Vowel Space Area in Children Using Cochlear Implant

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Abstract

This study investigated vowel space area in children with unilateral cochlear implant (CI) and compared it with typically developing (TD) children. More specifically, this study compared the vowel space characteristics across the short vowels /a/,/i/, /u/ in word medial position in Tamil. Subjects were divided into two groups. Group I consisted of 10 children with unilateral cochlear implant (CI) in the age range of 3 to 11 years. Group II consisted of 10 age matched peers. Pictures for the three words with short vowels /a/, /i/ & /u/ in the word medial position were prepared and presented to children individually and were instructed to name them. Audiorecording of naming was done using Computerized Speech Lab 4500 and formants 1 and 2 were extracted. Using the frequency values of formant 1 and 2, vowel triangle was plotted. The formant values and vowel triangle space were compared between the groups. Results of the study showed significant differences in first and second formant frequencies between the groups and a smaller vowel space area for children using CI. The reduced vowel space area represents deviant articulation abilities in children with CI when compared TD children during vowel production.

Keywords: Vowel space area, Tamil language, Cochlear implant, Formant frequencies

Introduction

Speech is an oral expression of language which constitutes voice, fluency, articulation, resonance and prosody. Speech is used as the primary mode of communication by most of the humans. Hearing plays a crucial role in the development of speech and language in children. Thus, children with hearing impairment have significant delay in the speech and language skills. Cochlear implant is one among the various management options that is available for individuals with hearing loss. A cochlear implant is a device that provides direct electrical stimulation to the auditory nerve in the inner ear. Children and adults with a severe to profound hearing loss are benefited with cochlear implants. Following Cochlear implant surgery, auditory verbal training is essential for acquiring listening, language, and speech skills which would in turn improve their speech intelligibility. Speech intelligibility is influenced by accurate, precise production of speech sounds. Speech sounds consists of vowels and consonants. Vowelsare produced witha minimal constriction of vocal tract.

The vowel space is an acoustic measure for indexing the size of the vowel articulatory working space. It is a graphical method to represent vowels, and their location in both acoustic and articulatory space. Vowel space is constructed using the first and the second formant frequencies (F1 and F2) of vowels /a/, /i/ and /u/, (Fant, 1973). Vowel working space (VSA) area signifies gross motor ability of the tongue and jaw coordination. Vorperian and Kent (2007) examined acoustic data on development of vowel production in children. From the findings, vowel development is expressed acoustically as, (a) establishment of a language-appropriate acoustic representation (e.g., F1-F2 quadrilateral or F1-F2-F3 space), (b) gradual reduction in formant-frequencies and F1-F2 area with age, (c) reduction in formant-frequency variability, (d) emergence of male-female differences in formant-frequency by age 4 years with more apparent differences by 8 years, (e) jumps in formant-frequency at ages corresponding to growth spurts of the vocal tract, and (f) a decline of F_0 after age 1, with the decline being more rapid during early childhood and adolescence.

Few studies investigated vowel formants and vowel space area in individuals with cochlear implantation. Hocevar-Boltezar, Boltezar and Zargi (2008) studied the influence of cochlear implantation on vowel articulation in13 prelingually deaf children and 12 postlingually deaf adults. Voice samples of vowels /a/, /i/ and /u/ were analyzed before and 6-12 months after the implantation. The frequencies of the first (F1) and second (F2) formants, the F1/F2 ratio of all three corner vowels, and the area of the vowel triangle were calculated and compared before and 6 to 12 months following the implantation. In adults, no significant differences in the formant frequencies, the F1/F2 ratio or the area of the vowel triangle was seen before and after the implantation. However, significant change in formant frequencies was detected in the group of 13 prelingually deaf children. The results also suggest that the area of the vowel triangle is a useful and sensitive indicator of the more precise articulation after implantation. Another study by Neumeyer, Harrington and Draxler (2010) compared the vowel spaces in 10 adult-cochlear implantees with age-matched normal hearing control group acoustically. The results showed no differences between the two groups on Euclidean distances for the first formant frequency. In contrast, Euclidean distances for F2 of the CI group were shorter than those of the control group, resulting in reduced vowel space.

In Indian scenario, a study on vowel production in CI children was carried out in Hindi. Kant, Patadia, Govale, Rangasayee and Kirthane (2012) compared the acoustic characteristics of speech in children using CI with TD children. Sustained productions of vowels and words with selected consonants were recorded using Praat software. The speech tokens were measured for F1, F2, and F3 of vowels, centre frequency (Hz) and energy concentration (dB) in burst; voice onset time (VOT in ms) for stops; centre frequency (Hz) of noise in /s/; rise time (ms) for affricates. Results revealed significant difference in the voice onset time (VOT) for /b/, F1 and F2 of /e/, and F3 of /u/ between the groups. The study implicated that acoustic analysis of speech is an essential method for understanding characteristics which have or have not been improved by cochlear implantation and thus for planning intervention.

From the above studies, it is evident that children with hearing impairment have affected articulation due to which vowel space area can vary and also, these studies have been carried out in languages like English (Hocevar-Boltezar, Boltezar & Zargi (2008), Neumeyer, Harrington & Draxler, 2010) and Hindi (Kant, Patadia, Govale, Rangasayee & Kirthane, 2012). There are no studies reported in CI children in Tamil speaking environment. Considering vowel working space area as an index of accuracy of the articulation, the present study was planned to compare the vowel space area in children with unilateral cochlear implant with typically developing children from Tamil speaking environment. This provides a baseline data on the vowel space area of children with unilateral cochlear implant which can be helpful in intervention program. The main aim of the study is to investigate the vowel space area in children using unilateral cochlear implant (CI) and to compare it with typically developing (TD) children.

Method

The study was conducted in children between the age of 3 and 7 years. Subjects were divided into two groups. Group I consists of 10 children with CI and Group II consists of 10 TD children with the same age from Tamil speaking environment. Children with bilateral cochlear implant, multiple disability or children who have associated neurological conditions were excluded from the study. Children with unilateral cochlear implant who participated in this study had attended 6 months of auditory verbal training which focuses specifically on developing listening and language skills.

Data was collected individually for each child in a silent room. Familiar words withshort vowels /a/, /i/, and /u/ in their medial position in Tamil were selected. The words thus selected were /k ʌ n/ (eye), /k i l I/ (parrot)and /m ʊ d I/ (hair). Pictures of the selected words were presented to the children thrice in a random order and they were asked to name them. Verbal outputs obtained from them were recorded using Computerized Speech Lab 4500 with the help of Zebronic microphone which was placed at the distance of 10cm from the speaker's mouth. From the spectrographic display of the words, frequencies of F1 and F2 of vowels /a/, /i/ and /u/ were obtained. Mean values of the formants were plotted on F1-F2 plane for all the three vowels and the vowel space triangle was obtained for both the groups. The vowel space area was then calculated from frequencies of F1 and F2 of vowels /a/, /i/ and /u/ values using the equation,

Vowel space area= ABS {[F1i * (F2a- F2u) + F1a * (F2u - F2i) + F1u* (F2i -F2a)]/2}
Where "ABS" is absolute value.

SPSS-20 was used for statistical analysis. Mean and standard deviation (SD) of the formant frequencies were obtained and paired t test was used to compare the mean values of F1 and F2 between the groups.

Results and Discussion

For vowel /a/, the mean values of the F1 in children using CIare lower than the TD age matched peers and mean of F2 is higher in children with CI. The mean values of F1 and F2 for vowel /i/ in children using CI are significantly higher than the TD age matched peers. Similarly, for the vowel /u/ the mean values of F1 and F2 in children using CI are higher than the formant frequencies in TD children. Paired t test revealed significant difference(p=0.00) in frequency of F1 and F2 across the vowels /a/, /i/ and /u/ between the groups. Mean values, standard deviations and 'p' values of formant frequencies (F1 and F2) across the vowels /a/, /i/ and /u/ for both groups are provided in table 1.

Formants	/a/					/i/					/u/				
	CI		TD		p value	CI		TD		P value	CI		TD		P value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
F1 (Hz)	506.2	35.6	813.1	88.4	0.00*	634.8	49.8	412.9	64.4	0.00*	553.86	40.00	387.4	63.9	0.00*
F2 (Hz)	2132.5	212.7	1464.4	374.8	0.00*	2388.9	169.8	2195.6	200.3	0.03*	2352.8	146.36	1383.4	412.04	0.00*

Table 1: Mean, SD and 'p' values of F1 and F2 across the vowels /a/, /i/ and /u/ in CI and TDchildren. *-significant difference.

Vowel space (triangle) area calculated indicated that children with CI have reduced area compared to TD group. Table 2 shows vowel space area in children.

Group	Vowel Space area (Hz^2)
CI	8221.67
TD	171844.02

Table 2: Vowel space area in children

Reduced vowel space area indicates a restriction of tongue elevation and front-back movement for the children with CI when compared to TD children in vowel production. Figure 1 shows the vowel space area of children in both groups.

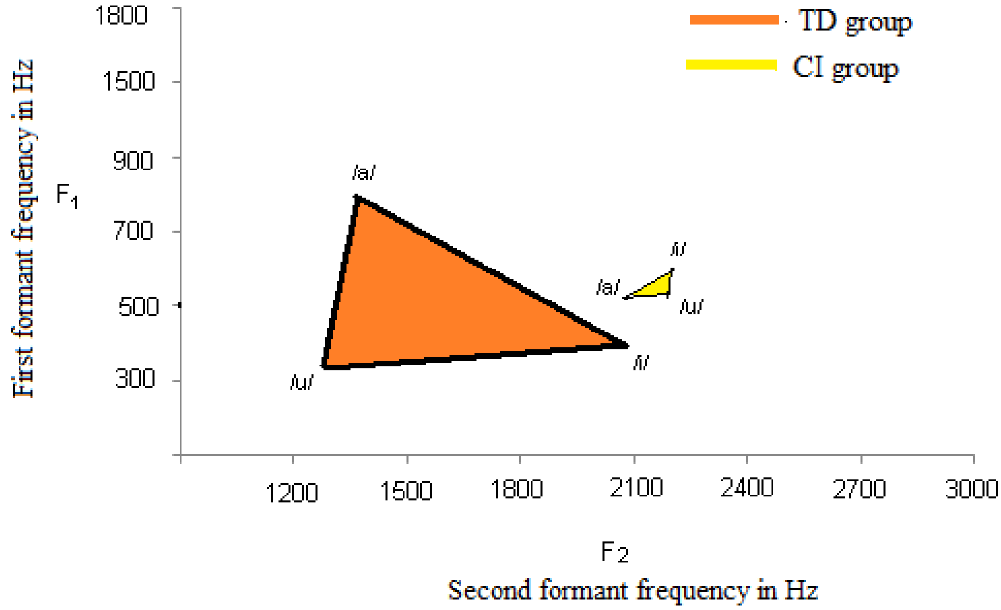

Figure 1: Vowel space area in children with CI and TD children.

The results obtained clearly shows that there is a significant difference in frequency of F1 and F2 between the groups and smaller vowel space area for children with CI when compared with TD children which indicates impaired articulatory abilities and a delay in development of distinct vowel articulatory position for children with CI. This is due to reduced hearing and perceptual abilitiesprior to cochlear implantation and the delay in targeting articulatory skills following CI. Children with CI whoparticipated in the study had attended 6 months of auditory verbal training withspecific focus on listening and language skills. Focusing on articulation therapy along with language training would help in acquiring distinct vowel production, thereby aid in enhancing speech intelligibility.Similar results are obtained by Neumeyer, Harrington & Draxler (2010) where the Euclidean distances for F2 of the CI group were shorter than those of the control group, resulting in reduced vowel space.

Conclusion

The children with CI exhibited smaller vowel space when compared to age matched TD children. The present study reported findings of CI children at 6 months following auditory verbal therapy. The follow up study of these children at regular interval at 1 year, 1.5 year, 2 years, and so on would reveal a developmental trend in their articulation abilities.

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