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Factors contributing to communication skills development in cochlear implanted children

Faktori koji doprinose razvoju komunikacijskih veština kod dece sa kohlearnim implantatima

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Abstract

Background/Aim. Over the last 10 years more than 300 persons received cochlear implant in Serbia and more than 90% of the recipients were children under 10 years of age. The program of cochlear implantation includes postoperative rehabilitation in which cognitive, integrative and developmental methods are used. The study was conducted to reveal factors affecting communication performance (CP) of cochlear implanted (CI) children. Special attention was focused on the influence of the duration and intensity of rehabilitation and hearing age on further development of communication skills**. Methods.** A group of 30 CI children (13 boys and 17 girls) aged 2 to 5 years was enrolled in the study. All of the children had average intelligence and no other developmental disorder. They lived in families and attended rehabilitative seances 3 to 5 times a week. Their parents/caregivers answered structured questionnaire about functioning after pediatric cochlear implantation (FAPCI) and the results were the subject of detailed statistical analysis. **Results.** Analysis of variance did not show any difference between the boys and the girls regarding FAPCI achievements ($F_{(1, 28)} = 2.909$; $p = 0.099$) and age aberration in CP score ($F_{(1, 28)} = 0.114$, $p = 0.738$). Correlation analysis showed a statistically significant difference in FAPCI scores related to hearing age and duration of rehabilitation. Regression analysis (enter method) showed that model consisting of indipendent variables significantly contributed to prediction of overall FAPCI scores and Adjusted R^2 value could explain 32% difference in communication skills of participants in this study. **Conclusion.** Communication skills of CI children evaluated by FAPCI are falling behind normatives for normal hearing children 18.6 months on the average. Hearing age, duration and intensity of rehabilitation have positive predictive value for communication skills development. Later identification of hearing loss and later cochlear implantation lead to delayed development of communication skills.

Key words:
cochlear implants; child; communication; questionnaires.

Apstrakt

Uvod/cilj. U poslednjih 10 godina, kohlearna implantacija (KI) urađena je kod oko 300 osoba u Srbiji, od kojih 90% čine deca ispod 10 godina. Program KI praćen je odgovarajućom rehabilitacijom u kojoj se koristi saznajni, integrativni i razvojni metod. Ovo istraživanje ispitivalo je faktore koji doprinose razvoju komunikacijske veštine (KV) kod dece posle KI. Posebno smo ispitivali doprinos dužine i intenziteta procesa rehabilitacije i slušnog uzrasta razvoju ovih sposobnosti. **Metode.** Ispitali smo 30 KI dece (13 dečaka i 17 devojčica) uzrasta od 2 do 5 godina. Sva deca bila su prosečnih intelektualnih sposobnosti, bez udruženih smetnji u razvoju, živela su u porodičnom okruženju, a bila su uključena u program rehabilitacije od 2 do 5 puta nedeljno. Instrument u ovom istraživanju bio je *Functioning after Pediatric Cochlear Implantation* (FAPCI) upitnik za roditelje/staratelje. **Rezultati.** Poređenje rezultata KI ispitanika dobijenih FAPCI upitnikom sa normativima uspostavljenim za decu bez implantata pokazuju da razvoj njihovih komunikativnih veština (*communication performance* – CP) u proseku kasni 18,6 meseci. Među ispitanom decom nisu utvrđene statistički značajne polne razlike u CP, a one nisu zabeležene ni s obzirom na razliku u aberacijama u odnosu na uzrast u CP skoru ($F(1, 28) = 0.114$; $p = 0.738$). Rezultati korelacione analize pokazuju da je postignuće na FAPCI statistički značajno povezano sa slušnim uzrastom i dužinom trajanja rehabilitacije. Rezultati regresione analize *stepwise* izdvajaju slu-

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šni uzrast kao jedini značajan prediktor ukupnog skora na FAPCI upitniku, a vrednost prilagođenog R^2 pokazuje da se njime objašnjava oko 32% razlika u komunikacijskim veštinama ispitanika. **Zaključak.** Slušni uzrast, trajanje i intenzitet rehabilitacije pozitivno doprinose razvoju komunikativnih veština kod KI dece, dok kašnjenje u uspostavljanju dijagnoze i sprovođenju KI ometa ovaj aspekt razvoja.

Ključne reči:
kohlea, implantat; deca; komunikacija; upitnici.

Introduction

Before cochlear implantation (CI) was introduced speech and language achievement of severely and profoundly deaf children was far worse than in their hearing peers [1]. Speech and language of profoundly deaf children amplified by conventional hearing instruments was specific, with lot of restrictions and distortion. Their knolwedge was scarce and their language lacking grammar and syntax, their speech was concrete with poor articulation, they were reluctant to communicate verbally [2]. Introduction of cochlear implantation in the deaf chidren rehabilitation process had tremendous impact on educational choices and future perspectives. Before cochlear implants deaf children were mainly educated in special schools or in mainstream schools implementing special curriculum [3].

Since cochlear implantation in Serbia started 10 years ago more than 300 deaf persons received cochlear implant, mostly children under 10 years of age (90%) [4]. Rehabilitation treatment in the begining was based on auditory training principles and experience [5] and elements of program for improvement of auditory attention, such as NEAP (Nottingham Early Assessment Package) [6] etc. Nowadays we combine cognitive, integrative and developmental method. It is based on immitation of phases of motor, cognitive, sensitive and communication development in normal hearing and typically developing children [7]. Rehabilitation begins as soon as the hearing loss is detected. Depending on the age at implantation it lasts for several years, until the school begins. It could be continued after the child enters school if any further support is needed. The children in this study were enrolled in continuous rehabilitation and the outcomes were directly related to the hearing age, duration and intensity of rehabilitation. Our previous studies have shown that hearing age alone, without rehabilitation, does not lead to favorable results regarding speech and hearing [3]. Longer hearing age improves auditory perception, but not the overall communicative performance. Speech and hearing rehabilitation of CI children gives meaning to the sounds perceived through CI and than analyzed by the cortex [8].

Inclusive education has been introduced and became obligatory in Serbia in 2009. Children with developmental disorders are mainstreamed [9]. Since 2011 all of the children are included in mainstream schools regardless of the degree of the handicap [10]. In spite of the legislation, personal assistants for such children have not been provided yet, so that the deaf children from mainstream schools are depending on support of rehabilitation centers. Long before the new law on inclusive education was introduced, we used to send well rehabilitated deaf children to the mainstream schools years before the CI era in Serbia, so that we have more than three decades of experience on inclusive education for deaf.

There are numerous empiric studies which have proved the impact of CI on development of communication skills in children. Results of those studes have proven that CI improves perception of sound and speech as well as speech production, linguistic maturity and reading skills [9–11]. Some of the studies referred to speech understanding in deaf children without visual clues and they have shown that CI children were capable of understanding questions [12]. Negative impact of deafness affects mostly communication skills, but there is also considerable impact on personality of a deaf person [13] which is attributed to the lack of abstract categories. Investigators have shown a statistically significant difference between deaf children with cochlear implants and hearing aids regarding their ability to learn acquire and use abstract categories [14]. Rehabilitation results are evaluated through overall achievement of deaf and hard of hearing children in communication skills, education and fulfillment of individual desires and needs [15].

Objectives of clinical studies usually address some elements such as perception and certain segments of speech-language development. The need for more humanistic approach has induced studies on overall communication skills and quality of life of cochlear implant recipients. Medical publications define quality of life (QoL) as the capacity to have normal functional life and feel good about everyday activities [16, 17]. In people using aids or having permanent disability category of “health related QoL” (HRQoL) is used. Zaidman-Zait and Smith [10], examined improvements in children’s HRQoL as a result of cochlear implantation. They assessed the HRQoL *via* condition-specific items concerning the relative benefits and problems associated with implant use, the child’s behavior and social activities. Eleven parents and their children with cochlear implants (age range 6–20 years) reported both significant improvements in the child’s HRQOL and minimal negative effects of the cochlear implant. When parents rated the items, the areas rated as having the greatest benefit were hearing environment sounds, speech perception, and speech production. Overall communication skills, child’s sense of safety, self-esteem, vocabulary or language skills and relationship with family were rated as a benefit for the child.

The aim of this study was to investigate if hearing age, duration and intensity of rehabilitation are related to development of communication performance (CP) in CI children. Precisely, the study encompassed the factors affecting communication development in CI children, addressing particularly the impact of hearing age, duration and intensity of rehabilitation tretament.

Methods

The study encompassed 30 CI children (13 boys and 17 girls) of chronological age 2 to 5 years. All of the children in the study had average intelligence and no other developmental disorder. They lived in families. All of them were enrolled in speech and hearing rehabilitation 2 to 5 times a week. The instrument used in this study was the questionnaire Functioning after Pediatric Cochlear Implantation (FAPCI) for parents and caregivers [16].

FAPCI represents a psychometrically-validated unidimensional scale of communicative performance. Each of the 23 items contributes monotonically to the overall score on the scale. Scoring completed FAPCI surveys is best done using the protocol. The FAPCI instrument is a psychometrically validated survey that is used to evaluate the real-world verbal communicative performance of children aged 5 years or younger using cochlear implants. This instrument was designed to fill a gap in our current approach to the assessment of cochlear-implanted children, and FAPCI scores reflect a child's ability to communicate in real-world settings (e.g. at home or when interacting with family members). A special advantage of the FAPCI instrument is that detailed examples of communication situations are described thus helping the parents or caregivers to assess communicative behavior of their children.

The survey was conducted in 2013, Clinical Center of Serbia, Clinic for ENT&HNS, Audiology Rehabilitation Department, Belgrade, Serbia.

Descriptive statistics methods have been used for data analysis, Pearson's correlations for assessment of correlation between variables, unifactor analysis of variance (ANOVA) to assess differences between groups and multiple regression analysis to define predictive value of certain variables for final FAPCI scores.

Results

Patients characteristics are presented in Table 1.

The ANOVA results did not show a significant gender difference between the boys and the girls in FAPCI scores ($F_{(1, 28)} = 2.909$, $p = 0.099$) or age aberration in CP scores ($F_{(1, 28)} = 0.114$, $p = 0.738$), although the girls had slightly higher average FAPCI scores and slightly lower age aberration scores than the boys in this study (Table 2).

The results of correlation analysis (Table 3) showed that hearing age and rehabilitation duration affected FAPCI scores significantly. Correlation rang is moderate, but positive, suggestive of improvement of communicative skills with longer hearing age and rehabilitation.

It should be noted that some variables that were not among FAPCI achievement parameters showed significant connections (Table 3), such as high positive correlation between chronological age at the diagnosis and chronological age at implantation, as well as hearing age and duration of rehabilitation.

Table 1

Characteristics of patients (n = 30) included in the study

Patients characteristics	x̄	SD	Range
Chronological age (months)	41.83	10.71	25–58
Chronological age at onset (months)	16.93	9.21	1–33
Chronological age at CI (months)	27.27	10.23	11–44
Hearing age (months)	13.97	9.21	5–41
Rehabilitation duration (months)	22.70	9.61	9–50
CI rehabilitation intensity (frequency)	4.00	1.29	1–5

CI – cochlear implants.

Table 2

Descriptives for FAPCI total score and age aberration in communication performance (CP) score (by gender)

Data	FAPCI total score			Age aberration in CP score (months)		
	Gender		Total	Gender		Total
	male	female		male	female	
n	13	17	30	13	17	30
Mean	65.92	79.12	73.40	19.46	17.94	18.60
SD	19.788	21.857	21.676	14.89	9.69	12.01
Range	29–95	29–105	29–105	0–49	4–42	0–49

FAPCI – functioning after pediatric cocholear implantation.

Table 3

Correlations among study variables

Variables	2	3	4	5	6	7	8
1. FAPCI total score	-0.510**	0.170	-0.030	-0.232	0.478**	0.463**	-0.138
2. Age aberration in CP score	1	0.754**	0.411*	0.692**	0.083	0.202	0.089
3. Chronological age		1	0.425*	0.586**	0.492**	0.591**	-0.050
4. Chronological age at onset			1	0.663**	-0.289	-0.226	0.166
5. Chronological age at CI				1	-0.393*	-0.140	0.343
6. Hearing age					1	0.851**	-0.399*
7. Rehabilitation duration						1	-0.131
8. CI rehabilitation intensity							1

***p* < 0.05; ** *p* < 0.01.**

FAPCI – functioning after pediatric cocholear implantation; CP – communication performance; CI – cochlear implants.

The results of regression analysis (enter method) showed that the model obtained by combination of those independent variables contributed to the prediction of the overall FAPCI score, and value of adjusted R^2 could explained 28% of difference in communication skills of subjects (Table 4). Although regression coefficient for none of the predictor variables reached statistical significance, the highest Beta value was observed for hearing age. It has positive value, suggesting that increase in hearing age leads to increase in communication skills.

The results of regression analysis (stepwise method), choosing the set of most useful predictors, were somewhat different. Regarding the overall FAPCI score a statistically significant model is elicited using regression ($F_{(1, 25)}$ = 13.142; p = 0.000) and that could explain 32% of variance with hearing age as a unique significant predictor (β = 0.587, t = 3.625, p = 0.000).

Table 4

Summary of multiple regression analyses with the FAPCI total score and age aberration in CP score as dependents (enter method)

Multiple regression analysis	*β*	*t*	*p*		*β*	*t*	*p*
Regression 1				*Regression 2*			
Chronological age	-0.759	-0.987	0.334	Chronological age	1.346	2.737	0.012
Chronological age at CI	0.866	1.130	0.271	Chronological age at CI	-0.391	-0.797	0.434
Hearing age	1.291	1.757	0.093	Hearing age	-0.695	-1.478	0.154
CI rehabilitation intensity	-0.133	-0.683	0.502	CI rehabilitation intensity	0.114	0.916	0.370
F	3.540				16.587		
do	4.22				4.22		
p	0.022				0.000		
ΔR^2	0.281				0.706		

Regression 1: FAPCI total score as a criterion. Regression 2: Age aberration in CP score as a criterion.
FAPCI – functioning after pediatric cocholear implantation; CP – communication performance; CI – cochlear implants.

Discussion

The average age aberration in CP score in this group of children was 18.6 months (SD = 12.01) indicating that they fall behind their hearing peers from a normative sample. Normal hearing and typically developing children reach maximal FAPCI scores by the age of 3 years. Other authors did not specify the delay of CI children, although it has been proved in numerous test [17, 1]. The majority of the children in this sample were impanted between 1 and 3 years of age 24/30 (89%). FAPCI scores did not reflect significant differences regarding age at implantation in this study, although numerous studies have proven a considerable progress in communication skills in early implanted children [18–21]. A wide range of differences in this sample (from 0 to 49 months) reflects heterogenous structure regarding communicative skills of the children in this study, some of them being extremely delayed, while the others achieve age appropriate normatives for normal hearing children. The key issue is to establish the factors leading to such huge differences between CI children. Sometimes it could be due to preoperative rehabilitation and communicative achievements before the implantation or dynamics of auditory perception maturation in the first months after switch-on of CI [22]. The variability of data on communication skills obtained through this study confirms other authors experience [23] that there is still a great challenge in clinical evaluation of the outcome of cochlear implantation. Early implanted children enrolled in intensive postoperative rehabilitation have varible communication skills due to numerous individual (intelligence, motivation, personality type) or environmental (family, society) factors.

The correlation between varibales in this study shows a moderate negative correlation between FAPCI and age abberation in CP scores, higher age abberation in CP score corresponds to lower FAPCI score. High age abberation in CP scores could be a predictor of poor communicative performance. Unlike overall FAPCI score, there is high positive correlation between age abberation in CP score and chronological age and age at implantation. A higher age abberation in CP score corresponds to higher chronological age and age et implantation in this group of children. There is a moderate positive relation between age abberation in CP scores and age at diagnosis (higher abberation in later detected children). This finding supports the conclusion that late detection of hearing loss followed by late cochlear implantation is responsible for the major delay in communication skills development in CI children.

It should be emphasized that some variables apart from FAPCI achievement have shown considerable correlation, especially age at diagnosis and age at implantation, as well as hearing age and duration of rehabilitation. Comparative study of 22 children with cochlear implant and adequate sample of hearing impaired children with hearing aids [24] shows that hearing age and rehabilitation affect considerably better achievements in children with CI.

Multiple regression analysis was applied to evaluate relative predictive value of single variables for FAPCI score. Predictors included chronological age, chronological age at implantation, hearing age and frequency (intensity) of rehabilitation. It should be emphasized that some predictors were omitted from a final pedictor set, because of the high correlation with other indipendent variables, such as chronological age (high correlation with chronological age at implantation) and duration of rehabilitation (extremeley high correlation with hearing age). Apart from that, following preliminary results of casewise diagnostics exclusion of 3 participants from final analysis due to extremely low FAPCI scores has been suggested and done.

Regression analysis (enter method) showed that the model consisting of those indipendent variables contributed considerably to prediction of overall FAPCI scores and adjusted R^2 could explain 28% of differences in communicative performance between the children in this study. Although regression coefficient of none of the predictor variables did not reach statistical significance, the highest Beta value was observed for hearing age variable. It has positive value suggestive of increase in communication skills through increase in hearing age. Review of the literature [3, 21, 22] has shown that among all the investigated variables hearing age had always extremely positive impact on communication development in CI children. Development dynamics of auditory skills following cochlear implantation is clearly defined and increase of hearing age is followed by certaininity in listening and development of communication skills in all users of cochlear implant enrolled in rehabilitation.

Regression using the same set of predictors provides a statistically significant model and explanation for 70% of differences between the subjects if age abberation in CP score is used as prediction criterion. In this model, the only statistically significant value of Beta coefficient was obtained for chronological age of a child, which means that increase in chronological age leads to a detected delay in comparison with the normative group. This result emphasizes the significance of the chronological age of CI children; higher chronological age induces bigger delay from normative values for normal hearing children [18].

The results of stepwise regression analysis, using the most versatile set of predictors a slightly different. If a FAPCI total score is used as criterion, regression provides a statistically significant model explaining 32% of variance, with hearing age being a single significant predictor, whereas regression using age abberation in CP score as dependent variable, in statistically significant model which explains 72% intersubject variability, depict both chronological and hearing age of a child as significant predictors. The sign of Beta coefficients corroborates previous conclusions: increase in hearing age improves FAPCI scores and decreases delay compared to normative group, whereas increase in chronological age increases delay from normatives for normal hearing children.

Apart from a small number of CI children in this study, cetain limitations could be attributed to the normative data we have used [18]. Normative data were not standardized and validated for Serbian population, although the authors find that the FAPCI is not language specific and could be successfully used to depict develomental characteristics of deaf implanted children.

Conclusion

Based on the data obtained in this study on the assessed sample it could be concluded that cochlear implantation has a significant, positive contribution to the development of communication skills of deaf children. Data evaluation shows that the early diagnosis and early intervention implemented in clinical practice, corroborate by a high correlation of chronological age at the diagnosis and chronological age at implantation. Communication skills of cohlear implanted children increase accordingly with increasing hearing age and the duration of rehabilitation.

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Addendum

FAPCI Instrument [17]

Item	Response format
How often does your child respond to phrases that s/he overhears from a nearby conversation?	F
Given an unlimited set of possible choices, how many age-appropriate items would your child be able to point to when they are presented in spoken language without visual cues?	Q
How many age-appropriate 2-step spoken commands presented without visual cues does your child understand?	Q
When riding in a car, my child is able to understand...	E
When listening from a different room of the house, my child is able to understand...	E
When in a noisy environment, my child is able to understand...	E
When using the telephone with a familiar caller, my child is able to understand...	E
How often does your child appropriately answer simple questions presented in spoken language without visual cues?	F
How many age-appropriate items would your child be able to identify with spoken language when they are pointed to?	Q
How much of your child's speech would an adult who is not familiar with your child understand?	Q
How does your child typically respond when greeted by a familiar person?	E
How many people's names does your child use in spoken language?	Q
Which statement best describes your child's singing?	E
What is the main way that your child communicates his/her wants when not coached by an adult?	E
How many of the following types of words/phrases does your child use in spoken language: what, where, why, inversion questions, which?	Q
How many of the following types of words/phrases does your child use in spoken language: words to describe size or color, numbers to describe how many, words to describe quantity, plural endings, possessive ending?	Q
How often does your child ask simple questions using spoken language?	F
How often does your child talk about his/her experiences during the day or about a past event using simple spoken sentences?	F
How often does your child use the past tense in spoken language?	F
How often does your child use the negative in a 2–3 word spoken phrase?	F
How often does your child correctly use pronouns in spoken language?	F
How often does your child correctly use prepositions in spoken language?	F
How often does your child initiate a spoken conversation with another child?	F

Detailed instructions, specific examples, and tips for responding to all items are provided with questions in the actual FAPCI instrument. Response format: F = Frequency-based questions (response levels of "never", "rarely", "sometimes", "frequently", and "always"); Q = Quantity-based questions (response levels with either specific quantities or "almost none (0-4%)", "few (5-24%)", "some (25-49%)", "most (50-95%)", or "almost all (96-100%)"); E = Example-based questions (response levels contain a description or an example of a behavior, and levels correspond to an ordinal scale of functioning adjudicated by the authors).