International Journal of Pediatric Otorhinolaryngology (2007) 71, 1605–1611

ELSEVIER

International Journal of Pediatric Otorhinolaryngology

www.elsevier.com/locate/ijporl

Deaf children with cochlear implants before the age of 1 year: Comparison of preverbal communication with normally hearing children

M. Tait [a], L. De Raeve [b], T.P. Nikolopoulos [c,*]

[a] *The Ear Foundation, Nottingham, United Kingdom*
[b] *KIDS-Hasselt, Belgium*
[c] *Department of Otorhinolaryngology, Athens University, Attiko University Hospital, 116 George Papandreou Street, Nea Philadelphia, Athens 143-42, Greece*

Received 12 May 2007; received in revised form 6 July 2007; accepted 7 July 2007
Available online 10 August 2007

KEYWORDS
Language development;
Cochlear implant;
Vocal;
Auditory;
Communication;
Preverbal;
Observation;
Interaction;
Deaf;
Young;
Children;
Outcome;
Early;
Implantation under 1

Summary

Objectives: To compare preverbal behaviors of deaf children implanted under 1 year of age with age-matched hearing children.
Methods: The study assessed 20 children; 10 deaf children implanted under 1 year of age and 10 normally hearing children of the same age. Preverbal skills were measured before, 6 months, and 1 year after implantation, using Tait Video Analysis that is able to predict later speech outcomes in young implanted children.
Results: Regarding vocal turns, the normally hearing group outperformed the implanted group although the latter children became quite vocal, nearly 60% of their turns being taken in this way. The mean vocal autonomy in implanted children, 1 year after implantation, was very close to the respective of hearing children (38.5 versus 43.5). Regarding the non-looking vocal turns, by the 12-month interval, hearing children had somewhat higher scores than implanted children, but the difference was not significant and the increase in implanted children was much higher (40-fold increase versus 4-fold increase). However, implanted children were more likely to use silent communication than hearing children, although gestural turns were decreasing with time.
Conclusions: The small numbers in this study, although two of the largest European cochlear implant centers were combined to recruit such young implantees, led us to be cautious in interpreting the results. However, it seems that in deaf implanted children under 1 year of age, some preverbal communication behaviors are developing to an extent (although at a somewhat lower level) not significantly different from those of age-matched normally hearing children.

* Corresponding author.
E-mail address: Thomas.Nikolopoulos@Nottingham.ac.uk (T.P. Nikolopoulos).

0165-5876/$ – see front matter © 2007 Published by Elsevier Ireland Ltd.
doi:10.1016/j.ijporl.2007.07.003

1. Introduction

It is well known that the first years of life are generally acknowledged to be a critical period for spoken language development [1]. It is not surprising, then, that age at implantation has been found to be a significant factor where young profoundly deaf children's development of speech perception and intelligibility are concerned [2—5]. Therefore the mean age at implantation is decreasing worldwide and in many centers has become lower than 2 years of age. Several studies have suggested that implantation under the age of 2 years brings a marked advantage compared with implantation over 2 years, in terms of early development of auditory processing [6—8]. This advantage applies even when comparing the under-2s with children as young as between 2 and 3 years old [3]. De Raeve confirmed that 3 years after implantation the expressive language of 50% of the children who received their implant between 10 and 18 months is already within the normal range, in comparison with 25% of children receiving an implant between 18 and 36 months [9,10].

With the advent of Newborn Hearing Screening and increased surgical experience, cochlear implantation is now feasible for profoundly deaf children below 12 months of age. Because the results with children under 2 are promising it is logical to assume that children implanted beneath 1 year of age will do even better, near-normal acquisition of speech becoming possible by shortening the time-lag before there is auditory access to spoken language. It is therefore important to evaluate the progress of these children, particularly in the first year after implantation, and to make comparisons with normally hearing children. New behavioral procedures are developed for this purpose. As standardized tests and procedures are not suitable for this age, observation of babbling and visual habituation seem more appropriate [11—14]. Also interviews with parents and caretakers can be of importance [15—18]. In addition, parental measures have been developed such as the MacArthur Communicative Development Inventories that provide information on reception and production of gestures as well as on speech and pragmatics [19].

An objective observational method is to examine the development of communicative behaviors by using video recordings of children in the home environment interacting with someone they know well. This has an advantage over live observation in that the record of the interaction is permanent and can be viewed repeatedly. The development of communication in children under the age of 12 months can be assessed by examining their preverbal communication behaviors, which are the natural precursors of language development in all children, whether deaf or normally hearing. Preverbal behaviors include appropriate eye contact, conversational-style turn-taking, autonomy and auditory awareness of the sound of speech, and constitute the normal pattern of language development which begins in early infancy.

The method of video analysis reported in this paper was developed by the first author in the 1980s for the assessment of preverbal language skills in children with acoustic hearing aids, and has been used since the establishment of the Nottingham Paediatric Cochlear Implant Programme in 1988 to monitor the development of early vocal and auditory communication skills in children with cochlear implants [20]. Measures from the analysis, taken before and 12 months after implantation, have been found to be strongly related to speech discrimination and intelligibility outcomes 3, 4 and 5 years post-implant [21,22]. The method has been shown to be reliable by two studies: the first analyzing transcripts of children between the ages of 2 and 5 [23] and the second children under 1 year of age [24].

In a recent study [3] the authors compared three groups of children implanted between 1 and 2 years, 2 and 3 years, and 3 and 4 years, in terms of their development of vocal and auditory skills. However, it did not seem reasonable to compare the under-1s, whose communication skills would be at such an early stage of development, with children whose communication skills would be considerably more mature. Therefore, the aim of the present study was to compare preverbal behaviors of deaf children implanted under 1 year of age with an age-matched group of normally hearing children.

2. Material and methods

2.1. Subjects

The group of normally hearing children comprised five boys and five girls from the East Midlands, UK, contacted through two post-natal maternity groups. They were in the same age range, 8—11 months, as the group of 10 profoundly deaf children. This group comprised three from Nottingham and seven from Hasselt; their characteristics are listed in Table 1. To obtain a group of 10 profoundly deaf children implanted under 1 year of age it was necessary for two centers to combine, as there were relatively few children implanted under 1 at the Nottingham

Table 1 Characteristics of profoundly deaf children

Child	Sex	Age onset of deafness	Age implant	Age at first recording	Cause of deafness
1	Male	0 months	8+ months	8 months	Genetic
2	Male	0 months	9+ months	9 months	Genetic
3	Male	0 months	9+ months	9 months	Genetic
4	Male	0 months	10+ months	10 months	Genetic
5	Male	0 months	11+ months	11 months	Unknown
6	Female	0 months	9+ months	9 months	Genetic
7	Male	0 months	11+ months	10 months	Genetic
8	Male	3 months	11+ months	11 months	Meningitis
9	Male	0 months	10 months	8 months	Genetic
10	Female	1 month	11 months	10 months	Meningitis

Cochlear Implant Programme who had reached the 12 months post-implant interval. The KIDS-Hasselt (Belgium) program therefore joined The Nottingham Ear Foundation in this study. One advantage of joining with the KIDS-Hasselt program was that the same method of video analysis has been used there for 8 years. Professionals on the Hasselt program were originally trained in the video analysis method by the first author in 1999. Since that date there have been many discussions between us on specific points of analysis, and the approach is therefore consistent.

2.2. Recording

Two-minute samples were taken from longer recordings made in the home or other very familiar environment. The recordings of the deaf children were made shortly before implantation, and 6 and 12 months post-implant. The recordings of the normally hearing children were made at the same age-related intervals. The recordings were made in good lighting and reasonably quiet conditions. The camera recorded the child almost full-face, with a profile view of the adult if they were sitting opposite the child. Sitting alongside or on the adult's knee presented no difficulties of observation. In this way, any signs, gestures or facial expressions could be clearly seen. Children were filmed in interaction with their mother or another very familiar adult, activities being chosen that were interesting and that would promote interaction. All the children were under 12 months of age, ranging from 8 to 11 months. The measures of preverbal behaviors, that have been described in detail elsewhere [25], are as follows.

2.3. Turn-taking

Initially, 'turns' are identified. These are instances where the child has an opportunity to communicate. Opportunities occur when the adult has left a pause, but also included are instances where the child interrupts the adult's communication. The turns are further classified as vocal, where the child has used voice to communicate, with or without the addition of sign, gesture or facial expression; or as gestural, where sign, gesture or facial expression are used, without vocalization. Purposeful eye contact made by the child with their mother is classified as gestural communication. Vocal and gestural turn-taking are each calculated as a percentage of the total number of turns. Instances where the child does not take the opportunity to communicate are classified as no response.

2.4. Autonomy

Children's use of autonomy in their turns is assessed by counting the number of turns in which they communicate something which cannot be directly predicted from the adult's preceding turn. As with turn-taking, autonomy can be either vocal or gestural (silent). For example, a child may push away something that is offered and point to a preferred item. This would be classified as gestural autonomy if done silently, or as vocal autonomy if vocalization was also used. Both vocal and gestural autonomy are expressed as percentages of the total number of turns.

2.5. Auditory awareness

Auditory awareness of the adult's speech is measured by the non-looking vocal turn (NLVT). A NLVT occurs when a child vocalizes communicatively in their turn after not being in eye contact with the adult during the adult's previous turn, no visual clue, such as a sign or a pointing finger, having been given, and the child's vocalization not occurring as a vocal clash with the adult's. Again, the number of NLVTs is expressed as a percentage of the total number of turns.

Table 2 Mean vocal turns before, at 6 months, and 12 months after implantation

	Mean		
	Before	6 months	1 year
Deaf (implanted under 1-year old)	**13.5**	**37.5**	**59.5**
Hearing of same age	**35.5**	**57.5**	**84.5**
Statistical significance	$p = 0.01$	NS	$p = 0.003$

NS = not statistically significant. Means in bold when both distributions are normal.

2.6. Statistical analysis

Student's *t*-test was used for comparisons of normally distributed variables and Mann—Whitney *U*-test for variables not normally distributed. In normally distributed variables, means were given. When one at least of the variables was not normal, both means and medians were given. Statistical significance was accepted at the $p < 0.05$ level.

3. Results

The three measures that show a deaf child's development of vocal communication and auditory processing are vocal turn-taking, vocal autonomy and non-looking vocal turns. Table 2 shows the mean and median vocal turn-taking over the 12-month period. It can be seen that before implantation and 12 months after implantation the difference between the deaf group and the normally hearing group reaches significance, though it does not do so at the 6-month interval. However, the deaf group, though not as vocal as the normally hearing group, are nevertheless quite vocal, nearly 60% of their turns being taken in this way. Where vocal autonomy is concerned (Table 3), although the normally hearing group has higher scores there is no significant difference between the groups at any interval. A similar result is seen with non-looking vocal turns (Table 4). Before implantation only one of the deaf children has any NLVT score, and that score a very low one, so not surprisingly the difference between the two groups at this stage reaches significance. By the 6- and 12-month intervals after implantation, though the normally hearing group has somewhat higher scores than the deaf group, the differences do not reach significance.

The two measures that show use of non-vocal communication are gestural turn-taking, shown in Table 5, and gestural autonomy, shown in Table 6. These tables show that there is a significant difference between the two groups by the 12-month interval, the deaf group being more likely to use silent communication than the normally hearing group. At this interval they are also significantly more likely to show autonomy in their silent communications, whereas this has not been a notable

Table 3 Mean and median vocal autonomy before, at 6 months, and 12 months after implantation

	Before implantation		6 months after implantation		12 months after implantation	
	Mean	Median	Mean	Median	Mean	Median
Deaf (implanted under 1-year old)	9	0	**23.5**	22.5	**38.5**	30
Hearing of same age	10	7.5	**24.5**	17.5	**43.5**	47.5
Statistical significance	NS		NS		NS	

NS = not statistically significant. Means in bold when both distributions are normal.

Table 4 Mean and median non-looking vocal turns before, at 6 months, and 12 months after implantation

	Before implantation		6 months after implantation		12 months after implantation	
	Mean	Median	Mean	Median	Mean	Median
Deaf (implanted under 1-year old)	1	0	**28.5**	27.5	**42.5**	35
Hearing of same age	13.5	10	**43**	55	**58**	55
Statistical significance	$p = 0.02$		NS		NS	

NS = not statistically significant. Means in bold when both distributions are normal.

Table 5 Mean gestural turns before, at 6 months, and 12 months after implantation

	Mean		
	Before	6 months	1 year
Deaf (implanted under 1-year old)	47	33.5	27.5
Hearing of same age	39.5	31	12
Statistical significance	NS	NS	$p = 0.01$

NS = not statistically significant.

feature in the normally hearing group at any interval. Over the 12-month period both groups have shown a decrease in the measures of silent communication, and a considerable increase in the vocal and auditory measures.

4. Discussion

Though the development of communication in both groups follows a similar pattern, there are nevertheless some differences. Although before implantation there is no significant difference between the deaf group and the normally hearing group at the same age-interval where gestural turn-taking is concerned, it is clear from a comparison of Tables 2 and 5 that at this stage the children in the normally hearing group are equally likely to communicate silently or vocally, whereas the children in the deaf group are far more likely to communicate silently. The pattern has changed by the 12-month interval, as by then both groups are communicating more vocally, though the significant differences between the groups where both vocal and gestural turn-taking are concerned show the normally hearing group to be ahead of the deaf group in terms of vocalization. The normally hearing group are also ahead of the deaf group where the percentages of vocal autonomy and non-looking vocal turns are concerned; however, here the differences do not reach significance. Moreover, the mean vocal autonomy in implanted children, 1 year after implantation, is very close to the mean vocal autonomy of hearing children of the same age (38.5 versus 43.5). Why is it that the deaf children appear to be progressing along 'normal' lines where vocal autonomy and non-looking vocal turns are concerned? Are there any features of the early communication experiences of these young implanted children which would account for this?

By the 6- and 12-month intervals of the study all the children are between 1 and 2 years of age. At this period of their lifes normally hearing children gain much of their early beginning of understanding and use of spoken language because of the way their carers behave: carers habitually follow the children's line of gaze and comment on what the children are looking at. This has been called the reference triangle: the child's and the carer's lines of visual regard form two sides of the triangle, and the language input from the carer, received by the child through audition, forms the third side. Because the communication from the adult occurs at the same time as the child's attention to an object or event, the communication is naturally contingent upon it and therefore meaningful. For a profoundly deaf baby before cochlear implantation, this third side of the triangle of reference is not fully accessible except through vision. This means that without guidance as to where to position the object of references [26,27] it will be difficult for an adult inexperienced in sign to make their communication contingent and meaningful to the child; and it will be equally difficult for the child to integrate visual communication in parallel with visual attention to the object or event. This situation can be further complicated by the adult's attempts to engage the child: instead of following what is occupying the baby's attention and thoughts, the baby is expected to interpret what is the adult's focus of interest, which is impossible for a young infant [28].

Now, with the early provision of the cochlear implant because of Newborn Hearing Screening, the possibility is there for carers of these deaf

Table 6 Mean gestural autonomy before, at 6 months, and 12 months after implantation

	Mean		
	Before	6 months	1 year
Deaf (implanted under 1-year old)	21.5	17.5	15.5
Hearing of same age	5	8.5	2.5
Statistical significance	NS	NS	$p = 0.01$

babies to do what comes most naturally to someone caring for the very young: to supply the language for whatever is occupying the child's attention at any one time, without having to attract their visual attention. The children, for their part, will not need to learn to integrate visual and spoken signals, but can follow the normal procedure of receiving communication through audition—the third line of the triangle. That the more natural pattern of communication is effective is shown by the fact that at the 12-month interval there are no significant differences between the normally hearing and the deaf groups where the two most revealing measures are concerned: vocal autonomy and non-looking vocal turns. The vocal autonomy measure shows, not only that a child has communicated vocally, but that there is something which is important to them which they want to communicate vocally. Where the development of auditory processing is concerned, perhaps the non-looking vocal turns (40-fold increase in implanted children versus 4-fold increase in hearing children) are even more revealing: not only does the child communicate vocally but they do so in auditory response to the adult. It is likely that it is this vocal and clearly auditory response which gives the adult the feedback that encourages them to continue this natural pattern of communication, which in turn provides the framework for the child to continue to develop their vocal and auditory communication skills.

5. Conclusions

The small numbers in this study, although two of the largest European cochlear implant centers were combined to recruit such young implantees and assess them before, 6 months, and 1 year following implantation, led us to be cautious in interpreting the results. However, it does seem that in this group of deaf children, who have been given a cochlear implant before the age of 12 months, some vocal and auditory communication behaviors are developing to an extent (although at a somewhat lower level) not significantly different from those of the group of age-matched normally hearing children.

References

[1] R.J. Ruben, A time frame of critical/sensitive periods of language development, Acta. Otolaryngol. (Stockholm) 117 (1997) 202—205.

[2] T.P. Nikolopoulos, G.M. O'Donoghue, S.M. Archbold, Age at implantation: its importance in pediatric cochlear implantation, Laryngoscope 109 (1999) 595—599.

[3] M.E. Tait, T.P. Nikolopoulos, M.E. Lutman, Age at implantation and development of vocal and auditory preverbal skills in implanted deaf children, Int. J. Pediatr. Otorhinolaryngol. 71 (4) (2007) 603—610.

[4] T.P. Nikolopoulos, K.P. Gibbin, D. Dyar, Predicting speech perception outcomes following cochlear implantation using Nottingham children's implant profile (NChIP), Int. J. Pediatr. Otorhinolaryngol. 68 (2) (2004) 137—141.

[5] G.M. O'Donoghue, T.P. Nikolopoulos, S.M. Archbold, Determinants of speech perception in children after cochlear implantation, Lancet 356 (9228) (2000) 466—468.

[6] M. Manrique, F.J. Cervera-Paz, A. Huarte, M. Molina, Advantages of cochlear implantation in prelingual deaf children before 2 years of age when compared with later implantation, Laryngoscope 114 (8) (2004) 1462—1469.

[7] I. Anderson, V. Weichbold, P.S. D'Haese, J. Szuchnik, M.S. Quevedo, J. Martin, W.S. Dieler, L. Phillips, Cochlear implantation in children under the age of two—what do the outcomes show us? Int. J. Pediatr. Otorhinolaryngol. 68 (4) (2004) 425—431.

[8] K. Schauers, Early speech and language development in deaf children with a cochlear implant: a longitudinal investigation, doctoral thesis at University of Antwerp, Department of Linguistics, Antwerp, 2006.

[9] L. De Raeve, Invloed van vroege gehoorscreening en cochleaire implantatie op dove kinderen in Vlaanderen, Van Horen Zegge, Jaargang 47 (June) (2006) 10—17.

[10] L. De Raeve, Making the case for early detection and intervention in Flanders (Belgium), Volta Voices 13 (5) (2006) 14—17.

[11] V. Colletti, M. Carver, V. Miorelli, M. Guida, L. Colletti, F.G. Fiorino, Cochlear Implantation under 12 months—report on 10 patients, Laryngosope 115 (3) (2005) 445—449.

[12] K. Schauwers, S. Gillis, K. Daemers, C. De Beukelaer, P.J. Govaerts, Cochlear implantation between 5 and 20 months of age: the onset of babbling and the audiological outcome, Otol. Neurotol. 25 (3) (2004) 263—270.

[13] A. Sharma, E. Tobey, M. Dorman, S. Bharadwaj, K. Martin, P. Gilley, F. Kunkel, Central auditory maturation and babbling development in infants with cochlear implants, Arch. Otolaryngol. Head Neck Surg. 130 (5) (2004) 511—516.

[14] R.T. Miyamoto, D.M. Houston, T. Bergeson, Cochlear implantation in deaf infants, Laryngoscope 115 (8) (2005) 1376—1380.

[15] A. McConkey Robbins, D.B. Koch, M.J. Osberger, S. Zimmerman-Phillips, L. Kishon-Rabin, Effect of age at cochlear implantation on auditory skill development in infants and toddlers, Arch. Otolaryngol. Head Neck Surg. 130 (5) (2004) 570—574.

[16] A. Lesinsky-Schiedat, A. Illg, R. Heermann, B. Bertram, T. Lenarz, Pediatric cochlear implantation in the first and in the second year of life: a comparative study, Cochlear Implants Intern. 5 (2004) 146—159.

[17] J.B. Tomblin, B.A. Barker, L.J. Spencer, X. Zhang, B.J. Gantz, The effect of age at cochlear implant stimulation on expressive language growth in infants and toddlers, J. Speech Lang. Hear. Res. 48 (4) (2005) 853—868.

[18] L. Kishon-Rabin, R. Taitelbaum-Swead, R. Ezrati-Vinacour, M. Hildesheimer, Prelexical vocalization in normal hearing and hearing-impaired infants before and after cochlear implantation and its relation to early auditory skills, Ear Hear. 26 (4) (2005) 17S—29S.

[19] L. Fenson, P.S. Dale, S. Reznick, D. Thai, E. Bates, J.P. Hartung, S. Pethick, J.S. Reilly, The MacArthur Communicative Development Inventories: User's Guide and Technical Manual, Singular Publishing Group, San Diego, CA, 1993.

[20] M. Tait, Video analysis: a method of assessing changes in preverbal and early linguistic communication following cochlear implantation, Ear Hear. 14 (1993) 378—389.
[21] M. Tait, M.E. Lutman, The prediction value of measures of preverbal communicative behaviours in young deaf children with cochlear implants, Ear Hear. 18 (1997) 472—478.
[22] M. Tait, M.E. Lutman, K. Robinson, Preimplant measures of preverbal communicative behaviour as predictors of cochlear implant outcomes in children, Ear Hear. 21 (1) (2000) 18—24.
[23] M. Tait, T.P. Nikolopoulos, M.E. Lutman, D. Wilson, P. Wells, Video analysis of preverbal communication behaviours: use and reliability, Deaf Educ. Int. 3 (2001) 38—43.
[24] M.E. Tait, T.P. Nikolopoulos, P. Wells, A. White, The use and reliability of Tait video analysis in assessing preverbal language skills in profoundly deaf and normally hearing children under 12 months of age, Int. J. Pediatr. Otorhinolaryngol. (2007), in press, Jun 20 [Epub ahead of print].
[25] M. Tait, M.E. Lutman, T.P. Nikolopoulos, Communication development in young deaf children: review of the video analysis method, Int. J. Pediatr. Otorhinolaryngol. 61 (2001) 105—112.
[26] M. Harris, It's all a matter of timing: sign visibility and sign reference in deaf and hearing mothers of 18 month old children, J. Deaf Stud. Deaf Educ. 6 (2001) 177—185.
[27] G. Loots, I. Devise, W. Jacques, The impact of visual communication on the intersubjective development of early parent—child interaction with 18—24-month-old deaf toddlers, J. Deaf Stud. Deaf Educ. 10 (4) (2005) 357—375.
[28] D. Wood, H. Wood, A. Griffiths, I. Howarth, Teaching and Talking with Deaf Children, John Wiley & Sons, 1986.