Acoustic Signs of Supraglottal Constriction in Pathological Voices

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Abstract

Purpose: This study aims to identify the acoustic signs of supraglottal constriction and effects of some vocal manipulation techniques. It is hypothesized that some task-related acoustic contrasts would differ between voice patients with and without supraglottal constriction in vocal tract configurations. Methods: Classified through videofluoroscopic examinations, 30 participants were gender and age-matched to form two comparison groups ("constricted" and "non-constricted"), with five males and ten females in each group. Participants were asked to sustain a vowel ("a"/or /i/) for approximately three seconds in five tasks, including normal-pitch, low-pitch, high-pitch, m-/ion (i.e., with the consonant m/ preceding the vowel at normal pitch), and h-/ion tasks. Acoustic signals were analyzed to extract measures from the mid-portion of the vowel. Results: The "constricted" group showed a lack of task-related contrasts on signal-to-noise ratio, singing power ratio, frequency of the second formant, and the amplitude difference between the first formant and the harmonic one. Conclusion: Further investigations are needed to assess the predictive power of the proposed task-based acoustic approach for detecting supraglottal constriction.

Introduction

Supraglottal constriction is a type of vocal tract constriction related to the narrowing of the space above the true vocal folds due to movement of supraglottal structures (Stager, Neubert, Miller, Regnell, & Bielamowicz, 2003). As supraglottal cavities, along with nasal and oral cavities, determine the resonance for the sound waves generated at the glottal source, supraglottal constriction may affect some acoustic measures of voice. For example, vocal tract constriction has been found to have an impact on formant frequencies (Fant, 1960; 1961; Bickley & Stevens, 1986; Fant, 1980; Kent, 1993; Story, Laukanen & Titze, 2000). Changes of the acoustic pressure in the vocal tract due to vocal tract constriction may also affect patterns of vocal fold vibration such as the open time in a glottal cycle (Bickley & Stevens, 1986; Story, Laukanen, & Titze, 2000). As supraglottal constriction is often found in voice patients with incomplete vocal fold closure or excessive muscular tension, such as those referred to as having "dysphonia due to muscular imbalance" (Coyle, Weinrich, & Stemple, 2001), investigations on the acoustic signs of supraglottal constriction in pathological voices may provide information useful for assessing and modifying its associated voice quality and vocal behavior.

Assessment of Supraglottal Constriction: Identification of supraglottal constriction normally requires visualisation of the vocal fold movement through videofluoroscopy (Stager et al., 2003). As most of the current visual rating scales are not sensitive enough to changes in the positions of the supraglottal structures (Stager et al., 2001), development of more sensitive measures are needed. The acoustic measures most commonly used for general voice evaluation include fundamental frequency (F0), pitch range, loudness, maximum phonation time, and vocal stability. Acoustic measures related to vocal tract configuration may involve a frequency-domain analysis. Firstly, a spectral estimate by voice quality is the property of the voice based on the absolute or relative position of the maxima of the spectrum. Frequency difference has been found to be inversely related to the perception of harshness/roughness and positively to breathiness (Kreiman & Gerratt, 1987). Secondly, as vocal tract constriction has been shown to have an impact on formant frequencies, measures of formant frequencies may be useful for differentiating between voices with and without supraglottal constriction. Formant frequencies are the spectral envelope peaks representing the resonance characteristics of the vocal tract. It is well recognised that identification of a vowel is based on the relative loci of the first two to three formant frequencies (Paton & Barney, 1956; Smith & Scott, 1980; Nydahl & Lieberman, 1982; Hilenbrand & Gayvert, 1993). The frequencies of Formant one (F1) and Formant two (F2) have been found to be affected by the forwardness and the height of the tongue, the size of the oral and pharyngeal space, and the overall length of the vocal tract (Bakan & Orkoff, 2000). Specifically, F1 frequency is affected by the space between the glottal level and the point of the highest tongue position and is altered by the tongue height while F2 frequency is associated with the region of the front of the tongue and is altered by tongue retraction and protrusion. Thirdly, a measure of spectral slope termed "singing power ratio" (SPR) can be extracted from a long-time average (LTA) spectrum to reflect the vocal tract effect on the amplification or suppression of the harmonics generated from the vibrating source (Pershall & Boone, 1987). The SPR measure is defined as the energy ratio between the highest spectral peak in the 2-4 kHz frequency range, which is the region where the singer’s formant is normally located, and that between 0 and 2 kHz (Pershall & Boone, 1987). Having been related to the power of voice projection (Omoni, Kacker, Carroll, Riley, & Blaugrund, 1996), the SPR measure can be used to quantify the resonant quality of the singing voice (Lundy, Roy, Casiano, Xue, & Evans, 1994). Clinical studies have shown that singers have been found to exhibit a lower SPR, indicating a relatively higher level of energy around the frequency range between 2 and 4 kHz, as compared with untrained singers (Barranco, Heuer, Dean, & Satloff, 2001) or singers whose voice tract involving may contribute to vocal behavior such as laryngeal constriction (Bums, 1986; Stone, Cleveland, & Sundberg, 1999).

Results

Participants: Fifteen voice patients (5 males and 10 females) identified clinically by the attending speech therapist or otolaryngologist as showing supraglottal constriction and 15 gender and age-matched (within six years of age difference) voice patients as showing "no or very mild constriction" were selected for comparison. The age of the 30 participants ranged from 21 to 79 years. The mean age of the "constricted" group was 42.1 years (SD = 16.7) and the "non-constricted" group 42.4 years (SD = 12.8). Results: There were no significant differences between the two groups for age, gender, height, and weight. Participants were asked to sustain a vowel ("a"/or /i/) for approximately three seconds in three tasks, including normal-pitch, high-pitch, m-/ion (i.e., with the consonant m/ preceding the vowel at normal pitch), and h-/ion tasks. Acoustic signals were analyzed to extract measures from the mid-portion of the vowel. Results: The "constricted" group showed a lack of task-related contrasts on signal-to-noise ratio, singing power ratio, frequency of the second formant, and the amplitude difference between the first formant and the harmonic one. Conclusion: Further investigations are needed to assess the predictive power of the proposed task-based acoustic approach for detecting supraglottal constriction.

Conclusion

Supraglottal constriction may have a causative or reactive association with voice disorders. Identification of task-related vocal changes suggestive of supraglottal constriction may assist in the development of an efficient monitoring tool for managing voice problems. The present findings indicate that most task-related acoustic contrasts could be found in voice patients without supraglottal constriction but not in those with supraglottal constriction. Therefore, the acoustic measures shown to be affected by task in the "non-constricted" group alone may have the potential to be used as the objective screening tool for the detection of supraglottal constriction. Specifically, a lack of consistent between-task variation in the measure of the SPR, F2 (nor F1, H1, H2, amplitude difference) may be taken as a sign of the presence of supraglottal constriction. The lack of the context-related (i.e., isolated vowels vs. vowels preceded by m/ or h/) acoustic contrasts in the "constricted" group may be related to the obviating factors related to the altered vocal tract configuration immediately above the larynx. Follow-up studies are needed to assess the sensitivity and specificity of the identified acoustic measures employed in this task-based approach for the detection of supraglottal constriction.

References


