

## Research Article

# Benefit of a Hybrid Speech Processor in Implanted Young Children with Residual Hearing

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- Residual hearing
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- Early implantation

**Abstract**

**Objective:** To investigate in a retrospective study the residual hearing in young children after early cochlear implantation and the audiological observation of a Hybrid speech processor benefit after years of electrical stimulation only.

**Material and Methods:** Evaluating residual hearing in 6 children (mean 8.1 y) in the low frequencies, nine ears were fitted with a Hybrid speech processor. The mean age at implantation was 2.2 years. Speech recognition measures in quiet and in noise with the current CI map and with a hybrid map were carried out. For the assessment of subjective performance with CI and Nucleus 6 Hybrid speech processor a questionnaire was used.

**Results:** In nine ears residual hearing was observed to be fitted with a Hybrid system in average 5.9 years after the initial cochlea implantation. Results for speech understanding in quiet and noise showed no mean significant differences between the CI only and the Hybrid System. The subjective assessment of parents and children showed a non-significant advantage for the CI only.

**Conclusion:** In all cases residual hearing was observed even after long years of electric stimulation. Benefit from a Hybrid processor was highly individual. No significant mean improvement was evaluated for speech perception in quiet and noise.

**INTRODUCTION**

Today an increasing number of adults who still have low frequency residual hearing are supplied with a cochlear implant and confirm that even after cochlear implantation, this preserved residual hearing has numerous advantages. The prerequisite is that the existing low frequency residual hearing is still sufficient to be stimulated acoustically amplified by a hearing aid. The concept of cochlear implantation for patients with residual hearing goes back to von Ilberg [1] and colleagues in the late nineties. Many studies describe the benefit of electric-acoustical stimulation compared to the electrical stimulation alone [2-7]. Most of these studies examined adults with cochlea implants. Anagiotos et al., observed a correlation between age and the degree of hearing preservation [8]. Apart from this, little evidence exists about hearing preservation and electric-acoustic stimulation in children with cochlear implant [9-11] and the question if there is a potential benefit of hearing preservation after cochlear implantation in very young children. The problems we are facing are the preoperative diagnostic of young children

with a congenital hearing impairment, which gives limited information about the threshold in the low frequency range. Also after implantation the diagnostic tools in this patient group gives only restricted information about the residual hearing. The following study focused on two questions: "How frequent is residual hearing in early-implanted children even after years of implant?" and "Have early implanted children with residual hearing a benefit from a Hybrid speech processor even after years?"

**MATERIALS AND METHODS**

A retrospective chart review of children with congenital deafness who received a CI between March 2008 and March 2013 was performed. Altogether 6 patients (2 female, 4 male) were included into the study. After evaluating residual hearing in the low frequencies (125 Hz – 1000 Hz) nine ears with sufficient residual hearing were supplied with a Nucleus 6 Hybrid device. The average age at cochlea implantation was 2.2 years (range = 1.0 - 3.1). The mean age at the beginning of study was 8.1 years (range 6.1 – 9.4). The average experience with CI was 5.9 years

(range 5.1 – 7.0). All children were bilaterally implanted. In all cases the CI system was a device by Cochlear Ltd. 5 subjects were implanted with a Freedom contour advanced electrode, 3 with a 512 system and one with a 422 straight electrode. The type of sound processor was in 8 cases the CP810 and in one case the CP910 (Table 1). All children were German native speakers and had no additional handicaps.

All patients performed a postoperative rehabilitation in our rehabilitation center. On average, each child received 40 to 60 treatment units. During each treatment the speech processor was refitted and was followed by a hear-speech-training, which was carried out according to a phonetic approach. The postoperative rehabilitation took in average 48 to 60 months.

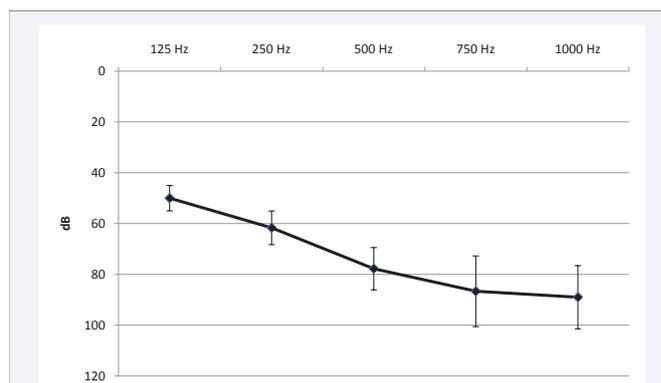
To determine the residual hearing in the low frequencies a pure tone audiometry was carried out. Children with residual hearing in the range of the amplification of the acoustic component of the device (cut off 80 dB) were included in the study. In the first part of the study the outcome with the current CI map was evaluated. Then the Hybrid processor was fitted. Usually one size power speaker unit and a power dome size 8mm were used. The children carried the processor for 4 weeks and after this time the same testing with the Hybrid System map was repeated.

For speech understanding in quiet monosyllabic words in quiet (@65dB HL) were tested. For speech understanding in noise the adaptive Oldenburg children sentence test (OLKISA) in two different settings (signal and noise in front, SONO + signal in front and noise at the contralateral ear, SON-90, noise always fixed at 65dB HL) was carried out. All speech tests were performed monaurally; the speech processor of the contralateral ear was switched off. For subjective assessment a questionnaire called CHILD (Children's Home Inventory for Listening Difficulties) was issued for parents and for children. It should be rated the use of the regular CI and the Hybrid device. The Spearman test within the SPSS Base System was used for statistical analysis. Statistical significance was defined as  $p < 0.05$ . The study was approved by the IRB (IRB-ukb-HNO-2014/11).

## RESULTS

In all cases residual hearing in low frequencies was found; even if standard contour electrodes were implanted and even after long years of electric stimulation. Figure (1) shows the

		<b>n</b>
Total no. patients		6
Total ears with audible residual hearing		9
Sex	Female	2
	Male	4
Type of electrode	CI 24 (RE) CA	5
	CI 512	3
	CI 422 (straight)	1
Type of sound processor	CP810	8
	CP910	1
Technical supply	bilateral CI	6
	bimodal (hearing aid + CI)	0
	unilateral CI	0



**Figure 1** Mean residual hearing for all patients in the low-frequencies (air conduction).

mean residual hearing for all subjects. The mean low frequency hearing loss (250 Hz, 500 Hz and 1000 Hz) was 66.3 dB. Table (2) shows the results of nine ears which have been supplied with the N6 Hybrid system.

The scores of monosyllables in quiet in all patients are presented in Figure (2). Monosyllabic word recognition in free-field shows no significant ( $p > 0.05$ ) differences between the CI only (88 %  $\pm$  7) and the Hybrid processor (86 %  $\pm$  13).

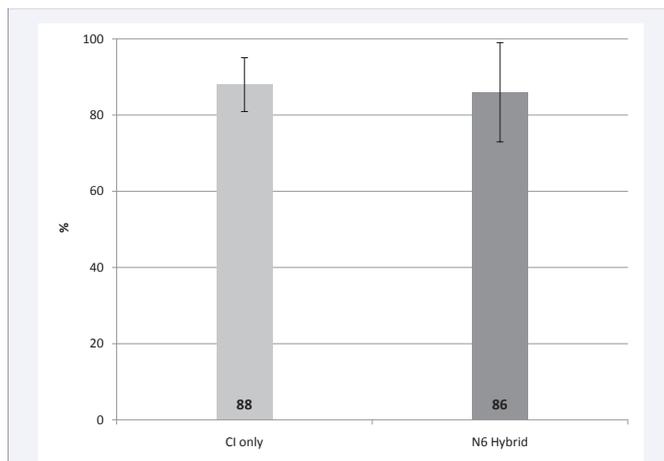
Figure (3) shows the outcome for speech comprehension in noise. In the setting SON0 no clear differences were found between CI only (- 1.3 dB SRT  $\pm$  1.4) and Hybrid (-1.8 dB SRT  $\pm$  2.7). In the setting SON90 speech recognition in noise with Hybrid (- 6.1 dB SRT  $\pm$  4.9) was better than with CI only (- 4.7 dB SRT  $\pm$  2.9) but not statistically significant ( $p > 0.05$ ).

In Figure (4) the estimates of the questionnaire CHILD are shown. The light grey bars represent the assessment with CI, whereas the dark grey bars show the estimation for the Hybrid device. The subjective assessment of parents and children demonstrate a non-significant advantage for the CI only condition ( $p > 0.05$ ). In most cases the assessment of the Hybrid system was rated lower. This is consistent with the speech-audiometric test results in quiet and noise.

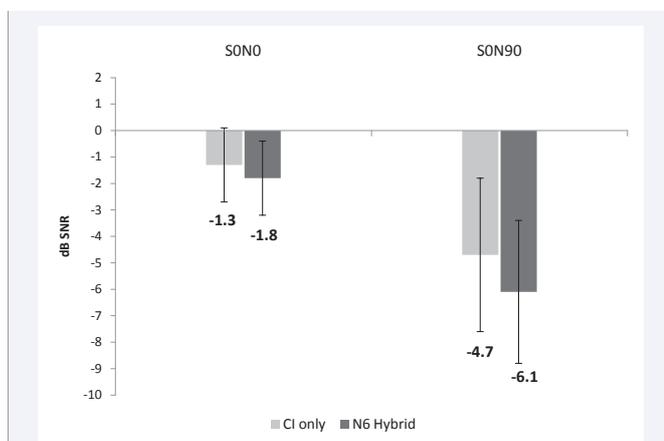
Table (3) presents the individual results. We found individual differences between the patients. Child 1 showed a very good acceptance and wanted to keep the Hybrid device. Child 4 and 6 did not accept the device from the beginning. For child 2 and 5 the filters often blocked due to earwax and the power speaker often slipped out of the ear canal. In these cases the parents indicated that the child had worse hearing with N6 Hybrid processor than with their regular processor.

## DISCUSSION

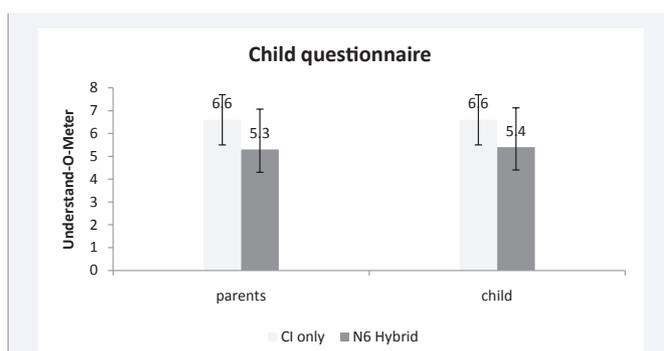
The study handled on two different questions. The first question was: "How frequent is residual hearing in early-implanted children even after years of electrical stimulation?" The results of 6 participants and overall 12 ears show that in each case residual hearing in the low frequencies was observed, even when standard contour electrodes were used and even after long years of electric stimulation. The results demonstrate that probably in all early-implanted children the residual hearing in low frequencies seems to be preserved.



**Figure 2** Results of the monosyllabic word test in quiet (@65 dB HL).



**Figure 3** Speech recognition in noise, Oldenburg children sentence test (noise fixed @65 dB).



**Figure 4** Results of the CHILD questionnaire.

It can be assumed that residual hearing can be found in many other children with CI even after long years of electric stimulation only. A higher resistance against an intra-cochlear trauma related to the surgical procedure for children in comparison to adults can be assumed. A pathophysiologic explanation might be a better ability to handle pressure changes related to a more patent aqueductus cochlea in children.

In every child an atraumatic surgical concept should be operational standard. Particularly in small children the neuronal tissue should be preserved undamaged. It can be assumed that they are before several implantations in their lifetime. Children with CI could benefit from future inventions longer if the cochlea structures remain intact.

The second focus of the study was to evaluate, whether early implanted children with residual hearing have a benefit from a Hybrid device even after years of electrical stimulation only. The outcomes of 9 ears with aidable residual hearing in low frequencies revealed no significant differences with CI only and with a Hybrid processor for speech recognition in quiet and in noise. The same could also be observed in the subjective evaluation where non-significant differences were detected between CI only and processor. The rating fell rather in favor of the CI only as for Hybrid. But even that was not statistically significant. These results are different to the finding of Wolfe et al. [12], who found in their study with older children that speech recognition in noise was always better with EAS. We found similar results in an own (unpublished) study with 11 adults where speech in noise test results revealed 1 – 2 dB better scores using an EAS device. This, however, might mainly be due to the different hearing experience of these patient groups.

An early electrical stimulation only seems to have a distinctive influence on the usability of residual hearing. Hearing and language development of early-implanted children was marked only by the electrical stimulation. The use of residual hearing with a hearing aid after years of electrical stimulation seems disturbing for some early implanted children who grew up with this sound. Changes in the central auditory pathway can be assumed, which determine the pathway on a pure electrical stimulation. This could be an indication to fit very young implanted children with a hybrid system from the very beginning. However, problematic is the postoperative determination of low frequency thresholds in these children. A reliable statement of residual hearing is still very difficult in this patient group. Also, it needs to be worked on the development of a “toddler appropriate” Hybrid-sound processor. It is necessary to develop childproof acoustic components and children-size speaker and earpieces to meet the demands of small children.

## CONCLUSION

We observed a high rate of preserved residual hearing in young children operated without a specific atraumatic surgical concept even after years of electrical stimulation. In every child an atraumatic concept should be the surgical standard with atraumatic techniques and electrodes. Benefit from the Hybrid system is highly individual. No mean improvement by a processor was evaluated speech perception in quiet and noise. An early electrical stimulation seems to have a negative effect on the usability of acoustic residual hearing. Supplying of early-implanted children with a CI Hybrid system after a long time of electrically simulation seems to be difficult. Difficulties with user-acceptance and no child-proof acoustic components can be regarded as the cause. However, the time of habilitation with the new device was rather short in our study. A longer time with the hybrid device might bring different and more in favor results for the system.

**Table 2: Residual hearing of Hybrid user, n = 9. CI xx different models of cochlear implants (Cochlear Ltd., Sydney).**

	Electrode	125 Hz	250 Hz	500 Hz	750 Hz	1000 Hz
Ear 1	CI 24RE (CA)	45	65	80	85	90
Ear 2	CI 24RE (CA)	50	60	65	65	80
Ear 3	CI 24RE (CA)	50	50	70	75	80
Ear 4	CI 512	50	65		85	*
Ear 5	CI 512	55	60	80	80	85
Ear 6	CI 512	60	70	85	90	*
Ear 7	CI 24RE (CA)	50	70	90	110	*
Ear 8	CI 422	45	60	70	105	110
Ear 9	CI 24RE (CA)	45	55	75	85	*

**Table 3: Individual results of Hybrid users.**

	N6 Hybrid Use	User acceptance	Comment
Child 1 (girl) 8.1 years	Right	+++	kept N6 Hybrid at the end of the study
Child 2 (boy) 8.7 years	Bilateral	+	parents were not satisfied ACO often slipped out Filters often blocked because earwax
Child 3 (boy) 8.1 years	bilateral	++	child more satisfied than parents application of health insurance for supply of with N6
Child 4 (boy) 6.1 years	left	---	no acceptance of N6 Hybrid from the beginning
Child 5 (boy) 8.2 years	bilateral	+	parents were not satisfied filters often blocked because earwax subjective evaluation was worse than the audiological results
Child 6 (girl) 9.4 years	left	---	no acceptance of N6 Hybrid from the beginning „everything sounds so dark and deep“

## ACKNOWLEDGEMENTS

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