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Acoustic analysis of voice in children with cleft palate and velopharyngeal insufficiency

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ABSTRACT

Background: Acoustic analysis of voice can provide instrumental data concerning vocal abnormalities. These findings can be used for monitoring clinical course in cases of voice disorders. Cleft palate severely affects the structure of the vocal tract. Hence, voice quality can also be also affected.
Objective: To study whether the main acoustic parameters of voice, including fundamental frequency, shimmer and jitter are significantly different in patients with a repaired cleft palate, as compared with normal children without speech, language and voice disorders.
Materials and methods: Fourteen patients with repaired unilateral cleft lip and palate and persistent or residual velopharyngeal insufficiency (VPI) were studied. A control group was assembled with healthy volunteer subjects matched by age and gender. Hypernasality and nasal emission were perceptually assessed in patients with VPI. Size of the gap as assessed by videonasopharyngoscopy was classified in patients with VPI. Acoustic analysis of voice including Fundamental frequency (F0), shimmer and jitter were compared between patients with VPI and control subjects.
Results: F0 was significantly higher in male patients as compared with male controls. Shimmer was significantly higher in patients with VPI regardless of gender. Moreover, patients with moderate VPI showed a significantly higher shimmer perturbation, regardless of gender.
Conclusion: Although future research regarding voice disorders in patients with VPI is needed, at the present time it seems reasonable to include strategies for voice therapy in the speech and language pathology intervention plan for patients with VPI.

1. Introduction

Perceptual assessment of voice is voice is fundamental for the evaluation of patients with voice disorders. Digital acoustic analysis of voice provides instrumental data complementing perceptual assessment. Digital acoustic analysis increases the knowledge concerning specific voice characteristics and it is helpful for understanding the mechanisms of voice production. Moreover, acoustic data are useful for following the patient's clinical course, documenting clinical improvement and providing visual biofeedback which can be used during the voice intervention [1].

Acoustic analysis includes measurement of several parameters. The most important for clinical purposes are Fundamental Frequency (F0), Jitter and Shimmer. FO is determined by the frequency at which the vocal cords vibrate during voice production and it is measured in Hz. Normal values of F0 for children have been previously reported [2]. F0 in normal female children ranges from 268 to 295 Hz. A mean F0 of 247 Hz in children under 12 years of age has also been reported, without significant differences when boys and girls were compared [3].

During consistent vocal cord vibration, F0 demonstrates a slight variation and also a variation of cycle-to-cycle amplitude, these phenomena are known as frequency perturbation or jitter and amplitude perturbation or shimmer. These variations or changes are a consequence of the mass and tension differences which characterize the vocal cords. Jitter and shimmer values can be expressed in a percentage. There are normative data for these percentages. Jitter percentage should be below 1% whereas

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shimmer percentage should be below 10%. It should be considered that shimmer and jitter are dependent of F0. Thus, in cases of abnormal voices with aperiodicity which precludes F0 measurement, shimmer and jitter are not useful [1].

Systematic changes of F0 can occur as a consequence of stress or intonation, which are inherent to speech. These changes affect the acoustic assessment of F0. Thus, the clinical evaluation of F0, shimmer and jitter is usually performed during the production of a sustained vowel sound. The most acoustically consistent vowel sound is the vowel/a/ [4,5].

Vocal qualities are the result of individual anatomical and physiological characteristics which are strongly influenced by age, gender and physical structure [6]. Therefore, for an adequate vocal production it is necessary that all the components of the vocal tract, from the glottis to the lips and including the resonance chambers of the nasal cavities and sinuses be structurally and functionally intact.

The most common craniofacial anomaly affecting resonance and speech is a palatal cleft. According to Kernahan and Stark [7], the most common cleft is the total cleft of the primary and secondary palate. Patients with a cleft of the secondary palate show abnormal nasal resonance and nasal emission, which are a consequence of the defective or incomplete seal of the velopharyngeal sphincter during speech. This anomaly is known as velopharyngeal insufficiency (VPI) and significantly affects speech intelligibility [8]. Besides hypernasality and nasal emission, some patients with cleft palate also develop compensatory behaviors known as compensatory articulation errors. These articulation disorders affect intelligibility even more severely than VPI [9].

Some papers have focused on the acoustic characteristics of voice in patients with cleft palate. Frequency instability, high intensity, abnormal formant distribution and abnormal spectrograms have been reported [10–12]. In 1989, Zajac and Linvile [11] studied voice perturbations in patients with VPI. They performed acoustic analyses and found a significant relationship between abnormally high jitter values and hypernasality.

The purpose of this paper is to study acoustic parameters of voice including F0, shimmer and jitter in children with persistent or residual VPI after surgical repair of a cleft palate. The acoustic parameters of these children were compared with a group of normal controls matched by age and gender, without any voice or speech disorder.

2. Materials and methods

A comparative, cross-sectional study was carried out at the Department of Speech and Language Pathology of the National Institute of Rehabilitation in Mexico City from January 2012 to December 2013. The protocol was approved by the Internal Review Board of the Institute.

2.1. Patients

Patients who met the following criteria were recruited for the study: (a) surgically corrected non-syndromic unilateral total cleft lip and palate (UCLP) with persistent or residual VPI as demonstrated by perceptual analysis of voice and videonasopharyngoscopy. The patients should present with UCLP as an isolated malformation, not associated with a sequence or syndrome; (b) normal hearing as demonstrated by a behavioral pure – tone audiometry; (c) 6–10 years of age at the time to be recruited for the study. This age group was selected in order to assure appropriate compliance during the behavioral audiometry and the acoustic assessment, as well as to prevent voice changes as a consequence of puberty. Patients with palatal fistula or with a history of laryngeal pathology or hoarseness were excluded. Patients present with compensatory articulation errors including glottal stops were excluded from the study group. Patients with neurological disorders or intellectual – cognitive deficits were excluded. Patients with severe nasal emission causing nasal rustle which was being picked up during the recordings procedures were also excluded.

During the recruiting period, a total of 14 patients met the criteria for being included in the study. Eleven patients were males and 3 patients were females. The age of the patients ranged from 7 to 9 years of age with a median of 8 years. The study protocol was carefully explained to the parents and/or legal guardians and all of them signed an informed consent form.

2.2. Controls

A control group was assembled, including 14 subjects matched by age and gender. These subjects were recruited at a nearby elementary school. All these subjects voluntarily participated in the study. The study protocol was carefully explained to the parents and/or legal guardians and all of them signed an informed consent form. All of these patients were examined in order to verify that there were no palatal anomalies (including submucous cleft palate), no voice disorders, no compensatory articulation errors and no perceptual signs of VPI (normal nasal resonance during speech).

2.3. Procedure

In patients with repaired cleft palate and persistent VPI, hypernasality and nasal emission were perceptually classified as previously reported [13,14]. Two experienced physicians certified by the Board of Speech and Language Pathology of Mexico (first and second authors of this paper) were in charge of conducting the examination. The examinations were performed independently. A Cohen's Kappa concordance index of 85 was found between both examiners. Regarding nasal emission a Cohen's Kappa index of 92 was found. Whenever there was disagreement, each case was discussed until a consensus had been reached. Hypernasality was detected in all patients. Only 4 patients presented with nasal emission across plosive and fricative phonemes. It should be pointed out that none of these patients showed nasal rustle that could be picked up by the microphone during the recording procedures. Eight patients presented with mild hypernasality. Six patients presented with moderate hypernasality.

All patients with repaired cleft palate and persistent VPI underwent a flexible nasoendoscopy following a protocol which has been previously reported [15]. Velopharyngeal movements during speech including velar and lateral pharyngeal motion, as well as presence of Passavant's ridge were classified as ratios, considering the position at rest as 0 and full contact or closure as 1.0. The size of the gap during speech was estimated as a ratio considering total velopharyngeal space at rest as 1.0. Eight patients demonstrated only bubbling during speech without a discernible gap. These cases were conventionally considered as a 10% gap and a mild VPI. Six patients demonstrated gaps with a size of 20%, that is, a moderate VPI. It should be pointed out that size of the gap as assessed by videonasopharyngoscopy is merely an estimate and not hard data. In other words, inter-observer reliability is not statistically significant. This is why the gaps are conventionally assessed in 10-point intervals (10–20–30%, and so on). It should be pointed out that the endoscope was passed further into the vocal tract in order to assess the vocal folds. All patients showed normal mobility of both vocal folds and no masses were identified in any of the cases. No stroboscopy was performed.

Acoustic assessments were performed according to the protocol that was previously reported [16,17]. The patients and subjects