the pharynx, the participants sat quietly for at least 10 minutes to adjust to the catheter prior to performing the swallowing tasks. The participants were asked to drink a 5-ml water bolus. Each bolus was delivered to the oral cavity via a syringe, and 5 swallows were analyzed for each participant.

Data were extracted using BioVIEW ANALYSIS software (Sandhill Scientific, Version 5.6.1.0). The maximum value of the swallowing pressure in any arbitrarily selected area is shown in millimeters, and it is the index that reflects pharyngeal contractility. Duration in the mesopharynx, which reflects the transit time of the bolus, was defined as the length of time pressure that was positive relative to baseline pressure in the region (Fig. 1c). The maximum pressure was the highest pressure recorded in that region; the minimum pressure was the lowest pressure recorded in that region. UES resting pressure was defined as the maximal pressure occurring during the normal respiratory cycle or nonswallowing phase. The time lapse between these pressure peaks is termed the UES opening time (Fig. 1d).

2.5. Examination of cough strength

To assess cough power objectively, cough peak flow (CPF) was measured using the Mini–Wright peak flow meter (Clement Clarke International Ltd, Harlow, UK) and a face mask. Although pneumotachograph-based CPF measurements are considered the gold standard, a study comparing them with those obtained with a portable peak flow meter showed no significant differences among 30 healthy subjects and 32 patients with neuromuscular diseases [28]. Here, the participant was asked to sit on a chair while wearing a face mask

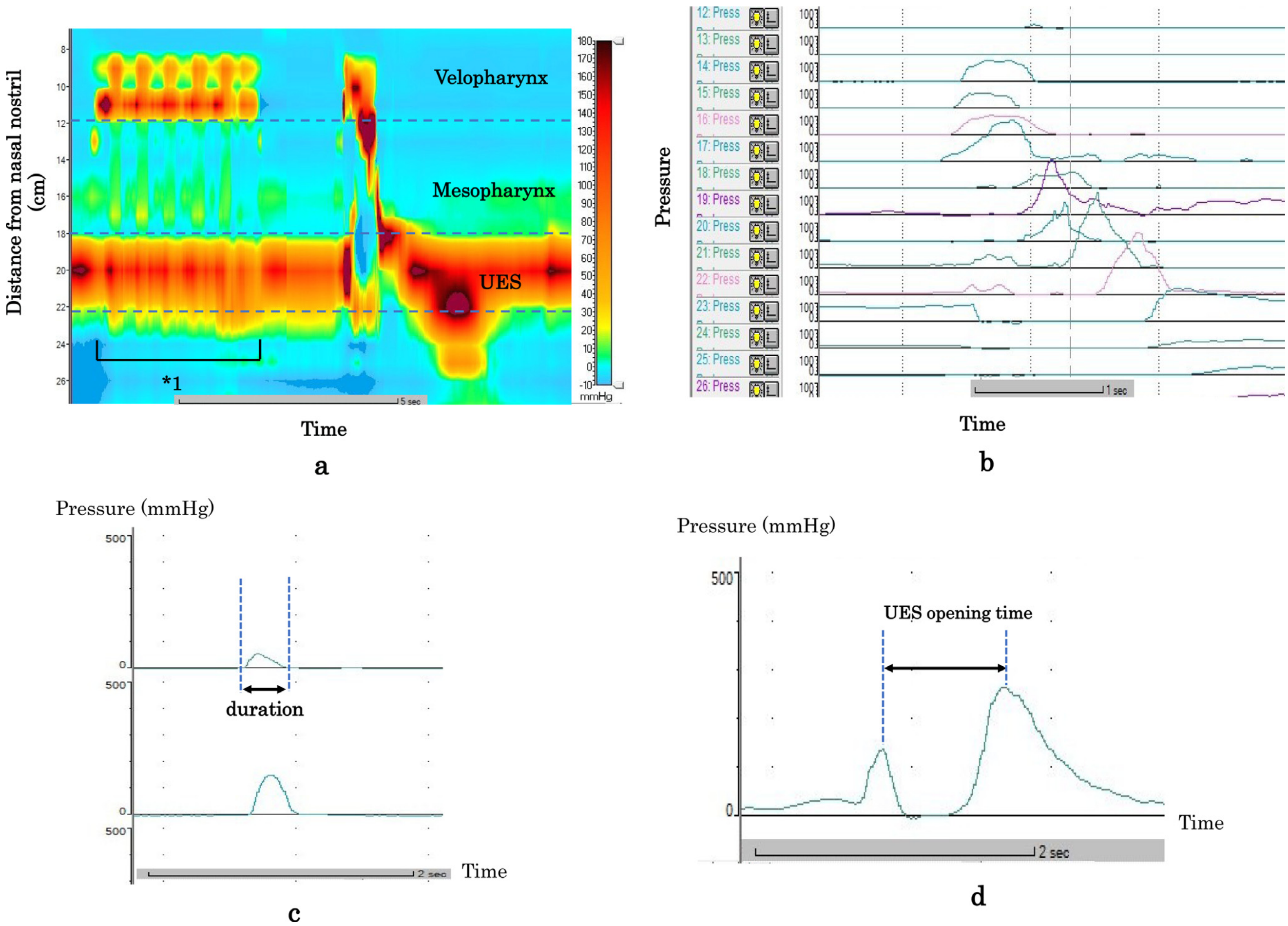

Fig. 1. Data from High-Resolution Manometry (HRM) a: Pressure topography. HRM shows swallowing pressure activity from the velopharynx to the upper esophagus in the spatiotemporal plot. The X-axis indicates time (black bar indicates 5 sec), and the Y-axis indicated the distance from the nasal nostril. Each pressure is assigned a color (legend right). *1 vocalizing “kakaka” b: Pressure waveform. If an examiner chooses any place from the Y-axis (distance from the anterior nostril) on the pressure topography, the pressure waveform of that place will be displayed. We can evaluate swallowing pressure at each point. The X-axis indicates time, and the Y-axis indicates the pressure of each waveform. c: Duration in the mesopharynx. Duration was defined as the length of time pressure being positive relative to baseline pressure in the region. d: UES opening time. The time lapse between these pressure peaks in the UES area is termed the UES opening time
UES; upper esophageal sphincter

attached to a spirometer to prevent leakage from the mouth and nose, as previously described by Dion et al. [29]. The subject was instructed to breathe out, breathe deeply, and then cough voluntarily with their maximum strength. The highest value from each of the three trials was used for analysis.

Approval for this study was obtained from the ethical review board of Tohoku University Graduate School of Medicine (2017-1-990). Written informed consent was given by all participants.

2.6. Statistical analysis

We used the Wilcoxon signed rank test to compare all continuous variables for examining differences in pre- and postoperative findings. We employed Fisher’s exact test to compare the proportions of categorical variables (such as the presence of liquid aspiration and EAT-10 $\geq$3) between preoperative and postoperative findings. A statistical software package (SPSS Statistics 21.0 for Windows) was used for these analyses. All tests were two−tailed, with differences considered significant at P <0.05.

3. Results

3.1. Clinical characteristics of UVFP patients

Fourteen patients with UVFP underwent laryngeal framework surgery such as AA combined with ML. As 1 patient did not consent to participate in this study, thirteen patients were ultimately included. Continuous variables are summarized as the median values and the interquartile range (defined as the difference between the 25th and 75th percentiles). All participants had a normal diet and no history of aspiration pneumonia.

The clinical characteristics of the patients with UVFP are shown in Table 1. There were 5 females and 8 males, with a median age of 69.0. UVFP was on the left side in 11 patients (84.6%) and on the right side in 2 (15.4%). With respect to the cause of UVFP, surgery for thoracic aortic aneurysm ac-

Table 1. Demographic and clinical characteristics of patients with UVFP (n=13).

Demographic	n (%)
Sex	
Male	8 (61.5)
Female	5 (38.5)
Side of UVFP	
Left	11 (84.6)
Right	2 (15.4)
Disease duration	
<180 days	1 (7.7)
≥180, <365 days	6 (46.2)
≥365 days	6 (46.2)
Etiology of UVFP	
Surgery for thoracic aortic aneurysm	7 (53.8)
Thyroid surgery	4 (30.8)
Radiation therapy for lung cancer	1 (7.7)
Intubation	1 (7.7)

UVFP, unilateral vocal fold paralysis

counted for 7 (53.8%) cases, thyroid surgery for 4 (30.8%), radiation therapy for lung cancer for 1 (7.7%), and intubation for 1 (7.7%). The period from onset of UVFP to evaluation was more than half a year for all but one patient. There was no possibility of recovery in this case because the patient underwent recurrent nerve resection during thyroid cancer surgery; the evaluation time point of this case was 117 days after onset.

3.2. Comparison of voice, swallowing, and cough strength data before and after surgery

The results of voice, swallowing, and cough strength measurements before and after the operation are provided in Table 2. Thirteen patients underwent preoperative examination, but one with a history of esophageal surgery refused to undergo VF and HRM. After the framework surgery, one patient rejected postoperative examination, and another patient could not be examined due to rehabilitation after reoperation for a thoracic aortic aneurysm. Although 11 patients underwent postoperative examination, two of them were unable to perform HRM. Thus, all postoperative data reported were collected from 9 cases.

In terms of voice evaluation, there were significant differences with regard to VHI, MFR and MPT before and after the operation. Subglottic pressure before surgery could not be measured in all cases, but all participants were in the normal range after the surgery.

Regarding swallowing evaluation, there was a significant difference in EAT-10 score before and after the operation: median value of EAT-10 decreased from 14.0 before the operation to 0 after, and the rate of abnormal EAT-10 scores (≥3) decreased from 92.3% to 45.4%. Moreover, the rate of “liquid aspiration (+)” significantly decreased from 69.2% to 9.1%. There was no significant difference before and after the operation in the rate of abnormal PAS values by VFSS. However, for two cases of aspiration, with a PAS score of 6 or higher, improvement after the operation was noted: one decreased from 7 to 4, and the other decreased from 6 to 1.

In terms of voluntary cough strength, there was a significant difference in CPF before and after the operation. All participants had improved CPF values, with the median CPF value increasing from 260.0 before the operation to 360.0 after the operation.

HRM data are shown in Table 3. There were no significant differences before and after surgery in any manometric parameters at the level of the mesopharynx and the UES.

4. Discussion

We must acknowledge that dysphagia commonly occurs in UVFP patients and that it can lead to serious morbidities, such as aspiration pneumonia. In this study, the patients with UVFP showed excellent improvements of all voice-related measures, including VHI, MFR, MPT, and subglottic pressure, after surgical intervention. For aerodynamic measures, the average value of MPT was above 10 s and that of MFR was below 200 ml/sec, approximating those of a nonimpaired person. This result has an important significance, in that sufficient glottic closure was substantially achieved during phonation in UVFP patients. Therefore, the effect of improved glottal competence might be reflected not only during phonation but also during swallowing, which involves a more complicated function.

In patients with UVFP who underwent AA combined with ML, the aspiration rate according to the VFSS was decreased; however, there were no significant differences before and after surgery. Nevertheless, all of the subjects actually exhibited similar or improved results relative to the preoperative PAS. Several authors have reported slightly higher aspiration rates of 38% [30], 20% [31], and 36% [32] than the 16.7% in our study. These differences may be attributed to swallowing compensation occurring between the time of identification of vocal fold immobility and the swallowing evaluation [33] because the subjects in this study were in a “stable condition”, as more than 6 months had passed since UVFP onset in 91.7%. After the surgical intervention, no subjects presented with aspiration, and the average value of the PAS also decreased from 2.4 to 1.6; thus, all subjects were cleared to safely take an oral diet.

Cough involves both respiratory and laryngeal mechanisms and effectively removes aspirated materials from the airway. Reduced cough strength is reported to be indicative of an increased risk of aspiration pneumonia in patients with Parkinson’s disease [34] or acute stroke [35]. A cough is created when inspired air is compressed by a closed glottis, thereby raising intrathoracic pressure, and is quickly released. Patients with UVFP have difficulty raising intrathoracic pressure, leading to decreased cough strength, which is commonly evaluated with measurement of the CPF. Few reports have obtained CPF measurements in UVFP patients; among them, investigation of the effect of office-based IL [29,36] revealed improvement in cough strength after the intervention, mentioning the possibility of restoring airway protection. We demonstrated that the CPF value in patients with UVFP was significantly improved after surgery. The improved CPF value of the subjects was comparable to that of normal healthy people who

Table 2. Differences in voice, swallowing and cough strength before and after surgery.

	Before (n=13)	After (n=11)	P value
VHI	57.0 [48.0, 74.0]	7.0 [4.0, 17.5]	<0.05 *1
MFR (ml/sec)	583.0 [493.0, 924.0]	199.0 [149.0, 257.0]	<0.05 *1
Subglottic pressure (mmH_2O)	N/A	6.9 [5.4, 7.8]	
MPT (sec)	3.5 [2.9, 3.6]	14.3 [11.4, 15.0]	<0.05 *1
EAT-10	14.0 [9.0, 15.0]	0.0 [0.0, 9.0]	<0.05 *1
EAT-10 (≥3)	12 (92.3%)	5 (45.4%)	<0.05 *2
Liquid aspiration (+)	9 (69.2%)	1 (9.1%)	<0.05 *2
PAS (≥6)	2 (16.7%)	0 (0%)	0.48 *2
CPF (L/min)	260.0 [240.0, 320.0]	360.0 [275.0, 390.0]	<0.05 *1

VHI, Voice Handicap Index; MFR, mean flow rate; MPT, maximum phonation time; EAT-10, Eating Assessment Tool 10; PAS, penetration-aspiration scale; CPF, cough peak flow; N/A, not available

*1 Wilcoxon signed-rank test *2 Fisher's exact test

Table 3. HRM data before and after surgery.

	Before (n=9)	After (n=9)	P value	
Mesopharynx				
Maximum pressure (mmHg)	368.3 [271.7, 505.6]	375.5 [291.5, 660.9]	0.17	*1
Duration (sec)	0.44 [0.35, 0.50]	0.40 [0.33, 0.47]	0.44	*1
UES				
Maximum pressure (mmHg)	402.7 [287.9, 456.6]	511.1 [365.8, 628.2]	0.14	*1
Minimum pressure (mmHg)	-11.0 [-14.8, -8.3]	-7.5 [-10.8, -2.3]	0.17	*1
Resting pressure (mmHg)	75.2 [65.5, 98.8]	68.3 [58.1, 93.7]	0.31	*1
Opening time (sec)	1.02 [0.92, 1.26]	0.94 [0.92, 1.09]	0.19	*1

HRM, high-resolution manometry; UES, upper esophageal sphincter

*1 Wilcoxon signed-rank test

participated in our previous study [37], though without considering age or sex. Although cough strength is an important factor related to aspiration pneumonia, our previous report found no correlation between CPF and dysphagia parameters, including the EAT-10 and PAS, in UVFP patients [37]. Hence, cough strength is not considered to be an essential factor for improving swallowing function, though improvement in effective airway clearance may decrease aspiration risk via expulsion of material from the airway or may help to alleviate throat discomfort in UVFP patients.

HRM is an emerging technique to measure pharyngeal and UES pressures during swallowing. We expected that changes in measured pressure before and after the intervention would help to define the nature of dysphagia in UVFP patients. To date, there have been a few reports about using HRM to evaluate measured pressures in patients with UVFP. Pinna et al. examined patients with vagal paralysis and showed that dysphagia was related to decreased pharyngeal pressure but that aspiration was related to decreased UES pressure [38]. In a comparative study between UVFP and healthy controls, Erdur et al. also demonstrated that UES basal and relaxation pressures were significantly lower and that pharyngeal pressure was significantly higher in UVFP groups than in control groups [39]. In light of the vagus nerve branches, the pharyngeal nerve innervates the pharyngeal muscles, and the superior laryngeal nerve promotes laryngeal sensitivity, which regulates the pressure wave required to propel a bolus and the protective mechanism of the larynx; additionally, the recurrent laryngeal nerve supplies intrinsic laryngeal muscles and the muscle of UES [38,40]. Dysphagia in UVFP patients presents with a wide range of severities, probably according to the level of neurologic injury, that is, the central lesion, proximal vagus nerve, or recurrent laryngeal nerve. In general, injury to the vagus nerve proximal to the branching point of the superior laryngeal nerve is known as high vagal paralysis, which results in more severe dysphagia because of loss of sensation and motion impairment. Changes in measured pressure of HRM after intervention, such as IL [25] or ML [41], have been reported, demonstrating significant increases in the mesopharynx maximum pressure but no change in UES parameters. In our study, there were no significant differences in any parameters of HRM. The value of the mesopharynx maximum pressure was higher after surgery but not significantly. We consider that our surgical intervention to strengthen incomplete glottic closure might raise pharyngeal maximum pressure by improving subglottic pressure [41,42]. On the other hand, our operative procedure may have caused some damage to the thyropharyngeal muscle, which was involved in the production of pharyngeal pressure. These opposite interactions regarding pharyngeal pressure production may have resulted in no significant change after the surgery. Additionally, since our study did not include any patients with high vagal paralysis, factors other than glottis insufficiency may have little effect on the production of pharyngeal pressure, unlike other reports [38,39].

It is common understanding that UVFP results in diminished airway protection; in fact, some individuals may aspirate material into the airway, which may result in aspiration pneumonia [32], but the precise pathophysiology of swallowing dysfunction in patients with UVFP remains uncertain. In addition to incomplete glottic closure, some authors consider poor pharyngeal movement [32,43] or decreased sensation [7] to be contributing factors to dysphagia in UVFP. Furthermore, Leder et al. stated that because of supraglottic laryngeal and pharyngeal dysfunction, UVFP may not be the single or even the most important factor contributing to dysphagia and aspiration [1]. In addition, Bhattacharyya et al. concluded that factors other than glottal incompetence, including pharyngeal bolus transport, are important for determining an effective swallow in patients with UVFP [44]. In the present study, although subjective examination of dysphagia, such as EAT-10 and liquid aspiration, in patients with UVFP indicated significant improvement, 45% of the subjects were still aware of abnormal swallowing after surgical intervention. However, all of them presented PAS values of 4 or less without aspiration and were able to consume a normal diet every day. We consider that factors other than glottic insufficiency must have influenced these discrepancies.

There have been several studies about the effect of strengthening incomplete glottic closure on swallowing function with UVFP through surgical intervention. From the result of significant improvement in the EAT-10 after IL and ML intervention, some authors have reported the effect of vocal fold medialization on dysphagia in patients with UVFP [14–16]. Nonetheless, despite significant differences before and after the intervention, postoperative mean values of the EAT-10 remained high at 4.2 [14], 3.9 [15], and 7.7 [16]. On the other hand, Nayak et al. reported that even after surgical intervention, including IL or ML, 44.8% and 23.9% of patients with UVFP show penetration and aspiration by VFSS, respectively. These authors concluded that as vocal fold medialization, such intervention may not be effective in improving swallowing and decreasing aspiration in UVFP patients [13]. Additionally, a few studies have compared the impact of IL to that of ML on swallowing, but no significant differences in improvement of swallowing between patients who underwent IL versus ML were found [13,44]. We consider that AA in combination with ML is the most effective technique that can medialize and close the glottis gap physiologically. Hoffman evaluated the effect of IL, ML, and ML combined with AA on phonatory measures in excised canine larynges and concluded that ML-AA resulted in the greatest improvement in phonatory parameters, including phonation threshold flow, phonation threshold pressure, phonation threshold power, mucosal wave amplitude, and signal-to-noise ratio [45]. It is expected to have a permanent stable effect on postoperative glottic closure that results in significant improvement of swallow function and not only phonation in UVFP patients. This is the first report about the impact of AA on swallowing function in UVFP patients in detail. The findings of our study suggest a great benefit for dysphagia in UVFP, both subjectively and objectively. Furthermore, we noted that an improved incomplete glottic closure in patients with UVFP resulted in the prevention of aspiration. Swallowing becomes more efficient when the subglottic pressure recovers close to normal [46]. We consider that sufficient glottic closure must play an important role in normal swallowing function.

The limitations of this study include the small sample size and possible selection bias. Because the subjects had no serious underlying diseases and no etiology of central or high vagal lesions, it is possible that swallowing function was relatively maintained despite severe dysphonia. Second, framework surgery may cause some damage to swallowing-related muscles, which might affect movement of the larynx. However, based on the results of postoperative swallowing function in UVFP patients in this study, it can be interpreted that the positive effect of achieving glottic closure sufficiently outweighs the negative effect.

5. Conclusion

Swallowing function of patients with UVFP who underwent AA combined with ML improved markedly, indicating the effect of this surgical technique. This study highlights the important role of glottic closure by strengthening the incomplete glottis in UVFP patients, which should decrease the risk of aspiration and improve swallowing function. It is emphasized that appropriate therapeutic intervention would increase the QoL of patients with UVFP.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest to report.

Author contributions

KW, KK: conception and design, acquisition of data, analysis and interpretation of data, drafting the article, final approval of the version to the published.

TS, TM: acquisition of data, analysis and interpretation of data, final approval of the version to the published.

SF, KY: conception and design, review for intellectual content, final approval of the version to the published.

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