Modifications of Vestibular Fold Shape From Respiration to Phonation in Unilateral Vocal Fold Paralysis

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Summary: The diversity of vestibular fold (VeF) behavior during phonation, as well as the lack of insight regarding both the anatomy and muscle fiber composition hinder our understanding of their role during phonation. The concave shape of the free margin of VeF appears to be standard, but little is known regarding the variability of this shape. We, therefore, sought to determine the laryngoscopic features related to changes in the free margin of the VeFs during phonation in patients with unilateral vocal fold paralysis. Laryngeal images from 39 patients with unilateral paralysis associated with recurrent laryngeal nerve damage were evaluated with regard to variations in length and shape of the VeFs (concave, straight, or convex) during both respiration and phonation. The VeFs on both the paralyzed and unaffected sides were analyzed during both phonation and respiration resulting in 156 total images. During phonation, all VeFs on the nonparalyzed side were straight or convex, whereas on the paralyzed side, only 20 of the 39 were straight or convex during phonation. During respiration, significant differences in the shape of the nonparalyzed side were observed. During phonation, a nonconcave appearance on the paralyzed side usually correlated with a similar appearance during respiration. VeF length decreased during phonation in 30 nonparalyzed VeFs in contrast to only 13 paralyzed folds. When subjects switched from respiration to phonation, the VeFs were typically nonconcave on the nonparalyzed side. In contrast, on the paralyzed side, nonconcave VeFs were consistent across both tasks. In patients with unilateral vocal fold paralysis, VeF conformation is likely determined from extralaryngeal than intrinsic muscle. These findings have important theoretical considerations for laryngeal treatment.
Key Words: Vestibular folds–Vocal fold paralysis–Larynx–Voice.

INTRODUCTION

The larynx is critical as the sound source for verbal communication. However, its principal biologic role is airway protection including active adduction of the vestibular folds (VeFs) during vocal fold closure.[1] Data are emerging that suggest that the VeFs are critical to voice production and vocal timbre. Although much is known regarding the composition and the behavior of the muscles of the true vocal folds, the anatomic correlates of the VeFs remain relatively unknown and controversial[2–4] likely resulting from inherent variability in musculature, which limit generalizations regarding both the form and function of these structures.

Despite the observation that a concave free margin of the VeF appears to be normal during phonation in subjects without vocal complaints, the diverse and complex behavior of VeFs limits our understanding of their functionality.[5–11] However, pathologic variations of normal voice production permit us to assess both the anatomy and physiology of VeFs, as well as their role in voice production. Unilateral paralysis provides an ideal scenario for this type of investigation. Voice production in these patients is typically characterized by increased supraglottic activity to compensate for glottic insufficiency. The objective of the present study was to identify laryngoscopic features related to modifications of VeF shape in patients with unilateral vocal fold paralysis during both respiration and phonation.

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MATERIALS AND METHODS

The present study was approved by the Ethics Committee of the Federal University of Sao Paulo, Brazil. Laryngeal images were retrospectively obtained from 183 patients seeking consultation for dysphonia associated with unilateral vocal fold paralysis. All images were obtained in a standardized manner. Briefly, all patients were seated and instructed to open their mouth and protrude their tongue. This position was maintained by a gauze-wrapped clamp. A Machida 70°, LY-C30 telescope was introduced into the oropharynx and images were recorded (Panasonic model GP-KS 162HD). During the assessment, all patients were instructed to mouth breathe effortlessly in addition productions of the sustained vowel /ϵ/, at a comfortable loudness and pitch.

Exclusion criteria for the present investigation included overt vocal fold injury, copious secretions obscuring visualization of the anatomy, inability to visualize the insertion of the VeF, excessive gag reflex limiting examination, poor image quality, and/or acute paralysis of less than 3 months.

Of the 183 patients, 39 met all inclusion criteria, because of the great number of exclusion bias. From the recordings of each patient, one frame was selected from the midportion of phonation and during inhalation and the images were digitalized (Adobe Premiere and Pinnacle DC1000). Two variables were identified: (1) VeF length and (2) alterations to VeF shape from breathing to phonation. Three anatomic landmarks were used to quantify these variables (Figures 1 and 2).

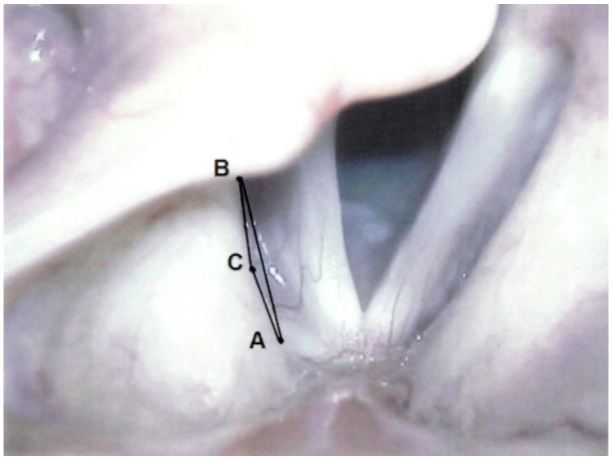

FIGURE 1. Telelaryngoscopic image during respiration. Right hemilarynx paralysis. Points A, B, and C, straight line AB and angle ACB on the paralyzed side.

Anterior point (A)

This point corresponds to the anterior insertion of VeF margin, close to the internal angle of thyroid cartilage.

Posterior point (B)

This point corresponds to the point where the free margin of the VeF ends posteriorly. A straight line between A and B was used to measure VeF length, in pixels. To identify shortening, we considered the percentage of the difference between VeF length during phonation in relation to respiration (ie, positive values were indicative of decreased VeF length).

Displacement point (C)

This point corresponded to the greatest distance from the VeF in relation to the straight line AB. The three points formed ACB angle, directed to the endolaryngeal space and measured in degrees. The line was considered straight when the angle was 180°; the angle was concave below this value and convex above it. Measurements were made using Adobe Photoshop 7.0.

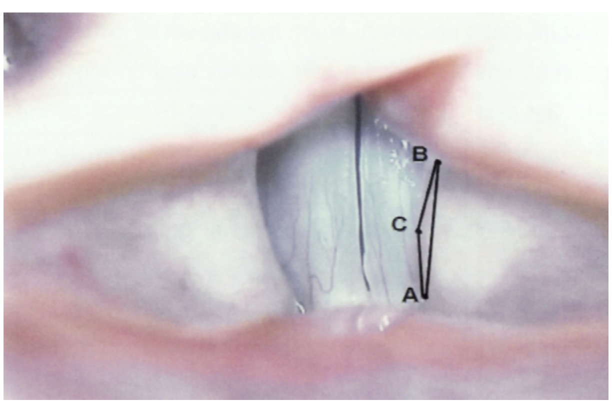

FIGURE 2. Telelaryngoscopic image during phonation. Right hemilarynx paralysis. Points A, B, and C, straight line AB and angle ACB on the nonparalyzed side.

A chi-square test was used to determine differences in the variables of interest ($\alpha = 0.05$).

RESULTS

In general, we observed more convex VeFs than other configurations, as shown in Table 1. Regarding this measurement, angles between 176.4° and 183.0° were considered straight as visual inspection did not allow for accurate discrimination of small differences within these parameters. As shown in Table 2, VeFs on the nonparalyzed side were nonconcave during phonation in all cases. However, on the paralyzed side, 20 cases (51%) were concave and furthermore, VeF shortening (VeF measured from respiration to phonation to detect activity resulting from intrinsic muscle action) was observed in all VeFs of the nonparalyzed side, similar to the loss of concavity. Changes in VeF shape from respiration to phonation occurred on the paralyzed side, but in most cases, the folds maintained their initial shape. In almost all cases, nonconcave VeFs (16/39) during phonation had the same configuration during respiration (22/39).

DISCUSSION

Any attempt to classify the shape of the VeFs based on simple visual appearance may raise questions regarding precision. The use of tracings with angle determination provides objective information in this regard. Despite the fact that the 70° scope could affect free laryngeal movement when compared with flexible laryngoscopy, the images have better resolution and are easier to be evaluated. Thus, in the present study, the straight line that theoretically corresponds to a 180° angle was actually placed between the angles of 176.4° and 183.0° (Table 1), as visual perception did not allow discrimination of differences among 180° angles within these parameters.

According to previous reports that used similar methods in patients without voice complaints, nonconcave VeFs (convex and straight shapes) were exceptions; concavity was observed in 83% of subjects by Nemetz et al[10] and 70% by Tuma et al.[11] However, our study in patients with unilateral vocal fold paralysis, the VeFs on the moving side were nonconcave. Our data suggest that the VeFs on the nonparalyzed side were nonconcave during phonation in all cases (Table 2). On the paralyzed side, it was observed that 20 cases (51%) were nonconcave, a much greater incidence than previous reports in patients without dysphonia. If we assume that the modification of VeF shape takes place only because of interlaryngeal muscle activity, this finding is unexpected on the nonparalytic side.

TABLE 1.
Minimum and Maximum Values of Vestibular Fold Angles, in Degrees, According to Shapes and Respective Occurrence

	Shapes		
Angles	Concave	Straight	Convex
Degrees	151.9–176.4	180	183.0–225.1
Occurrences	48	39	69

TABLE 2.
Incidence of Nonconcave Vestibular Folds During Respiration and Phonation as well as Shortening From Respiration to Phonation on Both Sides

	Without Paralysis		With Paralysis		Total		
Parameters	*n*	%	*n*	%	*n*	%	Chi-square
Nonconcave shape in phonation	39	100	20	51.3	59	75.6	<0.0001*
Nonconcave shape in respiration	27	69.2	22	56.4	49	62.8	0.3487
Presence of shortening	39	100	13	65	52	88.1	0.004*

* There is significant statistical difference.

To detect activity resulting from intrinsic muscle action, we measured changes in VeF length from respiration to phonation. VeF shortening was observed in all VeFs of the nonparalyzed side, similar to the loss of concavity (Table 2). In view of these findings, we believe that the shortening compressed the VeF contents, causing medial displacement and thereby modifying the shape. This reasoning led us to assume that decreasing the force underlying VeF shortening during phonation, would restore the inherent concavity of the VeF during breathing. This assumption was confirmed in 12 out of 39 VeFs on the nonparalyzed side, that is, 30.7% of the cases (Table 3).

Conversely, we noted that changes in shape from respiration to phonation occurred in both directions on the paralyzed side, but in most cases, the folds maintained their initial shape, and almost all cases with a nonconcave shape during phonation previously had the same configuration during breathing. This finding led us to hypothesize that other factors may act on the VeFs dictating the loss of concavity, particularly during respiration. Given that there is intrinsic muscular activity on this side, these modifying forces are likely the extralaryngeal structures.

In the present series, all patients presented with recurrent nerve damage. However, pharyngeal muscle activity was grossly intact. Pinho et al[7] stated that extralaryngeal forces might act on the endolaryngeal configuration by displacing fatty tissue in the region of the VeFs through preepiglottic and paraglottic spaces. Our observation supports this hypothesis and we believe that displacement of fatty tissue is a more stable situation than the deformity caused by compression during shortening.

Considering these two mechanisms is important for increased understanding of laryngeal dynamics, especially when considering attempts to correct glottic insufficiency. Thus, VeF shape may have important theoretical considerations for laryngeal management—the predominance of contraction should lead to a favorable response to therapy, whereas displacement should suggest the need for surgical treatment.

TABLE 3.
Modifications of Vestibular Fold Shape From Respiration to Phonation With and Without Paralysis

	Concave		Nonconcave	
Paralysis	Respiration	Phonation	Respiration	Phonation
Present	17	11	22	16
Absent	12	0	27	39

CONCLUSION

On the nonparalyzed side, the nonconcave shape of VeFs during phonation appeared when subjects shifted from respiration to phonation. On the paralyzed side, nonconcave VeFs were observed during both phonation and respiration. In patients with unilateral vocal fold paralysis, VeF conformation is likely determined from extralaryngeal than intrinsic muscle. In the treatment of unilateral vocal fold paralysis VeF shape may help decision making.

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