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ORIGINAL ARTICLE

The effect of intensive auditory training on auditory skills and on speech intelligibility of prelingual cochlear implanted adolescents and adults

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KEYWORDS

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Abstract *The aim of the study:* To study the effect of intensive auditory training using the modified version of the Arabic rehabilitation program for adults on both the auditory skills and the degree of speech intelligibility.

Materials and methods: The study was conducted on 30 patients who were divided into two groups according to intensiveness of the auditory training. Each group included 15 patients (10 males and 5 females). Both groups received the usual therapy program provided for cochlear implanted patients. Group (I) received an additional therapy other than the usual form. Minimal Auditory Capabilities Test (MAC Test) was used to assess auditory perception abilities and Speech Intelligibility Rating Scale (SIR) was used to assess speech production skills before implantation and at 3, 6, 12, 18 months post-operatively.

Results: A significant difference was found when comparing the two groups in spondee discrimination during the post-operative assessment periods, of 3, 6, 12, and 18 months with P value <0.05.A highly significant difference was found for spondee recognition, sentence identification and high context sentence recognition at the 18 month assessment with P value <0.01. A significant

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mean difference with P value < 0.05 for speech intelligibility scores at 18 months post implantation was found between the two groups.

Conclusion: The effectiveness of the modified form of the Arabic Adult rehabilitation was revealed in this study. Using more intensive auditory rehabilitation may result in a better improvement in auditory abilities and speech intelligibility of the prelingually deafened adult cochlear implanted population.

1. Introduction

Despite an early age at onset of deafness, patients in the prelingually deafened adult population achieve substantial speech perception benefits from a cochlear implant. As a result, clinicians are faced with increasing numbers of patients from this population seeking implantation. According to Teoh et al.[1] there are many factors which are responsible for large inter-individual differences in post-implant audiological outcomes. It is well known that the prelingually deafened population consists of individuals who may differ from each other on a large number of factors, such as etiology, age at onset of deafness, age of identification and first hearing aid (HA) fitting, education and communication training received in childhood, communication mode in adulthood, speech production abilities, residual hearing, and use of HAs and the type and intensiveness of the auditory training received after the cochlear implant.[1]

Auditory training aims to increase auditory skills to enhance the individual's ability to pick up the acoustic cues required for acquisition of auditory skills. Erber[2] defined auditory training as the process of training a person's residual hearing ability and suggested that an auditory training as intervention program should consist of four stages. The stages are detection, discrimination, identification and comprehension of sounds of speech. There are two main auditory training approaches, synthetic and analytic. The synthetic (or top down) approach focuses on gaining the meaning of a message through various communication strategies, such as improved hearing, attention, use of context and repair strategies.[3] In the analytic approach (bottom up), the exercises concentrate on the recognition of individual sounds and words, rather than work at the sentence, or meaning level. A combination of both approaches is also commonly used.

One of the measures of outcome that is used to assess the benefit of cochlear implantation of the prelingually deafened population is the degree of improvement in their speech intelligibility. Speech intelligibility is defined as the degree to which acoustical signal is understood by a listener. It is also expressed as a percentage of words, sentences, or phonemes (speech sounds) correctly identified by a listener or a group of listeners when spoken by a talker or a number of talkers.[4] Hearing impairment affects speech intelligibility both at segmental and supra-segmental levels.[5] The extent to which these parameters are affected depends on the degree and duration of hearing loss. The more severe and the longer duration of the hearing loss, the more severe is the unintelligibility.[6]

The authors of this work believe that the more the intensiveness of auditory training in the post-implantation period, the more is the reflection on their speech intelligibility. A limited number of studies measured the effectiveness of these programs on both auditory skills and speech intelligibility in this group of prelingually deafened adult implanted patients. In addition, there are increased numbers of those patients who get the chance of being implanted.

This work aims at studying the effect of intensive auditory training using the modified version of the Arabic rehabilitation program for adults on both the auditory skills and the degree of speech intelligibility.

2. Material and methods

2.1. Study design: prospective intervention study

The study was conducted on 30 patients who attended the outpatient clinic of Phoniatrics, of King AbdulAziz University Hospital and who were seeking post-implantation rehabilitation. All patients were reported with a history of pre-lingual hearing loss. Prelingual hearing loss was defined here as the presence of bilateral severe to profound hearing loss at or before the age of 4 years.[1] Twenty patients were males and 10 patients were females. The age range was 14.50–33 years. The etiology of hearing loss was meningitis in 2 patients, maternal Rubella in 6 patients and unknown in 22 cases.

The range of age at implantation was 14–32 years. All patients received the Nucleus multichannel cochlear implant (Cochlear Ltd., Australia).The subjects were programed with the recommended Speech processing strategy (ACE; The Advanced Combination Encoder Strategy for Nucleus implants).

All participants had a history of continuous HA use prior to implantation and variable periods of language therapy. The language level in both groups was assessed using the standardized Arabic language test[7] and revealed that language age range was 3–5 years. Seventeen patients were exposed to an oral environment where the oral communication or verbal language was the first mode of communication. The others (13 patients) were exposed to oral plus use of gestural communication. None of the patients had been exposed to an environment where primarily sign language was used.

All patients were exposed to an assessment of their auditory skills before and after implantation. MAC Test (Minimal Auditory Capabilities Test)[8] was used to assess auditory perception abilities before implantation then 3, 6, 12 and 18 months post-implantation period. MAC test includes the following 8 items: (1) Question statement identification, (2) Accent identification, (3) Vowel identification, (4) Initial consonant identification, (5) Spondee Discrimination, (6) Spondee Recognition, (7) Sentence identification, (8) High context sentence recognition. The score of each item was represented in a percentage form.

The Arabic version of the Speech Intelligibility Rating Scale (SIR)[9] which assesses speech production skills in a normal context was used at the same intervals before implantation and 3, 6, 12, and 18 months after implantation. It is used as a 5-point scale, where (1) represents the worst degree and (5) represents the most intelligible degree of speech intelligibility. The Arabic translation of the test scale was provided by (TeenEARS Test battery)[10] where validation of the translation was done by three bilingual speech language pathologists.

Three non-professional persons who were unfamiliar with the patients assessed the speech intelligibility using the former speech intelligibility rating scale. Spontaneous speech sample about a familiar topic or a chat about a daily activity was recorded. A reading passage for those who can read was also recorded. All three raters (who were fixed throughout the study) were asked to rate for the patients' intelligibility along the five point scale. Then the average score of the three raters was taken.

Auditory rehabilitation after implantation was done using the Saudi form of Arabic Rehabilitation Therapy program.[11]This program is based on the one used in Ain Shams University, Cairo, Egypt, after modification. It is based on a combination of both the synthetic and the analytic approaches. The modification was done mainly in the words and sentences used to match the Saudi dialect while preserving the important rules that govern each of the four rehabilitation levels. The modified version was reviewed by three Saudi speech language pathologists who documented the good use of the Saudi wording.

The 30 patients were classified into two groups. Group (I) included15 patients (10 males and 5 females). Group (II) included 15 patients (10 males and 5 females). Both GI and GII included 40% (6 patients) with severe to profound hearing loss and 60% (9 patients) with profound hearing loss at time of implantation (The two groups were matched, as much as possible, for age, duration and degree of hearing loss, as well as duration of language and speech therapy received prior to implantation).

Both groups received the usual therapy program provided for cochlear implanted patients. This is provided as a total of 15 one-hourly sessions scheduled along a 1-year interval. During these sessions, language and speech therapy are given, together with auditory training. However, Group (I) received an additional auditory training therapy other than the usual form of therapy. This was provided for patients in Group I in the form of one-hour weekly sessions over 6 months, and the patients were given parts of this auditory training program to be applied daily at home. The additional sessions tackled only auditory enhancement skills and the home tasks were only directed to auditory training. Group (II) patients were assigned under their group when they expressed their inability to attend extra sessions because they came from areas outside Riyadh city.

Data were represented as mean and standard deviations. Paired *t*-test was used to compare between preoperative and post-operative parametric results and Wilcoxon test for non-parametric variables for each group. Comparing the results of both groups was done using unpaired student-*t*-test for parametric results and Mann–Whitney test for non-parametric variables. For reliability measures Cronbach's Alpha was used for the detection of intra-class correlation coefficient. All tests were done using the Statistical Package for the Social Sciences, version 20 (SPSS Inc., Chicago, IL).

3. Results

3.1. Descriptive data

Table 1 shows the descriptive statistics of both groups concerning their chronological age, age of hearing loss discovery, duration of hearing aid use prior to implantation, and age at implantation.

3.2. Auditory perception skills

Statistically significant improvements were detected in both groups when comparing the pre-operative evaluation versus post-operative evaluations using paired *T*-test (or Wilcoxon test). These results are shown in Table 2 as the sign (**) on the mean and the SD in each column of the table. The scores reflecting improvements continued to increase gradually through the post-operative evaluations.

In each evaluation, the scores obtained from each group were compared by unpaired *T*-test (or Mann–Whitney test) to detect the difference between the two groups. These results are shown along the rows of the table at each evaluation. Up till the 18 month evaluation, no significant difference was detected between both groups in the items Q/S identification, accent identification, vowel identification and initial consonant identification. Spondee discrimination revealed significant differences between the two groups in favor of Group I in all evaluations starting from the 3 month evaluation ($p < 0.05$). Spondee recognition, sentence identification, and high context sentence recognition revealed a highly significant difference between both groups, in favor of Group I, only at the 18 month evaluation (Table 2).

3.3. Speech intelligibility scores

The reliability measures for the assessment of the intelligibility showed positive intra-class coefficient between the three raters along the five intervals of assessment with *P* value of <0.001 before implantation and 3, 6, 12 months post-operatively and with P value of $<.01$ at 18 months postoperatively (Table 3). This reflects a high inter-rater agreement.

Table 1 Demographic data of the patients ($n = 15$ in each group) expressed as means and ± SD.

	Group I Means + SD	Group II Means + SD
Age of subjects (in yrs)	21.90 + 6.08	21.04 ± 5.92
Age of discovery of hearing loss (in yrs)	4.47 ± 1.73	3.72 ± 1.52
Duration of hearing aid use (in yrs)	12.80 ± 3.44	13.40 ± 3.80
Age at implantation (in yrs)	20.67 ± 6.18	19 ± 5.70

Table 2 Comparison between MAC Test results in Groups I (N = 15 Patients) and II (N = 15 patients) at the 5 evaluations and comparison between the pre-operative evaluation and the rest of the evaluations within each test group.

		Group I	Group II	Significance
Q/S Identification	Pre	2.47 ± 5.59	0.13 ± 0.52	>0.05
	3 months	36.40 ± 17.86**	28.93 ± 10.43**	>0.05
	6 months	49.07 ± 20.14**	47.73 ± 16.08**	>0.05
	12 months	65.40 ± 18.29**	63.67 ± 18.87**	>0.05
	18 months	78.87 ± 17.97**	69.27 ± 17.19**	>0.05
Accent Identification	Pre	2.87 ± 6.47	0.00 ± 0.00	>0.05
	3	31.80 ± 13.12**	41.00 ± 15.91**	>0.05
	6	52.33 ± 14.50**	59.67 ± 14.33**	>0.05
	12	67.27 ± 14.61**	74.33 ± 13.71**	>0.05
	18	81.27 ± 14.9**	76.80 ± 11.83**	>0.05
Vowel identification	Pre	2.73 ± 8.22	0.00 ± 0.00	>0.05
	3	30.00 ± 11.57**	34.00 ± 12.22**	>0.05
	6	48.40 ± 15.16**	49.73 ± 17.58**	>0.05
	12	63.40 ± 15.61**	65.27 ± 18.44**	>0.05
	18	74.13 ± 14.87**	69.27 ± 14.98**	>0.05
Initial consonant identification	Pre	5.53 ± 10.01	0.47 ± 1.36	>0.05
	3	29.53 ± 16.25**	27.47 ± 6.69**	>0.05
	6	47.47 ± 20.41**	47.60 ± 12.05**	>0.05
	12	61.07 ± 17.67**	62.53 ± 11.32**	>0.05
	18	76.27 ± 14.61**	65.80 ± 10.60**	>0.05
Spondee discrimination	Pre	**2.53 ± 2.55**	**0.53 ± 1.46**	**>0.05**
	3	47.80 ± 15.92**	34.87 ± 10.89**	<0.05 (S)
	6	67.80 ± 16.3**	52.87 ± 14.85**	<0.05(S)
	12	79.80 ± 12.73**	68.47 ± 13.81**	<0.05(S)
	18	89.27 ± 10.71**	69.60 ± 13.18**	<0.05(S)
Spondee recognition	Pre	2.20 ± 6.30	0.00 ± 0.00	>0.05
	3	26.80 ± 17.85**	28.00 ± 17.85**	>0.05
	6	45.93 ± 18.32**	46.27 ± 8.74**	>0.05
	12	73.47 ± 19.56**	65.67 ± 10.55**	>0.05
	18	85.73 ± 12.09**	67.87 ± 8.65**	<0.001 (HS)
Sentence Identification	Pre	2.20 ± 1.62	0.07 ± 0.26	>0.05
	3	31.20 ± 13.42**	28.60 ± 7.56**	>0.05
	6	53.20 ± 16.86**	48.80 ± 13.31**	>0.05
	12	65.13 ± 14.91**	62.47 ± 11.84**	>0.05
	18	78.67 ± 11.86**	64.40 ± 9.61**	<0.01 (HS)
High context sentence recognition	Pre	2.01 ± 1.72	0.00 ± 0.00	>0.05
	3	27.27 ± 8.54**	26.47 ± 6.32**	>0.05
	6	47.67 ± 12.17**	45.20 ± 9.88**	>0.05
	12	60.60 ± 13.25**	60.40 ± 12.29**	>0.05
	18	77.00 ± 11.46**	63.07 ± 10.95**	<0.01 (HS)

Abbreviations: n = number of patients; SD = Standard deviation, Q/S = question versus statement, S = significant difference between both groups, HS = highly significant difference between both groups

** = level of significance in comparison between pre-operative and post-operative assessment within the same group.

The Mean and SD were detected for the intelligibility degree at 2 periods of assessment (pre-operatively and at 18 months after implantation).On comparing the mean difference between both scores of each group, the difference was found to be significant with a P value of 0.024 (significant) (Table 4).

4. Discussion

Many professionals believe that prelingually deafened adults receive only minimal benefit from a cochlear implant. They typically do not develop open-set word recognition abilities.[12–14] However, many of these subjects were able to recognize environmental sounds and demonstrated lipreading enhancement with their cochlear implants. In addition, some

Table 3 showing the reliability measures for the speech intelligibility scores given by the raters.

Time of assessment	Intra-class coefficient	P value
Pre-operative	0.825	<0.001*
3 month post-operative	0.734	<0.001*
6 month post-operative	0.657	<0.001*
12 month post-operative	0.643	<0.001*
18 month post-operative	0.549	<.01*

* = significant.

Table 4 Showing the scoring of speech intelligibility given to both groups at the first and final assessment (18 months) together with comparison of the mean difference between them in each group.

	Group I (Mean + SD)	Group II (Mean + SD)	*P* value
Pre-operative speech intelligibility score	2.49 + 0.7	2.87 + 0.5	0.09
18 month speech intelligibility score	3.53 + 0.6	3.60 + 0.3	0.71
Mean difference between both scores (18 month score – pre-implant score)	1.04 + 0.35	0.73 + 0.36	0.024*

* = significant.

report improvements in their own speech production following implantation.[15] These reports, however, did not refer to the role of any rehabilitation programs on the outcome measures. We believe that the rehabilitation programs and their intensiveness may be mandatory to give full benefits of the implant. This study was done to examine this assumption using an Arabic adult rehabilitation auditory training program. This program was adapted to suit the Saudi dialect.

In the present study, patients in both groups were nearly controlled for a large number of variables, such as the duration of hearing loss, period of utilizing the hearing aid, and mode of communication. This was done in an attempt to reduce the variations in the underlying factors that generally cause large inter-individual differences in post-implant speech perception outcomes. For ethical reasons, the subjects who were assigned to Group II were those who, in the first place, expressed their inability to attend the clinic as frequently as Group I subjects.

The results using this program were promising where the results were almost significant in both groups when each group was compared at different intervals of assessment in comparison to the preoperative period. This is clear by the highly significant difference that was obtained in all speech perception parameters starting from 3 months' evaluation. However, this effect is actually a cumulative effect of both the implant and the rehabilitation. The effect of the intensive rehabilitation was clear on three parameters, namely spondee recognition, sentence identification and high context sentence recognition in favor of Group I. This significant difference was only clear in 18 months' assessment, signifying the positive effect of the more intensive auditory training on Group I who received extra auditory training sessions over 18 months.

The modified Arabic rehabilitation program utilizes combined analytic and synthetic approaches for auditory training. Subjects of both groups showed progressively improving results in all parameters of speech perception skills with a tendency of higher scores in Group I. It seems that the auditory training program is more overloaded with the synthetic approach training material. According to Ross,[16] studies dating from 1970 through 1996, suggested that auditory training can improve speech recognition skills to some extent, especially if it used in a synthetic training approach. The best results were obtained with the more intensive programs (longer duration and more sessions per week). According to Tremblay et al.,[17] adults retain neural plasticity in relationship to auditory learning where the brain activity has been shown to change as a result of auditory training.[18]

The common problem with pre-lingual adults implanted at a later age of preadolescence and adolescence is their poor speech intelligibility. Because speech intelligibility is measured by relatively subjective tests, it was necessary to statistically evaluate the degree of agreement between the raters. The intra-class coefficient showed a gradual decrease in value along the consecutive evaluations. Nevertheless, they remained highly significant till 18 months' evaluation. The decrease in the coefficient is natural and expected as the variation in the degree of intelligibility of subjects' speech continues to increase by time.

Many studies[1,5,6,19] showed that the pre-lingual hearing impaired subjects usually suffer from certain speech abnormalities that usually affect their speech intelligibility. Studies have also shown that they are more rigid to changing their speech habits than those implanted at a younger age. The usual form of training our subjects is directed to language promotion, speech production enhancement as well as auditory training. The extra sessions given to Group I and the home program were only directed to auditory training.

Along 18 months, repeated assessments showed slowly increasing scores for speech intelligibility of both groups. In spite of this, the recorded scores did not reach statistically significant differences compared to the pre-implant scores. However, Group I showed a significantly higher mean difference in intelligibility between the 18 month evaluation and the pre-implant evaluation when compared to the mean difference of the other group. These results reflect the difficulty of changing the long-term used faulty speech habits. At the same time, they highlight the fact that longer durations of auditory training are mandatory for changing such habits. This also explains observed decreasing reliability scores between rates as such minor changes can be detected by some and not by others.

There seems to be an underlying linguistic structure that links speech perception and speech production.[20] By auditory training, subjects learn to utilize the auditory information to improve speech production. They also learn to monitor their speech and they give more attention to the supra-segmental aspects of what they hear. In doing this, they learn gradually to improve their own speech and thus improve their speech intelligibility. This effect appears to require a prolonged intensive program of auditory training that is more overloaded with the analytic approach.

6. Conclusion

Data and results of this study revealed effectiveness of the modified form of the Arabic Adult rehabilitation program in the two groups of pre-lingual hearing impaired cochlear implanted adolescents and adults. An intensive form of auditory training can result in an improvement of both auditory abilities and speech intelligibility in this group of subjects. Enhancing the auditory recognition and discrimination skills actually indirectly improves speech intelligibility of these subjects.

6.1. Recommendations

- The analytic part of the auditory training program should be more stressed in order to reflect on all auditory perception skills.
- It is advised to design an auditory training program with detailed instructions, strictly addressed to families of cochlear implanted individuals who cannot get frequent access to training centers.
- Further evaluations should be done in order to determine the long term effects of auditory training on both speech perception and speech production.

Conflict of interest

We have no conflict of interest to declare.

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