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Ultrasound strain imaging in assessment of false vocal folds in adults: A feasibility study

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ABSTRACT

Purpose: The aim of the study is to investigate the feasibility of ultrasound strain imaging (USI) in assessing magnitude and symmetry of false vocal folds (FVF) deformation as a quantitative marker for estimating FVF movement.

Methods: From October 2016 to July 2017, we performed USI of FVF in 44 adults [33 healthy controls and 11 subjects with unilateral vocal fold motion impairment (VFMI), 17 men and 27 women, mean age 43 years]. Real time ultrasound data of FVF in different configuration (abduction and adduction) was acquired through transcutaneous anterior-mid neck. Peak to valley strain (strain magnitude of maximum to minimum) representing the largest FVF deformation was estimated using 2-D speckle tracking. We developed peak to valley strain index [(Peak to valley strain $_{right}$ − Peak to valley strain $_{left}$)/Peak to valley strain $_{maximum}$] to assess the symmetry of FVF deformation.

Results: The difference in peak to valley strain between left and right FVF was significant in subjects with VFMI, whereas it was not in healthy controls. The peak to valley strain index was small (≤ 0.25) in symmetric FVF deformation in healthy controls whereas it was large (≥ 0.53) in asymmetric FVF deformation in subjects with VFMI. The area under receiver operating characteristics for peak to valley strain index in the determining asymmetric FVF deformation was 1.

Conclusion: Our results suggest that USI seems feasible to quantify both magnitude and symmetry of FVF deformation in adults. Further validation of USI in assessing VFMI is warranted.

1. Introduction

False vocal folds (FVF) appear as wedge-shaped tissues containing mucosal membrane, fatty tissue, and numerous mucous glands. FVFs are located superolateral to the true vocal fold (TVF) and between the angle of the thyroid cartilage and anterolateral surface of the arytenoid cartilage [1]. The dynamic movement function of FVF has a strong impact on assisting glottis flow in voice production [2], maintaining normal breath, and preventing food and water from entering the airway while swallowing [3]. It is proposed to estimate the symmetry of the laryngeal tract in abduction and adduction, and to diagnose recurrent nerve paralysis based on the visual impression of vocal fold immobility either during laryngoscopy or in real time sonography [4]. Diagnosis remains the greatest challenge, as laryngoscopy does not reliably distinguish innocent laryngeal asymmetry from hypomobility caused by paresis. Even when glottis closure appears grossly adequate, asymmetries in vocal fold tension may affect pitch, vocal stamina, and high or low intensity phonation [5]. In addition, it is difficult to visualize true vocal folds (TVF) using conventional gray scale ultrasound imaging. TVFs, thin and hidden by the FVFs, are difficult to follow during phonation, partly because of their out-of-plane motion [4]. In addition, the thyroid cartilage obscures ultrasound beam penetrating to TVF [6]. These anatomic and sonographic drawbacks contribute to a low rate (50%) of sonographic visualization of TVF and it is even lower in older males because of an increase of thyroid cartilage calcification following the age [7,8]. In contrast, it is easier to visualize FVF, relatively hyperechoic glands parallel to the TVF. Therefore, the movement characteristics of FVF can be used as an alternative for indirectly assessing TVF motion impairment because compensation of FVF adduction is considered as a result of abnormal or pathological TVF function [9].

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Fig. 1. The figure shows that the transducer (white arrow) is placed on the anterior mid neck at the level of thyroid cartilage when the subject is in the supine position with a mild neck extension. Static conventional grayscale images and real time ultrasound data of bilateral false vocal folds in abduction and adduction are acquired through this transcutaneous approach.

There are two main etiologies in the development of vocal fold motion impairment (VFMI). One is the change in vocal fold viscoelastic properties (e.g., scarring, atrophy, or edema) which greatly affects vocal fold movements leading to various degree of dysphonia [10,11]. The other is the recurrent nerve dysfunction leading to vocal fold abductor paralysis either as processes or as results in neuromuscular disorders (e.g., Parkinson's disease, stroke, and multiple system atrophy) [12–14] or traumatic injuries (e.g., thyroidectomy, tracheotomy, and intubation tube placement) [15–17].

Understanding the participation of FVF in laryngeal physiology may have practical application for better assessing functional vocal fold impairment in different conditions and for defining strategy for appropriate treatment [18]. Among ultrasound imaging techniques, a few studies of using conventional grayscale sonography to evaluate FVF dynamic movement in vivo were reported [6,19,20]. We did not find an introduction of using ultrasound strain imaging (USI) to assess the magnitude and symmetry of FVF movement in humans during our literature review. Ultrasound strain imaging has been used to assess muscle dynamic motion of the myocardium to evaluate cardiac function [21] and to assess skeletal muscles dynamic movement in both physiologic condition and pathologic damage [22].

Given that USI can assess tissue dynamic movement [22] and that FVF movement is associated with TVF function in abduction and adduction [9], we aimed to investigate the feasibility of USI in quantifying the magnitude and symmetry of FVF movement in healthy adults and in individuals with unilateral VFMI.

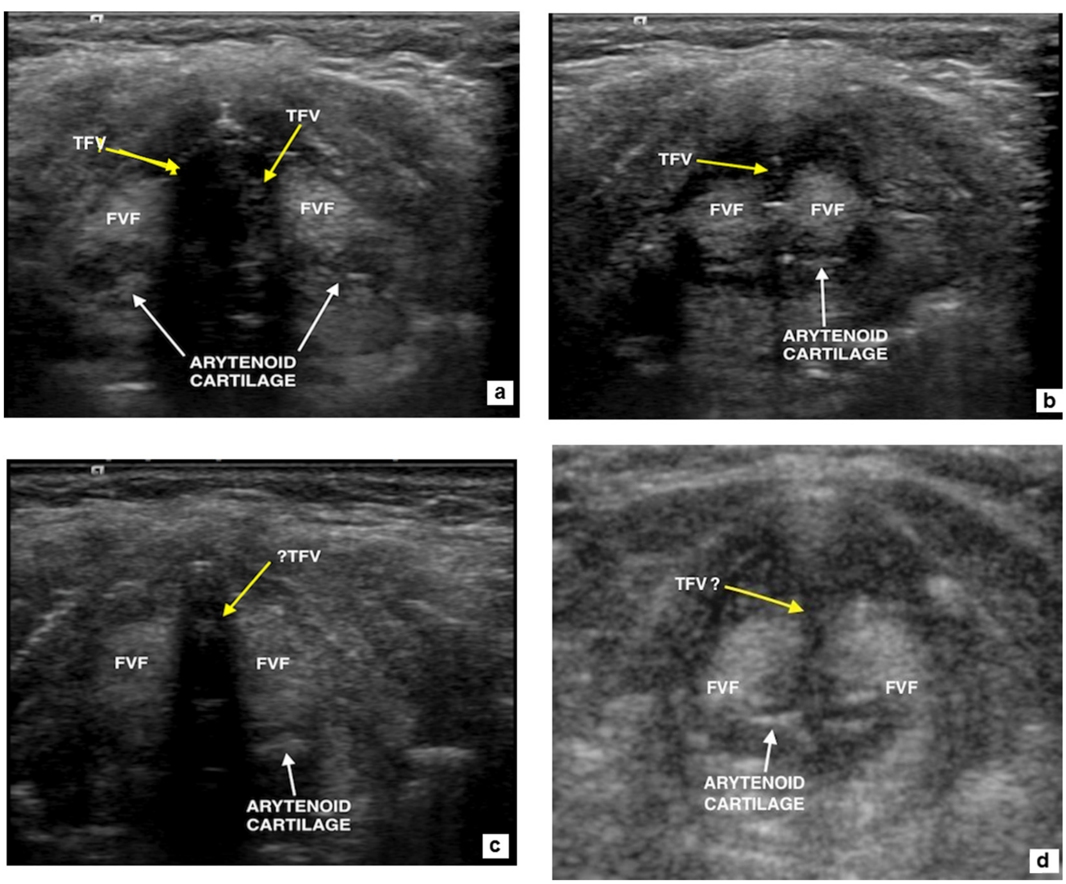

Fig. 2. a–d Gray scale images of true vocal folds (TFV, yellow arrows) and false vocal folds (FVF) in transcutaneous laryngeal sonography obtained from two healthy subjects. Transverse section of both left and right TVFs and FVFs in abduction (a) and in adduction (b) are clearly visualized in a 32 years old healthy woman. However, TVFs (yellow arrows with question mark) are not optimal in abduction (c) or in adduction (d) in a 65 years old man because the thyroid cartilage obscures sound beams penetrating to the TVF. An important note is that bilateral FVFs are visualized well in abduction and adduction in both subjects.