Computerized Tomography Measures During and After Artificial Lengthening of the Vocal Tract in Subjects With Voice Disorders

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Summary: Purpose. The present study aimed to observe the effect of two types of tubes on vocal tract bidimensional and tridimensional images.

Methods. Ten participants with hyperfunctional dysphonia were included. Computerized tomography was performed during production of sustained [a:], followed by sustained phonation into a drinking straw, and then repetition of sustained [a:]. A similar procedure was performed with a stirring straw after 15 minutes of vocal rest. Anatomic distances and area measures were obtained from computerized tomography midsagittal and transversal images. Vocal tract total volume was also calculated.

Results. During tube phonation, increases were measured in the vertical length of the vocal tract, oropharyngeal area, hypopharyngeal area, outlet of the epilaryngeal tube, and inlet to the lower pharynx. Also, the larynx was lower, and more closure was noted between the velum and the nasal passage.

Conclusion. Tube phonation causes an increased total vocal tract volume, mostly because of the increased cross-sectional areas in the pharyngeal region. This change is more prominent when the tube offers more airflow resistance (stirring straw) compared with less airflow resistance (drinking straw). Based on our data and previous studies, it seems that vocal tract changes are not dependent on the voice condition (vocally trained, untrained, or disordered voices), but on the exercise itself and the type of instructions given to subjects. Tube phonation is a good option to reach therapeutic goals (eg, wide pharynx and low larynx) without giving biomechanical instructions, but only asking patients to feel easy voice and vibratory sensations.

Key Words: tube phonation–semi-occluded exercises–vocal tract–voice therapy–functional dysphonia.

INTRODUCTION

One aspect considered in voice therapy and training is the modification of vocal tract structures. These changes partially shape the spectral energy distribution, and this in turn, can produce different voice qualities or vocal timbres. It is generally agreed among clinicians and voice trainers that vertical laryngeal position (VLP), pharyngeal width, and laryngeal constrictions are important aspects that shape voice quality in both normal and pathological voices.[1–7] A wide variety of voice exercises are used to accomplish modifications in these vocal tract features, one being the semi-occluded vocal tract exercises.

Several effects have been attributed to semi-occluded vocal tract postures. One of the effects that has been explored is the modifications of vocal tract configuration during and after phonation into different types of tubes used in voice therapy. Two earlier investigations have been performed using computerized tomography (CT). Guzman et al,[8] in a single case study, reported that during Finnish glass tube and stirring straw phonation, hypopharyngeal area widened, the laryngeal position lowered, and more closure was seen between the velum and the nasal passage compared with open vowel phonation. All changes were more prominent during stirring straw phonation than during glass tube phonation in air. In another CT and finite-element modeling single case study, the most dominant change during phonation into the tube was the expansion of the cross-sectional area of the oropharynx and in the oral cavity due to a different tongue position.[9] CT images also revealed that the velum rose to seal the nasopharyngeal port during tube phonation and also remained raised after it.[9] Moreover, the total volume of vocal tract was considerably larger after phonation into the tube. Laukkanen et al[10] observed similar vocal tract modifications during glass tube phonation in a female subject using magnetic resonance imaging. All of the previously mentioned studies were carried out with vocally trained participants without vocal fold pathology.

Vocal tract changes during eight different semi-occluded exercises were recently studied using flexible laryngeal endoscopy in a group of patients diagnosed with hyperfunctional dysphonia. Findings revealed that all exercises produced a lower VLP, a narrower aryepiglottic opening, and a wider pharynx than resting position.[11]

To the best of our knowledge, to date, no studies with semi-occluded postures have been performed using CT in patients with voice disorders. The present research aimed to observe the effect on vocal tract bidimensional and tridimensional images of two types of plastic tubes commonly used in voice therapy and training. Based on previous data, we hypothesize that during tube phonation, the vocal tract should experience the following modifications compared with open vowel production: (1) larger total volume of the vocal tract, lower VLP, raised velum, and a wider pharynx; (2) changes should be more prominent during narrow

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tube phonation compared with wide tube phonation; and (3) these changes are not expected to remain after exercises.

METHODS

Participants

Ten participants were included in this study (six women and four men). The average age of the subjects was 26 years, with a range of 21–43 years. Inclusion criteria included (1) age range of 20–45 years, (2) laryngoscopic diagnosis of mild hyperfunctional dysphonia, and (3) no previous voice training or therapy. None of the participants reported previous experience using tube phonation or other semi-occlusions as vocal training or warm-up exercises. Subjects did not report any known voice or hearing pathology at the time of the experiment. Several definitions of laryngeal hyperfunction exist, but a recurrent feature in almost all descriptions includes excessive laryngeal musculoskeletal activity, force, or tension. The basic paradigm for the evaluation of laryngeal hyperfunction is to look for compression of the glottis and supraglottic structures during phonation. In the present study, diagnosis of hyperfunctional dysphonia was made based on the previous description. This study was reviewed and approved by the University of Chile Hospital Review Board. Informed consent was obtained from all participants.

Laryngoscopic assessment

All participants were asked to undergo flexible laryngoscopy (Olympus ENF-P4; Olympus, Center Valley, PA, USA) to confirm the presence of functional dysphonia. Endoscopic laryngeal examinations were performed by two laryngologists who are coauthors of the present study (C.O. and M.L.). Intranasal topical anesthesia was used during trans-nasal endoscopy for all subjects.

CT scanning

CT was carried out at the University of Chile Hospital, Department of Imaging and Radiology. The CT images were acquired using a SOMATOM Sensation 64 (Siemens Healthcare, Erlangen, Germany) CT machine. The CT imaging parameters used to provide images of the vocal tract were voltage of 100 kV, time of the rotation of 0.4 seconds, and slice thickness of 1.2 mm. In supine position inside the CT machine, subjects were asked to produce the following phonatory tasks: (1) to sustain vowel [a:] (baseline, condition pre), (2) to phonate a sustained vowel-like sound into a drinking straw (tube 1) (5 mm of inner diameter and 25.8 cm in length) for 15 minutes, and immediately after that, (3) to produce another sustained vowel [a:] (condition post). After 20 minutes of complete silence (vocal rest), subjects performed phonation into a plastic stirring straw (tube 2) (2.7 mm of inner diameter and 10.7 cm in length) for 15 minutes. Immediately after that, participants were asked to produce another sustained vowel [a:] (post condition). Subjects were allowed to breathe normally during tube phonation. All phonations were carried out at habitual loudness level and speaking pitch. Pitch was kept constant during all phonatory tasks and it was perceptually controlled by one of the experimenters using an electronic keyboard. Participants were required to produce a stable sound with a good closure at the lips; to feel vibratory sensations as strong as possible on the alveolar ridge, face, and head areas; and to produce an easy voice during tube phonation. Each subject was scanned once while producing each phonatory task. No more repetitions were performed because of the maximum allowed amount of radiation. Participants were asked to adopt a relaxed posture in the CT scanner and exactly the same body and head position was kept during the entire CT procedure. The head position was mechanically fixed in a frame during all experiments.

CT image analysis

Most of CT measures included in the present study were based in a previous research.[8] Five CT midsagittal images (five phonatory tasks × one repetition) were chosen from each subject to perform a series of distance measurements (mm). Anatomic distances (Figure 1) of interest included (1) vertical length of the vocal tract (which is indicative of the VLP) measured as the distance between the lowest point of the odontoid process of the atlas and the vocal folds following a vertical line; (2) horizontal length of the vocal tract measured as the distance between the lowest point of the atlas and the narrowest point between the lips, (3) lip opening measured as the distance between the lower edge of the upper lip and the upper edge of the lower lip, (4) jaw opening measured as the distance between the lowermost edge of the jawbone contour and the anterior end of the hard palate, (5) tongue dorsum height measured as the distance between the lowermost edge of the jaw bone and the uppermost point of the tongue dorsum, (6) oropharynx width measured as the distance between the lowest point of the second vertebra and the most posterior part of the tongue contour (to ensure the same angle, we used a straight line from the anterior

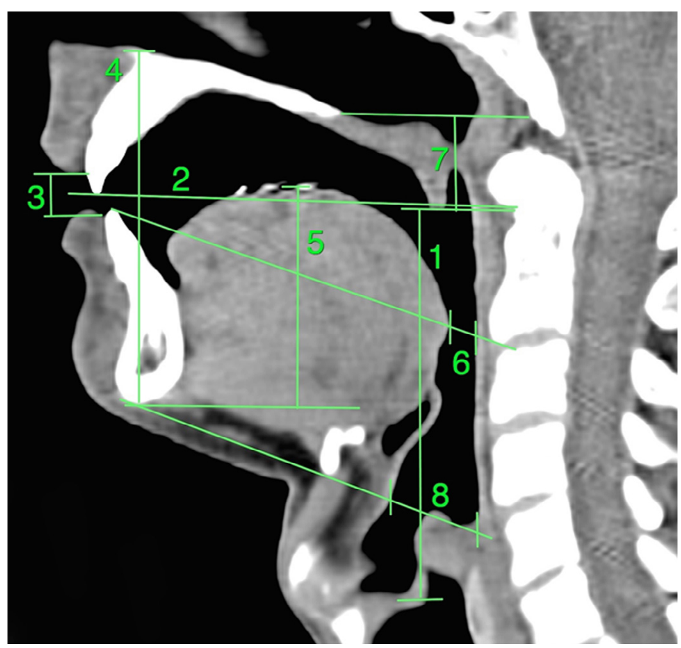

FIGURE 1. Distances (mm) measured in computerized tomography (CT) midsagittal images: (1) vertical length of the vocal tract, (2) horizontal length of the vocal tract, (3) lip opening, (4) jaw opening, (5) tongue dorsum height, (6) oropharynx width, (7) velum elevation, and (8) hypopharynx width.