Relação entre voz e percepção de fala em crianças com implante coclear*****

Relationship between voice and speech perception in children with cochlear implant

Ana Cristina de Castro Coelho*
Maria Cecília Bevilacqua**
Gisele Oliveira***
Mara Behlau****

*Fonoaudióloga. Especialização em Voz pelo Centro de Estudos da Voz. Endereço para correspondência: Praça Wenceslau Brás, 74 - Apto. 21 - Itajubá - MG - CEP 37500-038 (anacrisccoelho@yahoo.com.br).

**Fonoaudióloga. Professora Titular da Universidade de São Paulo e da Pontifícia Universidade Católica de São Paulo.

***Fonoaudióloga. Mestre em Distúrbios da Comunicação Humana pela Universidade Federal de São Paulo - Escola Paulista de Medicina (Unifesp - EPM). Vice-Coordenadora do Curso de Especialização em Voz do Centro de Estudos da Voz.

****Fonoaudióloga. Doutora em Distúrbios da Comunicação Humana pela Unifesp - EPM. Coordenadora do Curso de Especialização em Voz do Centro de Estudos da Voz do Programa de Pós-Graduação em Distúrbios da Comunicação Humana da Unifesp - EPM.

*****Trabalho Realizado no Centro de Estudos da Voz e na Universidade de São Paulo - Hospital de Reabilitação de Anomalias Crânio-Faciais - Centro de Pesquisas Audiológicas - Bauru - SP.

Artigo Original de Pesquisa

Artigo Submetido a Avaliação por Pares

Conflito de Interesse: não

Recebido em 28.08.2008.
Revisado em 08.12.2008.
Aceito para Publicação em 03.02.2009.

Abstract

Background: the use of cochlear implant results in the optimization of speech perception, and, as a consequence in the development of oral language, speech and voice of its users, demonstrating to be one of the most effective and promissing technologies to remediate hearing loss . However, little has been studied about the relationship between auditory skills and the voice of children using cochlear implants. Aim: to relate the speech perception abilities to the vocal characteristics of cochlear implant users. Method: perceptive and acoustic analysis of the long vowel /a/ and counting of numbers were carried out. This analysis was compared to a standardized speech perception protocol, that evaluates the recognition of words, its phonemes and consonants. Results: it was observed that the higher the recognition of consonants, the higher the maximum frequency, standard deviation of the fundamental frequency and average of intensity during the sequential speech, as well as fundamental frequency average during the emission of the vowel /a/. Also, the higher the recognition of consonants, the lower the standard deviation of the quality of voice and resonance in the perceptive-auditory analysis. Conclusion: among the children with cochlear implants, the ones with better speech perception abilities present lower perceptive-auditory deviations of the quality of voice.

Key Words: Voice; Quality of Voice; Cochlear Implant.

Resumo

Tema: o uso do implante coclear resulta na otimização da percepção de fala, e conseqüentemente no desenvolvimento da linguagem, fala e voz de seus usuários, sendo que tem se mostrado uma das tecnologias mais efetivas e promissoras para remediar a perda auditiva. Entretanto, pouco tem sido estudado sobre a relação das habilidades auditivas com a voz de crianças implantadas. Objetivo: relacionar as habilidades de percepção de fala com características vocais de crianças usuárias de implante coclear. Método: foram realizadas análises perceptivo-auditiva e acústica da vogal sustentada /a/ e da contagem de números. Essa análise foi comparada a um teste de percepção de fala padronizado que avalia o reconhecimento de palavras, seus fonemas e consoantes. Resultados: observou-se que quanto maior o reconhecimento de consoantes, maior a freqüência máxima, desvio padrão da freqüência fundamental e média de intensidade durante a fala encadeada, assim como a média da freqüência fundamental na análise da emissão da vogal /a/. Além disso, quanto maior o reconhecimento de consoantes menor o desvio geral da qualidade vocal e da ressonância. Conclusão: dentre as crianças com implante coclear, as que possuem melhor habilidade de percepção de sons da fala apresentam menores desvios perceptivo-auditivos na qualidade vocal.

Palavras-Chave: Voz; Qualidade da Voz; Implante Coclear.

Referenciar este material como:
Coelho ACC, Bevilacqua MC, Oliveira G, Behlau M. Relationship between voice and speech perception in children with cochlear implant (original title: Relação entre voz e percepção de fala em crianças com implante coclear). Pró-Fono Revista de Atualização Científica. 2009 jan-mar;21(1):7-12.

Introduction

The voice varies according to the context of speech and to the physical and psychological conditions of the human being, and so there is always a basic voice production pattern. Some factors, which include hearing loss, can bring disadvantages to the voice production that can cause social, educational, and speech limitations, with specific deviation on the communication related to speech and voice. Usually the voice is not the main focus of the speech-language pathology therapy with the hearing impaired, but its deviations can represent such a negative impact on this population that it can interfere on speech intelligibility and crucially compromise the social integration of the individual.

The commonly found vocal deviations include strain, breathiness, roughness, monotone, absence of rhythm, unpleasant quality (1), hoarseness, vocal fatigue, high pitch, reduced volume, loudness with excessive variation, unbalanced resonance, altered breathing pattern, hard vocal attack, and imprecise articulation (2). These characteristics are justified by the incapability of the deaf to control their vocal performance due to the lack of auditory monitoring of their own voice, caused by the hearing loss. Hence, the development of an intelligible speech with a good quality of voice on the hearing impaired is a challenge, despite the sophisticated technological advances of hearing aids and cochlear implant to optimize the residual hearing.

The cochlear implant is an electronic device, which partially performs the function of the sensorial cells of the cochlea and stimulates directly the auditory nerve, promoting great results of the communication and speech perception abilities of its users. Its indication for younger and younger children has been widely discussed because of the importance to facilitate the access to oral speech during the years or during the critical periods of speech acquisition, reducing the effects of the hearing loss (3). When done prematurely, the cochlear implant allows a speech development similar to normality after a certain period of use (4). Nowadays the implantation surgery is done with children from 12 months of age and in some international services even younger children have been implanted. The selection criteria include age, extension of the hearing loss and the results obtained with hearing aids (5). The cochlear implant brings global benefits for the expressive and receptive speech, including improvement of the voice quality. It results on the optimization of speech perception, and consequently on the oral communication of its users, and it has shown to be one of the most effective and promising technologies to amend hearing loss.

With the purpose of evaluating specific aspects of speech perception, researchers have developed strategies that use different types of speech stimuli. Delgado and Bevilacqua (6) proposed a speech perception evaluation procedure for children, who are hearing impaired. The protocol consists of a list containing twenty disyllable words with a consonant-vowel/consonant-vowel syllabic structure, containing every vowel and almost every consonant of the Portuguese language, in the beginning and middle of the words. The authors attributed scores for getting the right answer on words, right answer on phonemes (both vocalic and consonantal) and right answer on consonants. This subdivision of words into phonemes and consonants was done to try to establish which phonemic contrasts the child is able to hear, whereby a high rate of phoneme recognition, including consonant phonemes, suggests a good perception of determined sounds of speech.

The distinctive traces of consonant phonemes are harder to be recognized by the hearing impaired than the vocalic phonemes, and for that reason the analysis of the right answers of consonants was proposed. In the results of the study that proposed this test, it was concluded that the number of right answers of whole words was significantly lower than the number of right answers of phonemes contained in these words, because there are combinations the child is not capable of recognizing.

Many studies, although some are controversial, have shown the main vocal characteristics of cochlear implant users, such as significant decrease of fundamental frequency with the use of implant (7), normalization of speech loudness control, but not of the fundamental frequency (8), normal fundamental frequency and speech intelligibility (9), improvement of pitch deviation and of prosody of the deaf after six months of implantation, although with maintenance of resonance, rhythm , loudness and quality of voice deviations (10), decrease of hypernasality (11) and improvement of articulation (12).

The motor adjustments used so that a determined quality of voice is produced depend widely on hearing. The evaluation of the auditory-phonemic discrimination is normally poor on the

hearing impaired with vocal deviations. Therefore, it is vital that the auditory abilities are preserved, including good speech recognition for a good voice production (13).

The literature shows that the cochlear implant, besides all the auditory benefits, also brings great advantage to voice production. However, little has been studied about the relation between auditory abilities and the voice of children with cochlear implants.

Therefore, this study aims to relate the speech perception abilities with voice characteristics of children who are users of cochlear implants.

Method

This study received approval of the Ethics Committee on research of Centro de Estudos da Voz (CE-CEV 0115/07) and of the Ethics Committee of Research on Human Beings of the HRAC-USP (art 297/2007).

The parents/answerable were contacted so that the children could participate in the study, and, if in agreement, received the letter of information and the term of consent about the study and the guarantee of secrecy about any identification information of the child, according to orientation of the resolution of October 10th, 1996 of the National Health Board on studies with human beings.

Twenty five severe to profound hearing impaired children, all implanted at HRAC/USP, with five to ten years of age in the time of the surgery, users of the Nucleus 24k implant participated in this study.

The inclusion criteria were congenital severe to profound sensorineural bilateral hearing loss, absence of intellectual or emotional disorders, participation of the child in a rehabilitation program in the home-town and being a cochlear implant user for at least three years, with hearing threshold average of 500Hz, 1KHz, 2KHz and 4KHz lower or equal 30 dB.

From each participant the production of the vowel /a/ and of the counting of numbers from one to ten were recorded. The recording was done through a voice recording system in the Voice Lab of the Speech-Language Pathology Clinic of the College of Odonthology of the University of São Paulo. For the recording, the Sony Sound Forge program - Sony Pictures Digital Inc. Version 7.0, headset H 74 with plug P10 - Leson, positioned at 45º with a 3cm distance form the mouth, and pre-amplifier Voice Range Profile Preamplifier-Kay were used. The voice samples were recorded with a sampling rate of 44.100Hz and Mono channel on 16bit. The perceptual evaluation was done by three judges, specializing in voice, using a linear analogical scale in crescent order. The selected parameters were the grade of dysphonia, roughness, breathiness, instability, pitch, loudness, and resonance deviations. Each judge received a CD containing the two voice samples, which were analyzed separately so it wasn't possible to identify the subject the sample belonged to.

The acoustic analysis of the vowel /a/ was performed with the Multi-Dimensional Voice Program Advanced, and Multi-Speech of Kay Lab programs, which was also done in the Voice Lab of the Speech-Language Pathology Clinic of the College of Odonthology of the University of São Paulo. The parameters selected for the analysis of the vowel /a/ were the mean fundamental frequency, standard deviation of fundamental frequency, jitter, shimmer, noise to harmonic ratio (NHR), soft phonation index (SPI) and vocal turbulence index (VTI). The acoustic parameters analyzed were mean, minimum and maximum fundamental, and standard deviation of the frequency, mean, minimum and maximum intensity, and standard deviation of the intensity. In addition, the charts of the subjects were analyzed for the extraction of data from the Speech Perception Test previously described. The data extracted were the percentages of right answers of phonemes and consonants, once theses scores give sufficient information to determine the level of auditory recognition of the child (6).

The statistical analysis of the studied variables was done through the Correlation of Spearman, with a 5% significance level. The test was used for the comparison of acoustic and perceptive parameters with the phonemes and consonant perception score of the speech perception test proposed (6).

Results

On the perceptual analysis, it was observed that the higher the consonant scores, the greater the deviation of loudness ($p = 0,030$), and the smaller the deviation of the grade of dysphonia ($p=0,037$) and of resonance ($p = 0,049$). Moreover, it is worth to mention that the higher the recognition of phonemes and consonants, the lower the standard deviation of the sequential speech ($p = 0,055$) and the higher the consonant recognition, the lower strain ($p = 0,061$) and pitch ($p =0,072$) of the sustained vowel /a/ (Table 1).

The acoustic data found, when compared to the values of normality provided by Kay Elemetrics for pediatric analysis (14), suggested that all the studied

acoustic parameters, except the mean fundamental frequency and soft phonation index, are altered, with values above normality (Table 2).

In correlation to acoustic and speech perception, it was observed that the higher the consonant recognition, the greater the maximum frequency (p= 0,026), the standard deviation of the fundamental frequency (0,011) and the intensity mean during the sequential speech (0,014), as well as the fundamental frequency (p=0,020) and the mean fundamental frequency (p= 0,020) in the analysis of the vowel /a/ (Table 3).

TABLE 1. Correlation between the auditory-perceptive analysis of the quality of voice of the prolonged vowel and of the sequential speech with the scores of phonemes and consonants of the speech perception test (TPF).

Speech Material	TPF Phonemes		TPF Consonants	
	Corr	p-value	Corr	p-value
Vowel /a/				
Grade	26,1%	0,207	39,9%	0,037*
Roughness	25,5%	0,219	24,6%	0,236
Breathiness	-18,3%	0,380	-5,6%	0,789
Strain	24,2%	0,244	38,0%	0,061
Pitch	43,4%	0,030*	36,6%	0,072
Loudness	30,5%	0,138	43,4%	0,030*
Resonance	21,3%	0,308	39,8%	0,049*
Instability	11,2%	0,593	12,1%	0,563
Sequencial Speech				
Grade	38,8%	0,055	33,7%	0,100
Roughness	8,3%	0,695	21,2%	0,308
Breathiness	3,3%	0,877	12,6%	0,547
Strain	27,6%	0,182	14,9%	0,478
Pitch	9,8%	0,641	-4,8%	0,821
Loudness	14,7%	0,484	-9,1%	0,667
Resonance	15,9%	0,447	12,9%	0,538
Instability	24,1%	0,246	20,8%	0,319

TABLE 2. Comparison between the acoustic findings with values of reference of normality of the Main F0, Mean F0, and SD F0 (in Hz), jitter (%), shimmer (%), VTI (%), SPI (%), and of the NHR (%).

Acoustic Parameters	Normality	Mean of the found values
F_0 mean	279,05	261,93
F_0 DP	4,86	7,00
Jitter	1,24	1,32
Shimmer	3,35	3,73
VTI	0,05	0,06
SPI	9,8	4,99
NHR	0,11	0,13

F0: Fundamental Frequency; VTI: Voice turbulence Index; SPI: Soft Phonation index; NHR: Noise to harmonic ratio.

TABLE 3. Correlation between the acoustic parameters of the main, mean and SD of the F0 (in Hz), jitter (%), shimmer (%), of the VTI (%), SPI (%) and NHR (%) in the prolonged vowel, and of the mean, minimum, maximum and SD of the F0 (in Hz) in the sequential speech with the scores of phonemes and consonants of the speech perception test.

Speech Material	TPF Phonemes		TPF Consonants	
	Corr	p-valor	Corr	p-valor
Vowel /a/				
Mean F_0	38,2%	0,059	46,1%	0,020*
SD F_0	36,1%	0,076	28,8%	0,162
Jitter	4,7%	0,822	15,5%	0,460
Shimmer	16,8%	0,422	18,1%	0,386
VTI	23,3%	0,261	23,2%	0,265
SPI	-17,2%	0,411	-28,7%	0,165
NHR	11,4%	0,587	18,9%	0,366
Sequential speech				
Min F_0	-32,9%	0,108	-16,2%	0,440
Max F_0	36,8%	0,070	44,4%	0,026*
Mean F_0	-18,0%	0,389	-27,0%	0,191
DP F_0	39,0%	0,054	49,9%	0,011*
Min amp	-14,4%	0,491	6,0%	0,776
Max amp.	6,6%	0,756	8,1%	0,701
Mean Amp	27,5%	0,184	48,7%	0,014*
Sd Amp	18,3%	0,382	-5,5%	0,794

F0:: Fundamental Frequency; VTI: Voice turbulence index; SPI: Soft phonation index; NHR: noise to harmonic ratio.

Discussion

It was observed that the higher the score of consonants, the higher the deviation of loudness, as found in other studies (10), as well as the lower standard deviation of the quality of voice and resonance (Table 2). In addition, it was observed that the higher the score of consonants and phonemes, the lower the standard deviation of the sequential speech. These findings suggest that not only do the cochlear implants bring benefits for speech perception, but they also provide the auditory feedback necessary for a balanced voice production (11) and that these factors are entwined. Furthermore, the results show that the higher the consonant recognition, the lower the strain and pitch of the sustained vowel, which is also in favor of greater voice stability with the use of an implant. However, these findings contradict a few authors (7), who did not find correlation between speech recognition and speech production.

The comparison of the acoustic data found in the production of the vowel /a/ with reference values of normality suggest that every studied parameter, except the mean fundamental frequency and soft phonation index (SPI), are altered, with values above normality, indicating that the hearing impaired, even cochlear implant users present jitter, shimmer, noise to harmonic ratio, and vocal turbulence index altered.

It was observed that the higher the consonant recognition, the higher the maximum frequency, the standard deviation of the fundamental frequency and the higher mean intensity during the sequential speech, which can mean that children with better speech recognition present better conditions to present a richer intonation in terms of frequency and intensity during speech. Besides, the children with greater consonant recognition present higher mean fundamental frequency and lower standard deviation of the fundamental frequency in the analysis of the vowel /a/, suggesting that the subjects with higher speech recognition, although presenting a high pitched production of the vowel /a/, present more stability of it (Table 1). These findings are in agreement with a few authors (7) and in contraposition with others, who did not find any influence of the cochlear implant of the fundamental frequency, whereby only the intensity control was normalized with its use (8).

The remaining acoustic parameters, although altered, were not sensitive enough to do an accurate relation with speech perception abilities.

In a generic way, the results found demonstrate that there is a positive relation between speech perception abilities and a good voice production, as other authors assert (13), reporting that children with voice deviations present poor speech perception abilities. Cochlear implants bring significant benefits for hearing impaired children in prosodic and vocal terms. In addition, a few statements (1-2) about the voice characteristics of the hearing impaired do not apply to prematurely implanted children

Conclusion

There is a direct correlation between some vocal parameters with speech perception abilities, which are the main impact of voice deviation, the resonance deviation, strain deviation and pitch deviation. Hence, children with cochlear implant and better speech perception abilities present lower auditory-perceptive deviations of the quality of voice. It is important that the auditory skills are preserved, among them a good speech recognition for a good voice production.

References

1. Wirz SL, Subtelny JD, Whitehead RL. Perceptual and spectrographic study of tense voice in normal hearing and deaf subjects. Folia Phoniatr. 1981;33(1):23-36.

2. Hocevar-Boltezar I, Vatovec J, Gros A, Zargi M. The influence of cochlear implantation on some voice parameters. Int J Pediatr Otorhinolaryngol. 2005 dec;69(12):1635-40.

3. Frederigue NB, Bevilaqcua MC, Otimização da percepção da fala em deficientes auditivos usuários do sistema de implante coclear multicanal Rev. Bras. Otorrinolaringol. 2003 mar-abr;69(2):227-33.

4. Stuchi RF, Nasciemento LT, Bevilacqua MC, Brito Neto RV. Linguagem oral de crianças com cinco anos de uso do implante coclear. Pró-fono. 2007 abr-jun;19(2):167-76.

5. Moret AML, Bevilacqua MC, Costa OA. Implante coclear: audição e linguagem em crianças deficientes auditivas pré-linguais. Pró-Fono - Barueri (SP). 2007 jul-set;19(3):295-304.

6. Delgado EMC, Bevilacqua MC. Lista de palavras como procedimento de avaliação da percepção dos sons da fala para crianças deficientes auditivas. Pró-fono. 1999;11(1):59-64.

7. Hamzavi J, Deutsch W, Baumgartner WD, Bigenzahn W, Gstoettner W. Short-term effect of auditory feedback on fundamental frequency after cochlear implantation. Audiology. 2000 mar-apr;39(2):102-5.

8. Campisi P, Low A, Papsin B, Mount R, Cohen-Kerem R, Harrison R. Acoustic analysis of the voice in pediatric cochlear implant recipients: a longitudinal study. Laryngoscope. 2005 jun;115(4):1046-50.

9. Perrin ME, Berger-Vachon C, Le Dissez C, Kauffmann I, Morgon A. The normality of the voice of cochlear implant children. Advances in Otorhinolaryngology. 1995;50(2):167-73.

10. Lenden JM, Flipsen Jr P. Prosody and voice characteristics of children with cochlear implants. Journal of Communication Disorders. 2006 jan-feb;40(1):66-81.

11. Nguyen LH, Allegro J, Low A, Papsin B, Campisi P. Effect of cochlear implantation on nasality in children. Ear, nose throat J. 2008 mar;87(3):140-3.

12. Kunisue K, Fukushima K, Nagayasu R, Kawasaki A, Nishizaki K. Longitudinal formant analysis after cochlear implantation in school-aged children. 2006 dec, Int J Pediatr Otorhinolaryngol. 70(12):2033-42.

13. Buosi MMB. A interdependência entre habilidades auditivas e produção vocal. Fono Atual. 2002 abr-jun;5(20):54-7.

14. Campisi P, Tewfik TL, Manoukian JJ, Schloss MD, Pelland-Glais E, Sadeghi N. Computer-Assisted Voice Analysis: Establishing a Pediatric Database. Arch Otolaryngol Head Neck Surg. 2002 feb;128:156-60.