Voice Range Change After Injection Laryngoplasty for Unilateral Vocal Fold Paralysis

*,†,‡,§,[1]Yu-Cheng Pei, ¶,[1]Hsiu-Feng Chuang, ¶Chia-Fen Chang, *Tzu-Ling Chang, **Hui-Chen Chiang, and §,¶Tuan-Jen Fang, *†‡§¶*Taoyuan and* **Taipei, Taiwan*

Summary: Objectives. Patients with unilateral vocal fold paralysis (UVFP) caused by nerve injury manifest with voice changes. This study investigated vocal performance measured by voice range profile (VRP) in patients with UVFP and changes in VRP in response to intracordal hyaluronate injection.

Methods. Eighty-five patients with UVFP were enrolled prospectively, among whom 68 received intracordal hyaluronate injections. The outcome measurements included VRP, acoustic and aerodynamic analyses, peak turn frequency of thyroarytenoid-lateral cricoarytenoid muscle complex (TA-LCA) measured by laryngeal electromyography, and normalized glottal gap area by videolaryngostroboscopy.

Results. The peak turn frequency of the paralyzed TA-LCA showed a modest correlation with max fundamental frequency (F0) and F0 range. Closed-phase normalized glottal gap area showed modest negative correlations with max F0 and F0 semitone range. Regarding conventional acoustic and aerodynamic analyses, the paralyzed TA-LCA peak turn frequency was only correlated with maximal phonation time. Intracordal hyaluronate injection improved VRP performance by increasing max F0, decreasing min F0, increasing F0 range, and increasing semitone range (all $P < 0.01$) with small or medium strength of effect size (Cohen d, 0.39–0.76).

Conclusions. Change in voice pitch in patients with UVFP can partly predict impairment of neuromuscular functions and glottal gap. VRP provides a more sensitive reflection of the severity of neuromuscular impairment, compared with conventional voice analysis. The validity of VRP is further supported by a robust response to voice improvements following injection laryngoplasty.

Key Words: Unilateral vocal fold paralysis–Voice range profile–Phonetogram–Laryngeal electromyography–Hyaluronate injection laryngoplasty.

INTRODUCTION

Unilateral vocal fold paralysis (UVFP) usually interferes with voice production, affecting the patient's quality of life. Dysphonia caused by UVFP manifests with breathiness, diplophonia, and hypofunction,[1] although these voice changes are highly variable across patients. Voice production is considered to be a multidimensional phenomenon, and UVFP-related voice changes thus need to be measured using a variety of tools to reflect the unique dimensions of the voice.[2] Restricted pitch and loudness ranges may affect an individual's emotional expression in speech, given that reduced pitch variation is usually perceived to indicate a sad or neutral response, whereas wider pitch variation conveys frightened, angry, or happy responses.[3] The inability of the speaker to control their speech frequency and intensity adequately may therefore lead listeners to misjudge the conveyed message, and changes in pitch and loudness ranges as a result of UVFP-specific voice dysfunction may impair patients' communication performances in psychosocial domains. However, clinical evaluation of the dynamics of pitch and loudness is still lacking.

A voice range profile (VRP), also referred to as a phonetogram, voice range, or voice area, measures the voice's dynamic frequency range.[4] The features, shape, area, and dynamic range of the VRP can detect the presence of dysphonia[5] and reflect the effects of voice training.[6] Specifically, patients with vocal fold pathologies demonstrate limited VRP compared with healthy counterparts,[4,7,8] and the voice range has been shown to be altered in a variety of vocal fold pathologies,[4,7,8] including being decreased in patients with UVFP[4] (Figure 1). It is therefore important to describe the VRP characteristics of Mandarin speakers with UVFP.

Conventional laboratory voice assessment is commonly applied clinically, and it remains unclear if VRP could provide additional useful information for diagnostic and monitoring purposes. In conventional laboratory voice assessment, patients are usually asked to produce a sustained vowel at conversational pitch and loudness, and their voice is analyzed acoustically, yielding information on fundamental frequency (F0), jitter (frequency perturbation), shimmer (perturbation of amplitude), and harmonic-to-noise (H/N) ratio. These parameters have been shown to reveal voice impairments in patients with vocal fold pathologies.[9–12] In addition, laboratory voice assessment usually includes simple aerodynamic analyses, such as maximal phonation time (MPT)

Accepted for publication July 25, 2017.

Meeting presentation: This research was presented in a poster session at the American Laryngological Association Combined Otolaryngology Spring Meeting, April 26–30 2017, San Diego, CA, USA.

Financial disclosures: This research was supported by grants CMRPG 3D1413 (staff and consumables support) and 5F0091-4 and 3E1721 (data analysis) from the Chang Gung Medical Foundation and MOST105-2314-B-182A-070-MY2 from the Minister of Science and Technology, Taiwan. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. The authors have no other funding or financial relationships to disclose.

From the *Department of Physical Medicine and Rehabilitation, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan; †Center of Vascularized Tissue Allograft, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan; ‡Healthy Aging Research Center, Chang Gung University, Taoyuan, Taiwan; §School of Medicine, Chang Gung University, Taoyuan, Taiwan; ¶Department of Otolaryngology Head and Neck Surgery, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan; and the **Graduate School of Management, Ming Chung University, Taipei, Taiwan.

[1]These two authors contributed equally.

Address correspondence and reprint requests to Tuan-Jen Fang, Chang Gung Memorial Hospital, No. 5 Fushing St., Taoyuan, Taiwan 333. E-mail: fang3109@cgmh.org.tw

Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■

0892-1997

https://doi.org/10.1016/j.jvoice.2017.07.019

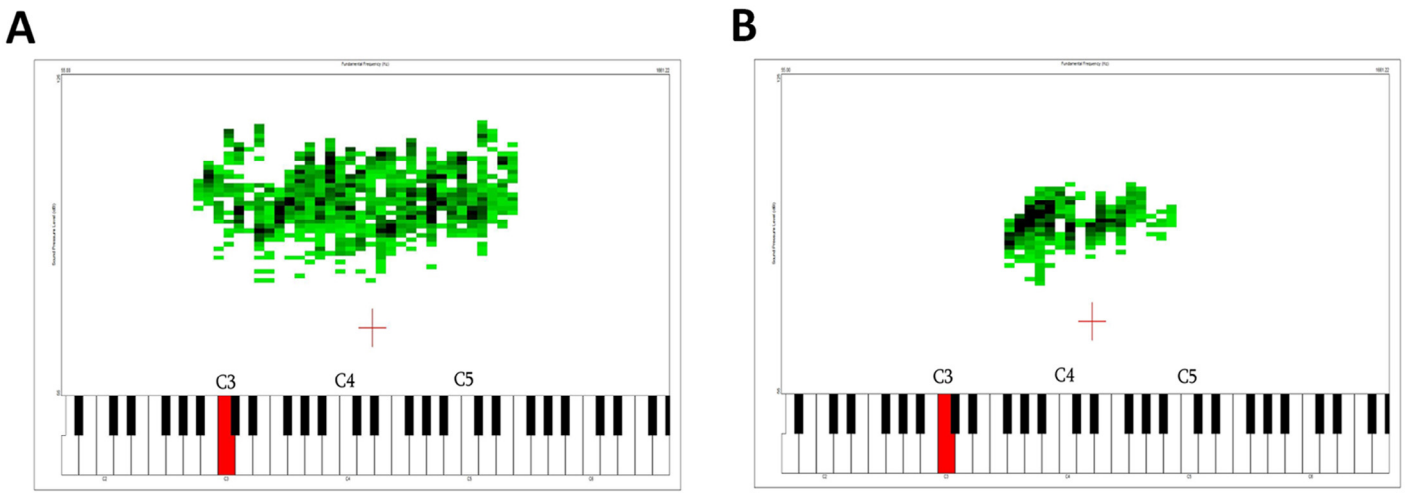

FIGURE 1. Voice range profiles (VRPs) obtained from a healthy subject (**A**) and a patient with UVFP (**B**). F0 range and intensity range were limited in the patient with UVFP compared with the normal subject.

and S/Z ratio, to evaluate the aerodynamic aspect of phonatory function.[12,13] In addition to these commonly used conventional acoustic and aerodynamic analyses, it remains unclear what aspects of impaired phonatory mechanisms in UVFP may be detected by VRP.

In this study, we investigated the relationships among VRP parameters, glottal gap measured by videolaryngostroboscopy, and neuromuscular control measured by quantitative laryngeal electromyography (LEMG) to characterize the pathophysiological changes underlying the limitation of voice frequency range in UVFP. We hypothesized that VRP ranges would be decreased in patients with UVFP and that limitations in VRP ranges may predict the severity of neuromuscular control. We also monitored VRP changes among patients following injection laryngoplasty.

MATERIALS AND METHODS

Patients

This prospective cohort study was approved by the Human Studies Research Committee of Chang Gung Medical Foundation. Written informed consent was obtained from each participant prior to recruitment. Patients with acute UVFP (<6 months since onset) diagnosed by videolaryngostroboscopy and confirmed by LEMG were recruited. The inclusion criteria were adult patients over 18 years old with unilateral immobile vocal fold and neuropathic signs in the thyroarytenoid-lateral cricoarytenoid (TA-LCA) muscle complex by LEMG. The LEMG criteria of neuropathy were defined as the existence of spontaneous activities (such as fibrillation, positive sharp wave, and complex repetitive discharge), >30% polyphasia, or decreased interference pattern (reduced, discrete, or no interference pattern). Exclusion criteria were a history of prior vocal fold palsy, a history of vocal fold surgery, a history of intracordal injections, inability to cooperate with evaluations, or a lack of evidence of denervation changes in the thyroarytenoid muscle in the involved side. Some of the recruited patients underwent office-based intracordal hyaluronate (Restylane, Q-Med AB, Uppsala, Sweden) injection through the cricothyroid membrane after the initial assessment, as described previously.[14,15]

All patients underwent quantitative LEMG, videolaryngostroboscopy, VRP, and laboratory voice analysis within a 2-week period. Patients who received intracordal hyaluronate injections also underwent a follow-up VRP assessment 1 month after the injection.

Voice acoustic and aerodynamic analyses

Voice samples were recorded by a certified speech pathologist using a computerized speech laboratory system (CSL4500B 5.05, Kay-PENTAX, Montvale, NJ, USA) through a unidirectional, dynamic microphone (model SM48, Shure, Evanston, IL, USA). The distance from the microphone to the subject's mouth was 5 cm.

For conventional acoustic voice analysis, the patients were asked to produce a sustained vowel /a/ at conversational pitch and loudness. A stable segment from the mid portion of the voice sample (repeated three times and the best trial was picked for analysis) was used for subsequent acoustic analysis to calculate F0, jitter, shimmer, and H/N ratio. Aerodynamic analysis consisted of measuring MPT and S/Z ratio. MPT represented the maximum duration that the patients could sustain an /a/. Finally, the patients were asked to produce a sustaining /s/ and /z/, respectively, for as long as possible, and the S/Z ratio was computed as the ratio of the /s/ and /z/ durations.

VRP

The protocol for VRP measurements has been reported previously.[16] Tone stimulus was initiated at F0 at 261.6 Hz (C4). The patients were asked to project the sustained vowel /a/ for each semitone along the musical scale, from the patients' highest to the lowest achievable pitch. The patients were asked to phonate at the target F0 using a sustained vowel /a/ for each tone stimulus ranging from the lowest to the highest achievable loudness, beginning at a comfortable voice intensity level and increasing to the patient's maximum level at the target F0. The patients were