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Electric-Acoustic Stimulation in Cochlear-Implant Subjects

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Today, cochlear implantation is the treatment of choice in cases of severe to profound hearing loss, but the speech understanding of many recipients in noisy conditions is still poor and the overall sound quality and ease of listening requires improvement. Residual low-frequency hearing has been shown to improve hearing performance in cochlear implant patients, especially in difficult listening environments (i.e. cocktail parties). It seems that low frequency information can enhance the segregation of competing voices which leads to better speech understanding in noise. For this reason, more and more subjects with low frequency residual hearing are being implanted with so called Hybrid or Electric-Acoustic-Stimulation (EAS) cochlear implant systems to preserve the residual hearing in the ear to be implanted. Results from more than 100 subjects with hybrid cochlear implant systems will be presented. Additionally, a group of more than 80 subjects with conventional cochlear implant systems on one side and residual acoustic hearing on the contralateral side will be demonstrated. Both groups show highly significant improvements in adverse listening environments when using the hearing aid additionally to the cochlear implant system. In this context, indication criteria for the use of acoustic amplification in cochlear implant subjects will be discussed.

INTRODUCTION

Cochlear implants are starting to enter the domain of conventional hearing aids. Subjects generally achieve significant open speech understanding using cochlear implants. Subsequently, more and more candidates with usable residual hearing are being implanted nowadays, as postoperative hearing performance especially in conjunction with low-frequency acoustic hearing is most remarkable. Different research groups showed that cochlear implant subjects with some degree of residual hearing on the contralateral ear benefit significantly by the combination of the acoustic and electric hearing (Ching *et al.*, 2004; Kong *et al.*, 2005; Dorman, 2007). Also, simulations of combined electric and acoustic hearing presented to normal hearing subjects demonstrated superior performance over the simulation of electric hearing alone (Turner *et al.*, 2004; Dorman *et al.*, 2005).

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The scores in this so called bimodal mode did not only show an addition of the scores with each hearing device alone, but a synergistic effect, similar to the results in (Dorman *et al.*, 2005).

Driven by the success of these findings, more and more subjects are being implanted with special devices with so called atraumatic electrodes that allow for a preservation of residual hearing in the implanted ear, at least to a great extent (Turner, 2004; Gantz, 2006; Lenarz, 2006). In these subjects, the remarkable benefit of the residual acoustic hearing in combination with the electric stimulation could also be shown (Büchner, 2009; Lenarz, 2009).

SUBJECTS AND METHOD

123 subjects with a severe to profound sensorineural hearing loss for frequencies >1500Hz and substantial residual hearing for frequencies ≤1500Hz have been implanted with a Nucleus Hybrid-L cochlear implant, 32 of them were small children where no standardised audiometric measurements could be performed.

The Hybrid L electrode was designed for patients with mild to moderate hearing loss in the low frequencies and severe to profound hearing loss in the high frequencies. The electrode provides electrical stimulation in the basal section of the cochlea, while protecting the apical low frequency hearing region to provide the benefit of acoustical stimulation. The electrode design features an electrode diameter of 0.25 mm at the tip to 0.4 mm at the basal end to support a minimally invasive insertion method through the round window. The electrode length is 16 mm and carries 22 electrode contacts. The typical insertion depth is 16 mm described by 250 to 270 degree.

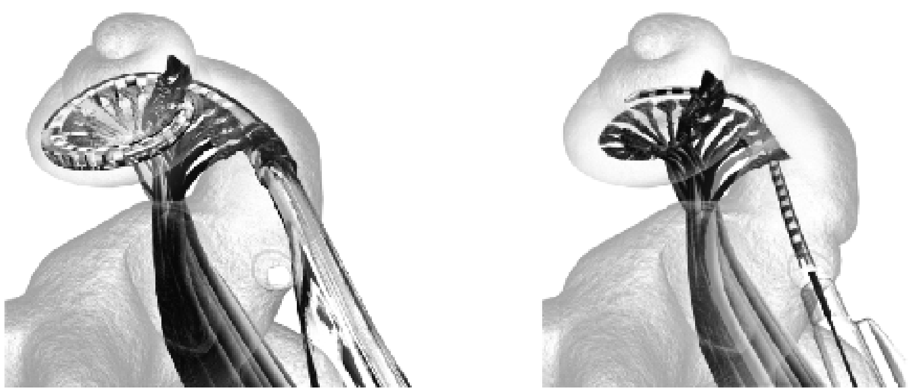


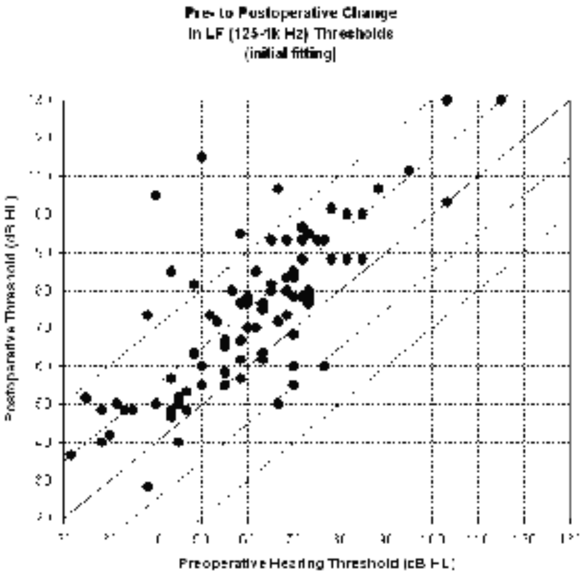
Fig. 1: A conventional electrode (left) vs. an atraumatic electrode (Cochlear Hybrid-L) on the right. The conventional electrode is being inserted through a drilled cochleostomy, while the Hybrid-L electrode is accessing the cochlea through the round window.

A single subject design with repeated measures of unaided auditory thresholds and speech perception performance was used comparing electric-acoustic and electric only stimulation. Evaluations were conducted pre-operatively, at initial activation, and at 6 and 12 months after activation of the implant. Pre-operative speech perception scores were measured monaurally under aided and unaided conditions individually at both sides and binaurally under aided conditions. The speech understanding was measured with the Freiburg monosyllabic word test in quiet @ 65 dB, HSM sentence test in quiet @ 65 dB and in CCITT-type speech-shaped background noise (10dB SNR), all under S0N0 condition. A reference group containing 165 cochlear implants subjects using the same implant electronics, but with the conventional Contour Advance electrode without residual hearing was identified for group comparison of speech performance results. For this group, only subjects with at least 15% monosyllabic word scores at the time of initial switch-on were selected to have a good performing comparison group for the Hybrid-L subjects who usually have good prerequisites for good hearing scores due to the short duration of deafness.

Apart from Hybrid-L subjects with residual hearing on the implanted side, results from 90 cochlear implant subjects with residual contralateral hearing have also been evaluated at MHH. These bimodal subjects were tested in two different conditions: a) with the cochlear implant alone, b) with the cochlear implant together with the contalateral hearing aid. The test battery for measuring the hearing performance in this particular patient group consisted of the Freiburg monosyllabic words in quiet and the HSM sentences in CCITT-type speech-shaped noise. Additionally, HSM sentences were presented with a competing talker instead of the standard CCITT-type noise to test the ability of the subjects to segregate talkers from each other. All tests were administered in the S0N0 condition.

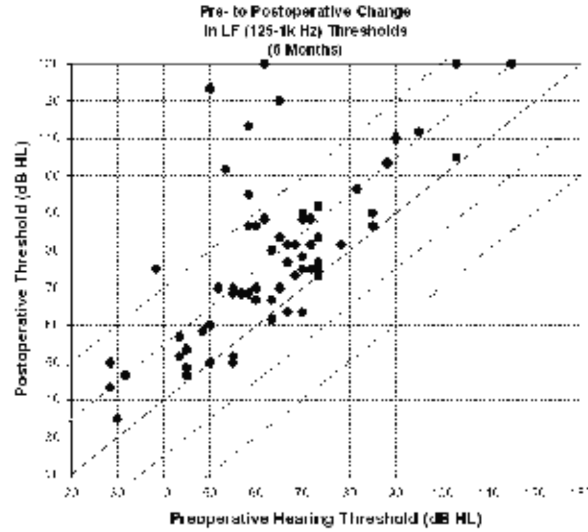
RESULTS

Hearing preservation (Hearing Loss < 30dB) has been observed in 93 percent of the cases with the Hybrid-L implant. Individual low-frequency thresholds of all 91 subjects are displayed in Fig. 2. The median pure tone air conduction thresholds of the subjects is displayed in Fig. 3 and shows different time intervals after surgery and the preoperative results for comparison. The bone conduction thresholds confirmed the results and indicate a conductive loss directly after surgery. This conductive loss is a result of fluid in the middle ear after surgery and couldn't be verified during measurements at initial activation.



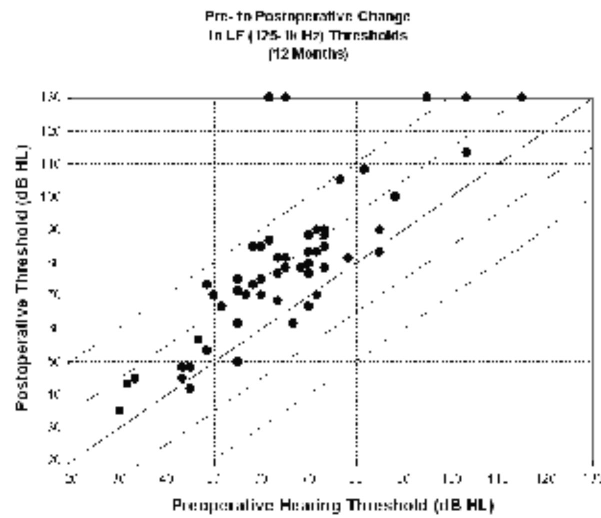
N	91	
N <15 dB	52	57%
N <30 dB	84	92%
N ≥30 dB	7	0%

Fig. 2a: Avg. thresholds (125 Hz – 1 kHz) for each individual subject before surgery and at the first fitting appointment, which usually takes place 5 weeks after implantation. 7 out of 91 subjects show a loss greater than 30 dB in the low frequencies at initial activation.



N	68	
N <15 dB	33	50%
N <30 dB	60	89%
N ≥30 dB	7	11%

Fig. 2b: Avg. thresholds (125 Hz – 1 kHz) for each individual subject before surgery and at the six months appointment.



N	56	
N <15 dB	33	69%
N <30 dB	53	95%
N ≥30 dB	3	5%

Fig. 2c: Avg. thresholds (125 Hz – 1 kHz) for each individual subject before surgery and at the 12 months appointment.

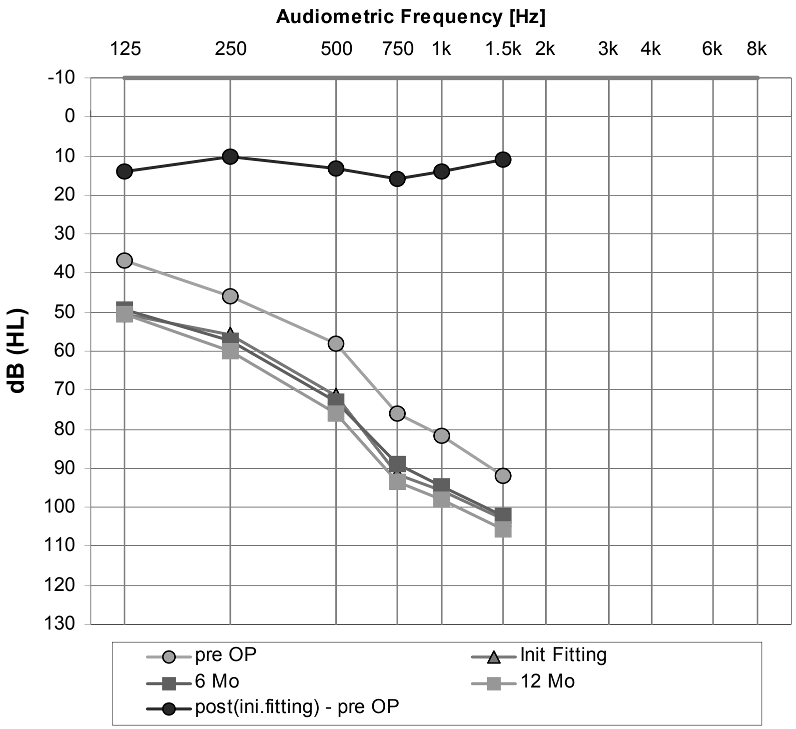


Fig. 3: Hybrid-L pure tone air conduction thresholds at different intervals

Fig. 4 shows the speech understanding results after 6 months, where the Contour-Advance control group is being compared with Hybrid-L subjects using electro-acoustic stimulation vs. electrical stimulation only. Significant differences could be found between groups for the sentence test in noise and for the monosyllabic word test. Note that not all subjects have reached their 6 months appointment, so group sizes vary across the appointments.

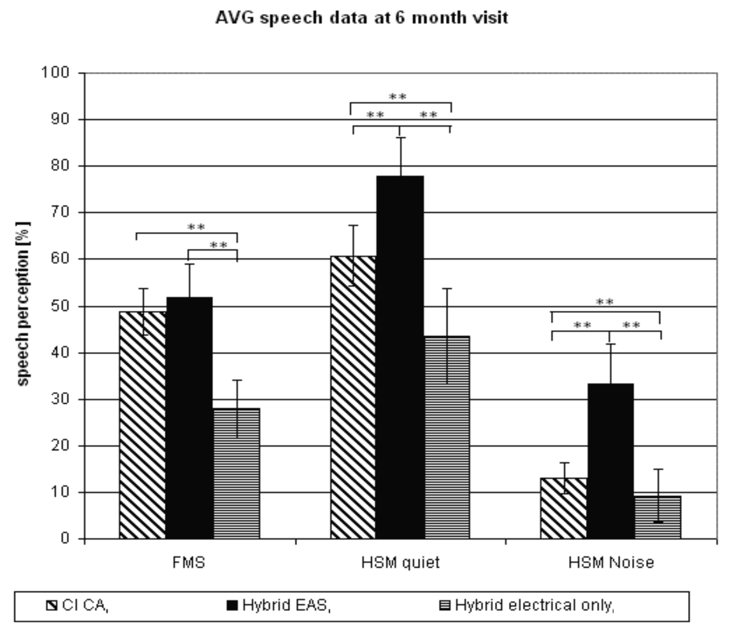


Fig. 4: Speech understanding at 6 months. Testing materials were: Freiburg monosyllables, HSM sentences in quiet and in noise (10 dB SNR). The groups tested were: Patients with conventional devices without residual hearing (reference group, n=134), subjects with the Hybrid-L implant using both electric and acoustic hearing (n=44) and the same group (Hybrid-L) tested with electric stimulation only.

Fig. 5 shows the speech test results from the 90 bimodal subjects, wearing a cochlear implant on one, and a conventional hearing aid on the other side.

The improvement of hearing performance when using the hearing aid jointly with the cochlear implant is highly significant.

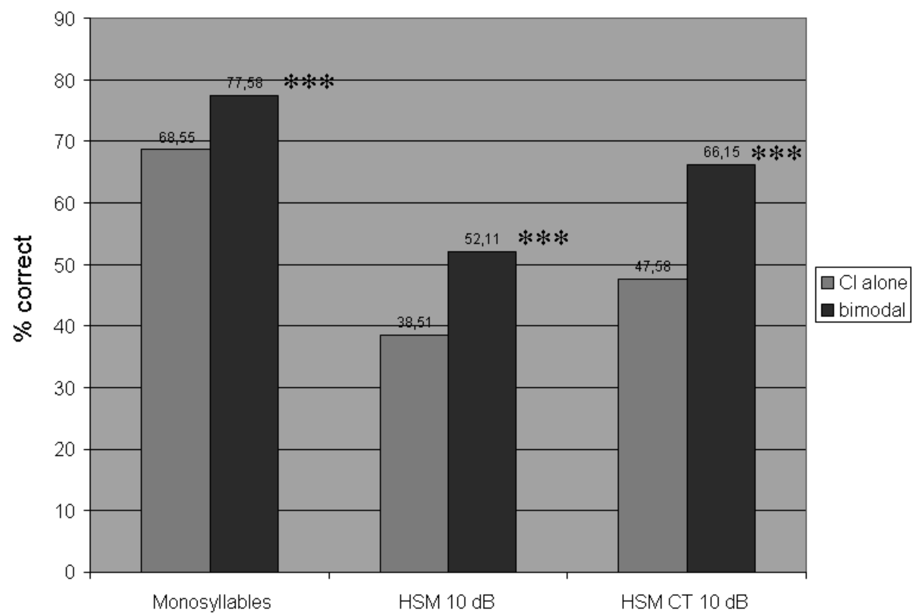


Fig. 5: Speech understanding for cochlear implant subjects wearing a contralateral hearing aid. Testing materials were: Freiburg monosyllables, HSM sentences in CCITT-noise (10 dB SNR) and with one competing talker (10 dB SNR). Extremely significant improvements were seen when the hearing aid was used additionally to the cochlear implant (bimodal mode).

DISCUSSION

The results indicate that residual hearing can be preserved with the Hybrid-L electrode in the majority of the cases. Considering that in only 7.6 % of the 91 subjects a hearing loss >30dB was observed at the time of initial activation and that the median loss of hearing was frequency independent, the Hybrid-L electrode provides the basic requirements to apply electric-acoustic stimulation. It could be demonstrated that long term hearing preservation is possible with the Hybrid-L electrode.

The significant difference in speech understanding of Hybrid users with electric-acoustic stimulation and electrical stimulation only could be caused by the acute change of the stimulation paradigm. The Hybrid subjects are used to combined electrical and acoustical stimulation and rely on their acoustical hearing in everyday life. During the measurements in electrical only mode, the ears have been plugged and the subjects could not use their residual acoustic hearing. This significant drop in performance also indicated how much they actually still rely on the acoustic hearing. The Hybrid-L subjects benefit from their acoustical hearing and gain a

significantly larger benefit with the combination of electrical and acoustical stimulation versus the reference group consisting of normal CI users. When changing the conditions by not allowing the Hybrid-L subjects to use the acoustic hearing, the performance drops significantly.

The bimodal subjects, having electric stimulation on one side and acoustic residual hearing on the opposite ear, show that a beneficial combination of the two hearing sensations also functions across ears. This patient group shows a highly significant advantage in terms of speech understanding in quiet, in noise and under competing talker conditions over electric only stimulation with a cochlear implant. These are important findings when considering a bilateral provision of cochlear implants, i.e. when to use bimodal hearing vs. cochlear implantation on both ears. Based on our data from this ongoing study, we are currently developing clinical guidelines for when to use bimodal stimulation vs. bilateral electric stimulation.

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