Compensatory Movement of Contralateral Vocal Folds in Patients With Unilateral Vocal Fold Paralysis

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Summary: Objectives. Previous studies of subjects with unilateral vocal fold paralysis (UVFP) as observed in a positron emission tomography-computed tomography (PET-CT) examination have demonstrated false positive results in the contralateral cricoarytenoid, in which the metabolism may be higher. This area may also be the site of contralateral compensatory movement in these patients. In this study, we compared the adduction speed of the contralateral vocal folds in patients with UVFP and in healthy subjects as measured by the stroboscopic laryngoscope frame rate. This study aimed to explore the contralateral compensatory movement of the vocal folds in subjects with UVFP.

Methods. (1) We collected visual data from 14 patients with UVFP and 14 healthy subjects through a stroboscopic laryngoscope. These subjects were divided into a vocal fold paralysis group and a control group, and we analyzed the excessive adduction of the contralateral vocal folds in the vocal fold paralysis group by examining vocal fold movement speed (pixels/s) as featured in a stroboscopic laryngoscope video. (2) We analyzed the uptake of 18-FDG in the posterior vocal fold from positron emission tomography-computed tomography imaging from four subjects with UVFP and 12 healthy subjects. An independent sample *t* test and a χ^2 test were used to compare data.

Results. Four subjects with UVFP had a higher metabolic rate in the contralateral cricoarytenoid joints, with a significant difference between the two groups, $P < 0.05$. Fifty percent of the cases of contralateral adduction of the vocal folds in the subjects with UVFP adducted past the midline, with a significant difference between the two groups, $P < 0.05$. The contralateral adduction of the vocal folds in subjects with UVFP had shorter video frames and higher adduction speed than the control group, and the difference was statistically significant, $P < 0.05$. There were fewer vocal fold abduction video frames and higher abduction speed of the healthy side of the vocal fold in subjects with UVFP than the control group, but there was no statistically significant difference, $P > 0.05$.

Conclusion. Subjects with UVFP exhibited faster adduction compensation in the contralateral vocal folds, and the contralateral cricoarytenoid joint's metabolism in subjects with UVFP was higher. These data may help clarify the diagnostic criteria for laryngeal nerve damage.

Key Words: Vocal fold−Vocal fold paralysis−Vocal fold compensatory movement−PET CT−Vocal fold movement.

INTRODUCTION

Unilateral vocal fold paralysis (UVFP) is often caused by injury to the vagus or recurrent laryngeal nerves (RLN). The clinical presentations include vocal fold dyskinesia, which often presents as glottic insufficiency, coughing, dysphonia, stridor, and shortening of the maximum phonation time.[1,2] Patients with UVFP may demonstrate compensatory hyperfunction, causing tightening of the neck muscles, compression of the glottis, and excessive compensatory movement of the contralateral vocal fold.[3] The contralateral vocal fold in patients with UVFP often appears to pass midline to reduce vocal fold insufficiency, improving vocal fold function.[4]

The contralateral vocal fold and the cricoarytenoid articulation in patients with UVFP often show false positive results in positron emission tomography-computed tomography (PET-CT) scans. Michael et al found that 15 subjects with false-positive results had UVFP.[5] Lu et al found that metabolism at the contralateral cricoarytenoid articulation was significantly increased in patients with UVFP, which may be due to excessive movement of the contralateral vocal fold.[6]

Therefore, we hypothesize that the contralateral vocal folds in patients with UVFP move with greater speed than in healthy subjects. To test this hypothesis, we compared the number of videostroboscopic frames of adduction and abduction of the contralateral vocal folds in subjects with UVFP and in healthy subjects to examine the compensatory movement of the contralateral vocal folds.

METHODS

Study subjects

Fourteen subjects with UVFP and 14 healthy individuals were recruited. All subjects signed an informed consent form and volunteered to participate in this study. This study was reviewed and approved by the institutional review

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board at the Xiamen University Zhongshan hospital. To protect patient privacy, patients' data were assigned unique identifiers. All subjects were protected and named the body with number for research. The mean age was 43.28 ± 13.68 years. Time since onset was 7.03 ± 6.05 months. Data from PET-CT scans conducted for reasons not related to the study was collected for four of the subjects with UVFP (three right vocal fold paralysis, one left vocal fold paralysis) (Table 1).

The inclusion criteria for the subjects with unilateral vocal fold paralysis were dysphonia, stridor, a paramedian or paraintermedian fixed unilateral vocal fold on stroboscopic laryngoscopic examination, and visible bilateral vocal processes. They were also diagnosed by laryngeal electromyography, the patients' RLN were paralytic and the external branch of the superior laryngeal nerve was normal.

The inclusion criteria for the healthy subjects were healthy adults with no dysphonia, no organic vocal fold lesions on stroboscopic laryngoscopic examination with comfortable phonation and high frequency phonation, normal vocal fold movements, and no compression of the glottis. For vocal fold movement speed comparisons, the UVFP subjects were matched for age and sex with healthy subjects at a ratio of one to one. For PET-CT image comparisons, the UVFP were matched for age and sex with healthy subjects for age and sex at a ratio of one to three.

Experimental methods

Assessment of the metabolic status of the contralateral vocal fold: We analyzed PET-CT images of four subjects with UVFP (three on the right vocal fold and one on the left vocal fold) and evaluated 18F-FDG uptake in the contralateral vocal fold.

Assessment of excessive vocal fold adduction: The contralateral vocal process of subjects with UVFP was considered to adduct excessively if it passed the midline (the line at the midpoint between the anterior commissure and the posterior median cricoid cartilage) (Figure 1).

Vocal fold movement speed was determined using vocal fold movement pixels and adduction time. Vocal fold movement pixels were calculated by measuring the distance in pixels between maximum abduction and maximum adduction (Figure 2). Adduction time was computed by counting the number of video frames per vocal fold adduction divided by a video frame rate, of 50 frames per second. Video segments with stable vocal fold adduction and abduction were selected, and videos in which nausea, coughing, and throat clearing occurred before adduction and abduction were excluded (Figure 3). For normal subjects, video segments with comfortable phonation and high-frequency phonation were selected respectively. We measured these parameters 3 times and took the average for analysis.

Statistical methods: SPSS software was used for statistical analysis. An independent sample t test and χ^2 test were used to compare the differences between the UVFP group and the healthy group.

RESULTS

1. The contralateral vocal folds of all four subjects with UVFP imaged with PET-CT scan showed greater 18F-FDG uptake (Figure 4). PET-CT software automatically calculated 18F-FDG uptake at a selected point in the posterior vocal fold. The contralateral vocal folds of these subjects (three with right vocal fold paralysis and one with left vocal fold paralysis) showed higher metabolism than the paralyzed vocal folds. As shown in Table 2, there was a significant difference between the two groups, $P < 0.05$, and between the normal group vocal fold and the paralyzed side in patients with UVFP.
2. In the UVFP group, there were seven subjects (50%) that had contralateral vocal fold adduction past the midline, with a significant difference between the two groups, $P < 0.05$ (Table 3).
3. Comparison of the number of frames of vocal fold adduction and abduction and movement speed:

The number of contralateral vocal fold adduction frames in subjects from the vocal fold paralysis group was significantly lower than the healthy group at a comfortable frequency, and this difference was statistically significant, $P < 0.05$ (Table 3). The contralateral adduction of the vocal folds in subjects with vocal fold paralysis had a significantly higher velocity than the healthy group at a comfortable frequency, $P < 0.01$, but the number of abduction frames and abduction speed did not indicate a difference between these two groups. There were fewer vocal fold abduction video frames of the healthy side of the vocal fold in subjects with UVFP than the control group, but there was no statistically significant difference, $P > 0.05$ (Table 4). The contralateral adduction speed of the vocal folds in subjects with vocal fold paralysis had a significantly higher velocity than the healthy group with high frequency, $P < 0.01$, however, other parameters did not show the significant difference between the vocal fold paralysis group and healthy group, $P > 0.05$ (Table 5).

DISCUSSION

Following nerve damage which impairs vocal fold function, compensatory function in the glottis protects the lower respiratory tract, and the resulting excessive contraction of the suprahyoid muscles causes laryngeal elevation, anteroposterior compression of the epiglottis and fissure,[7,8] and excessive vocal fold adduction. Coughing is usually present in the early stages of unilateral vocal fold paralysis, which may be caused by incomplete vocal fold closure. After a period of compensation, coughing generally decreases or ceases.

The results of this study showed that the contralateral vocal folds in subjects with unilateral vocal fold paralysis exhibit faster adduction. This may be beneficial for both the protection of the lower respiratory tract and phonation.

TABLE 1.
UVFP Subject Demographics

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Subject #	Sex	Age (years)	Duration (months)	Paralyzed vocal fold	CT	TA	PCA	Etiology	PET-CT
1	Male	53	9	Right	Normal	Giant potentials	Giant potentials	After lung cancer surgery	Yes
2	Male	42	24	Right	Normal	Giant potentials	Normal	After esophageal cancer surgery	Yes
3	Male	65	6	Right	Normal	Giant potentials	Normal	Idiopathic	Yes
4	Male	62	1	Left	Normal	Positive sharp waves 1+	Positive sharp waves 1+	Esophageal cancer	Yes
5	Male	59	9	Left	Normal	Normal	Giant potentials	After thyroid carcinoma surgery	No
6	Male	38	4.5	Left	Normal	Fibrillation potentials 1+, Giant potentials	Giant potentials	After thyroid carcinoma surgery	No
7	Female	23	1	Right	Normal	Positive sharp waves 2+	Positive sharp waves 2+	After thyroid carcinoma surgery	No
8	Female	35	2	Right	Normal	Positive sharp waves 1+, Giant potentials	Normal	After thyroid carcinoma surgery	No
9	Female	26	3.5	Left	Normal	Polyphasic potentials	Polyphasic potentials	After thyroid carcinoma surgery	No
10	Female	29	2.5	Right	Normal	Positive sharp waves 1+	Positive sharp waves 1+	After thyroid carcinoma surgery	No
11	Female	32	4	Left	Normal	Positive sharp waves 1+, Giant potentials	Normal	Idiopathic	No
12	Female	49	5	Right	Normal	Giant potentials	Giant potentials	After thyroid carcinoma surgery	No
13	Female	58	9	Left	Normal	Giant potentials	Giant potentials	After thyroid carcinoma surgery	No
14	Female	35	12	Right	Normal	Normal	Giant potentials	After thyroid carcinoma surgery	No

Abbreviations: LEMG, laryngeal electromyography; CT, cricothyroid muscle; TA, thyroarytenoid muscle; PCA, posterior cricoarytenoid muscle.

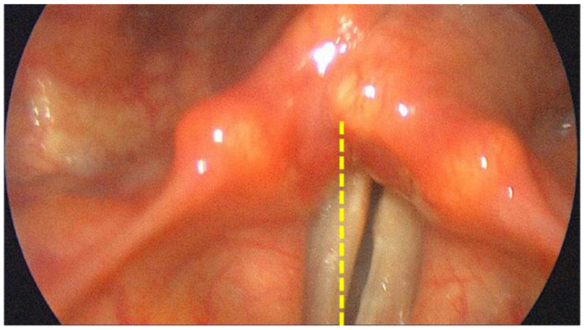

FIGURE 1. Excessively adducted vocal fold (the yellow dotted line was the normal line from the posterior commissure to the anterior commissure, the left vocal vocal fold was fixed in the paramedian position, the right vocal fold adducted excessively). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

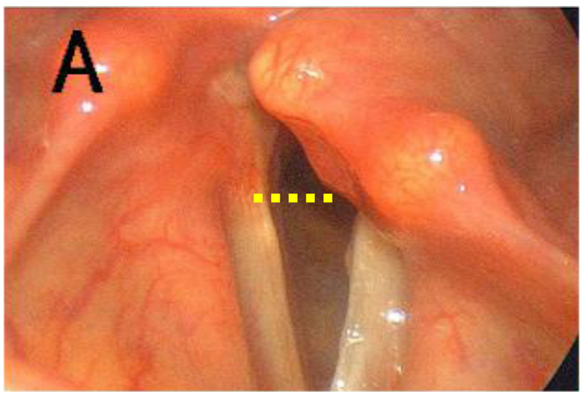

FIGURE 2. Vocal fold movement pixels measurement (the yellow dotted line was the distance between maximum abduction and maximum adduction measured by pixels). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

On the other hand, there was no statistically significant difference in abduction between the contralateral vocal folds in subjects with unilateral vocal fold paralysis and the healthy subjects. This may be because the velocity of abduction is sufficient to support breathing and phonation.

Patients with vocal fold paralysis often have a high habitual frequency because of heavy contraction of the cricothyroid muscle for the compensatory balance of the vocal fold movement to the midline.[9] Dailey and Mckenna reported that vocal fold movement for phonation at a high frequency was faster than at a low frequency.[10,11] We also compared the vocal fold paralysis group and healthy subjects with high-frequency phonation; it showed that the contralateral adduction speed of the vocal folds in subjects with vocal fold paralysis still had a significantly higher velocity than the healthy group with high frequency. So, we speculate that increased adduction speed may be because of compensatory contraction of the cricothyroid muscle. Further, the location of the increased activity suggests inflammation in the cricoarytenoid joint, or perhaps increased activity in the lateral cricoarytenoid muscle. Higher resolution scanning could clarify the precise location. Further, since some patients with unilateral vocal fold paralysis use a falsetto register as a compensatory strategy, additional research may also be needed to control for frequency.

Additionally, 50% of subjects with UVFP have excessive vocal fold adduction in this study, which is nearly the same outcome that Tanaka reported that contralateral vocal fold had passed midline in 42.5% patients with unilateral vocal fold paralysis.[12] This may be because the vocal folds of some subjects with vocal fold paralysis are fixed in a paramedian or paraintermedian position and there is no need for the vocal fold to adduct to the opposite side.

Many studies have shown that PET-CT scans have a high false positive rate for metabolism in the contralateral vocal folds in subjects with unilateral vocal fold paralysis.[5,6,13–15]

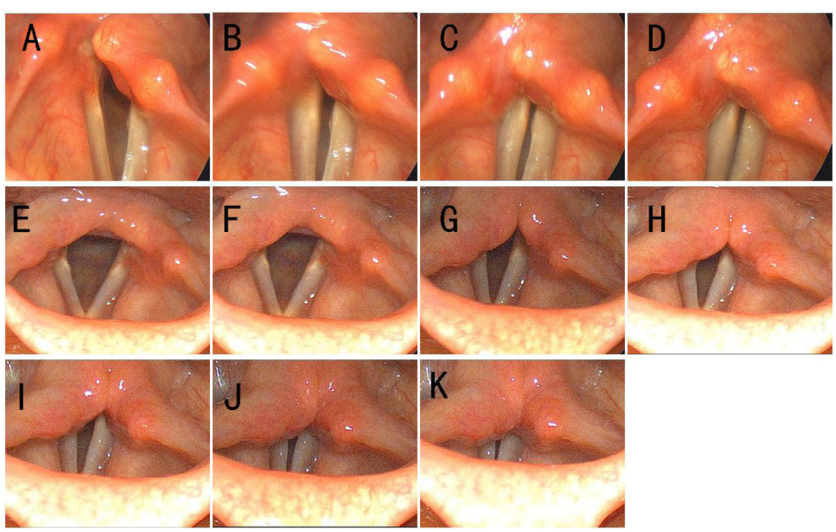

FIGURE 3. Frames A, B, C, and D show right vocal fold adduction in a patient with left vocal fold paralysis. Frames E, F, G, H, I, J, and K show vocal fold adduction in a healthy subject.

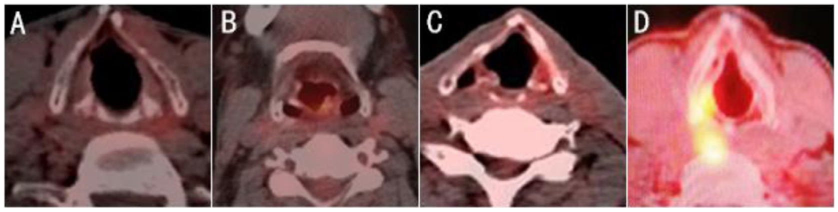

FIGURE 4. PET CT images from four subjects with UVFP (A, B, C were images from subjects with right vocal fold paralysis, D was from a subjects with left vocal fold paralysis).

TABLE 2.
18F-FDG Uptake in Healthy and UVFP Subjects

Group	Number of subjects	18F-FDG uptake normal side	18F-FDG uptake paralysis side	*t*	*P*
UVFP	4	2.76 ± 0.52	1.23 ± 0.31	2.76	0.035
Control	12	1.35 ± 1.20	1.35 ± 1.20		
t		3.15	0.265		
P		0.026	0.793		

TABLE 3.
Comparison of Subjects by Excessive Adduction

Group	Excessive adduction	No excessive adduction	Total
UVFP (n = 14)	7	7	14
Control (n = 14)	0	14	14
Total	7	21	28
χ^2	9.039		
P	0.003		

Vachha et al observed higher metabolism in the contralateral vocal folds in subjects with unilateral vocal fold paralysis through PET-CT scans.[16] Heller et al showed that higher FDG metabolism is present in the contralateral vocal folds of vocal fold paralysis subjects.[13] In PET-CT scans, increased FDG tissue uptake is closely associated with the level of metabolism in tissues and is valuable in distinguishing between malignant and benign tumors. However, PET-CT scans are also affected by tissue inflammation or excessive movement in the examined site, resulting in false positives. In this study, four subjects underwent PET-CT scans, and the results showed higher metabolism in the contralateral vocal folds and cricoarytenoid articulations, which is similar to the effects found in previous studies. These results indicate that faster or excessive movement may have been present in the contralateral vocal folds.

Studies have shown that after RLN resection, fibrinolytic changes and decreases in succinate dehydrogenase activity occur in the ipsilateral thyroarytenoid muscle fibers, while muscle fiber thickening and increased succinate dehydrogenase activity occur at the contralateral thyroarytenoid muscles.[17,18] Muscle fiber thickening is an indication of increased activation, while succinate dehydrogenase is an important enzyme for kinetic tissue metabolism which may improve vocal fold movement. Hence, the contralateral side may play some compensatory role in laryngeal function.

The 70° rigid laryngoscope used in this study may have affected the normal phonation of subjects as compared to a

TABLE 4.
Comparison of Means of Adduction and Abduction Movement Between UVFP Group and Control Group at a Comfortable Frequency

Group	Frames per adduction ± SE	Adduction speed (pixels/s) ± SE	Frames per abduction ± SE	Abduction speed (pixels/s) ± SE
UVFP (n = 14)	4.5 ± 1.02	2906 ± 1075	8.57 ± 3.41	1713 ± 899
Control at comfortable frequency (n = 14)	7.07 ± 2.53	744 ± 1323	8.21 ± 3.7	1264 ± 713
t	3.53	3.52	0.26	0.29
P	0.002	0.000	0.79	0.15

TABLE 5.
Comparison of Means of Adduction and Abduction Movement Between UVFP Group and Control Group at High Frequency

Group	Frames per adduction ± SE	Adduction speed (pixels/s) ± SE	Frames per abduction ± SE	Abduction speed (pixels/s) ± SE
UVFP (n = 14)	4.5 ± 1.02	2906 ± 1075	8.57 ± 3.41	1713 ± 899
Control at high frequency (n = 14)	5.64 ± 2.17	1658 ± 700	7.57 ± 3.41	1366 ± 772
t	1.784	3.639	0.775	1.093
P	0.086	0.001	0.445	0.285

flexible laryngoscope, but better resolution can be obtained with the former which permits more straightforward assessment of laryngeal function.

CONCLUSION

Compensatory hyperadduction is a pathophysiological phenomenon of vocal fold paralysis which may aid in diagnosis of that disorder. The contralateral vocal folds in subjects with unilateral vocal fold paralysis exhibit compensatory performance of excessive adduction and faster adduction. This may be the cause of higher metabolism in the contralateral vocal folds of these subjects. The speed of the contralateral VF movement could prove to be a valuable tool toward helping identification of laryngeal nerve damage.

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