Original Paper

ORL

ORL 2002;64:247–253

Received: September 5, 2001
Accepted: September 20, 2001

Preservation of Residual Hearing in Children and Post-Lingually Deafened Adults after Cochlear Implantation: An Initial Study

Henryk Skarżyński[a] Artur Lorens[a] Patrick D'Haese[b] Adam Walkowiak[a]
Anna Piotrowska[a] Lech Śliwa[a] Ilona Anderson[b]

[a]Institute of Physiology and Pathology of Hearing, Warsaw, Poland; [b]Clinical Research Department, Med-El, Innsbruck, Austria

Key Words
Residual hearing · Cochlear implant · Med-El · Soft surgery technique

Abstract
Objective: To investigate whether the residual hearing of severely hearing-impaired children and adults could be preserved using the soft surgery approach. ***Patients and Methods:*** This project employed a prospective study design. All testing and surgery took place in the Institute of Physiology and Pathology of Hearing, Warsaw, Poland. Twenty-six patients (7 children and 19 post-lingually deafened adults) with residual hearing were assessed. Subjects were assessed using conventional pure-tone audiometry at least 1 month prior to surgery. Cochlear implant surgery with a Med-El Combi 40/40+ standard electrode array was conducted, using the soft surgery approach. Pure-tone audiometry thresholds were re-assessed at least 1 month after surgery. The researchers assessed change in auditory thresholds using pure-tone audiometry to determine preservation of residual hearing. ***Results:*** Sixteen of 26 patients (62%) retained their residual hearing within 5 dB HL of pre-operative scores. Only 5 of 26 patients (19%) lost all measurable residual hearing after cochlear implantation. This suggests that surgeons are often able to preserve residual hearing during cochlear implant surgery using the soft surgery technique. ***Conclusions:*** Preservation of residual hearing is an important consideration in cochlear implantation in the light of changing selection criteria for cochlear implant candidates, and as younger children are receiving implants. This is important, as we do not know yet the long-term effects of inner ear damage due to traumatic insertions of electrodes. This finding suggests a good prognosis for future possibilities of re-implantation.

This paper was first presented as a poster at the 8th Symposium on Cochlear Implants in Children, Los Angeles, California, February 28 to March 3, 2001.

Introduction

Cochlear implants are increasingly becoming the preferred medium for (re-)habilitation of profoundly hearing-impaired individuals. Open-set speech understanding is now not unrealistic for the majority of post-lingually deafened adults [1–3] and for some children [1, 3–5]. As more positive results of implantation are demonstrated, electrode design is refined and surgical techniques improve, there is considerable emphasis on implanting in

KARGER

Fax + 41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

0301–1569/02/0644–0247$18.50/0

Accessible online at:
www.karger.com/journals/orl

Artur Lorens
Institute of Physiology and Pathology of Hearing
Ul. Pstrowskiego 1
PL–01-943 Warsaw (Poland)
Tel. +48 22 835 6670, Fax +48 22 835 5214, E-Mail artur@prezes.ifps.org.pl

individuals with severe hearing impairment [2]. Individuals with some residual hearing, also considered silver (101–110 dB HL) and gold (90–100 dB HL) [6] hearing aid wearers, are beginning to show considerable benefit when implanted [2, 3], with most achieving open-set recognition with a cochlear implant [7]. Individuals with residual hearing are already being considered as cochlear implant candidates, and criteria have expanded to include this population [1, 4].

However, there may be concerns about the traumatic process of surgery destroying most or all residual hearing. What if future generations of electrodes were able to utilise residual hearing? The potential to stimulate those with residual hearing already exists, using a combination of cochlear implant and hearing aid: electric-acoustic stimulation (EAS) [8]. Thus the question arises whether it is correct to implant children with residual hearing when we are not sure what the future may hold for them in terms of technological improvement.

Several studies have reported on residual hearing after cochlear implantation. Brimacombe et al. [2] reported significant losses of residual hearing in the implanted ear of 50 patients; Rizer [9] noted a loss in 7 reported patients, and Boggess et al. [10] in 12 patients. On a more positive note, Hodges et al. [7] reported a loss of residual hearing in roughly half of 40 implanted patients. Dye et al. [11] noted preserved residual hearing in 8 out of 20 patients implanted with a short, 6-mm electrode from 3M/House. Similar results were reported by Lorens et al. [16].

Some reports suggest that the use of a short electrode or one from the standard electrode array will result in the preservation of residual hearing [10, 11]; other studies suggest it is not possible to conserve residual hearing using a long (>14 mm) electrode [9, 11]. Further suggestions for preserving residual hearing refer to the use of soft surgery approach [12, 14].

There has been considerable improvement in cochlear implant technology, both in hardware and software. Long-term benefits of cochlear implantation are being published [1–3], and the boundaries of candidate selection are being widened as a result [1, 4]. The question arises: what about candidates with residual hearing? Are we implanting these individuals without knowing about long-term damage to the cochlea, and without long-term knowledge of implant benefits compared with a traditional hearing aid?

Thus this study aims to investigate whether using the Med-El Combi 40 or 40+ electrodes and the soft surgery approach would result in any loss of residual hearing in the implanted ear.

Table 1. Subject description and pre- and post-implant PTAs for 125, 250 and 500 Hz

Gender	Age at implantation	Device	Aetiology	PTA	
				pre-implant	post-implant
M	29	40	unknown	84	95
F	25	40	unknown	85	93
M	16	40	unknown	95	98
F	27	40	meningitis	96	95
F	16	40+	meningitis	95	100
F	16	40	meningitis	93	130
M	39	40+	genetic	96	130
M	19	40+	meningitis	90	85
M	50	40	ototoxic	88	91
F	8	40+	unknown	83	90
F	8	40+	unknown	105	130
F	52	40+	meningitis	111	111
F	57	40+	unknown	96	96
M	6	40+	meningitis	91	91
M	35	40	morbili	96	130
F	4	40+	unknown	93	93
F	12	40+	ototoxic	93	93
F	9	40+	unknown	100	100
F	8	40+	unknown	96	98
F	57	40+	unknwon	85	91
M	54	40	otitis media	91	98
M	38	40	unknown	96	96
F	54	40	ototoxic	98	130
F	26	40	accident	95	95
F	50	40	unknown	96	101
M	16	40+	accident	93	98

PTA = Pure-tone audiometry scores.

Methods

Up to the present date, over 300 patients have received cochlear implants at the Institute of Physiology and Pathology of Hearing, Warsaw, Poland. Of these, 26 children and post-lingually deafened adults presented with residual hearing pre-operatively. Residual hearing was considered measurable hearing in, at least, the frequency range 125–500 Hz. Pure-tone results show hearing loss in the severe to profound range. Of these subjects, 10 were male and 16 female. Seven were under the age of 16 at the time of implantation and 19 were adults. The mean age at implantation was 23.7 years (range from 4 to 52 years). Table 1 gives a detailed description of subjects, including details on the cause of hearing loss and pure-tone averages for frequencies 125, 250 and 500 Hz.

All testing was performed using a Siemens SD5 audiometer, calibrated to American National Standard (ANSI) standards, with a maximum output of 130 dB HL. Testing was performed in an IAC soundproof booth under Sennheiser HDA 200 headphones.

Pre-implant testing took place at least 1 month before cochlear implant surgery. Pure-tone testing was conducted at 125, 250 and 500 Hz in the implanted ear according to standard threshold procedures. These frequencies were selected to assess if there was any

Fig. 1. Med-El Combi 40+ standard electrode.

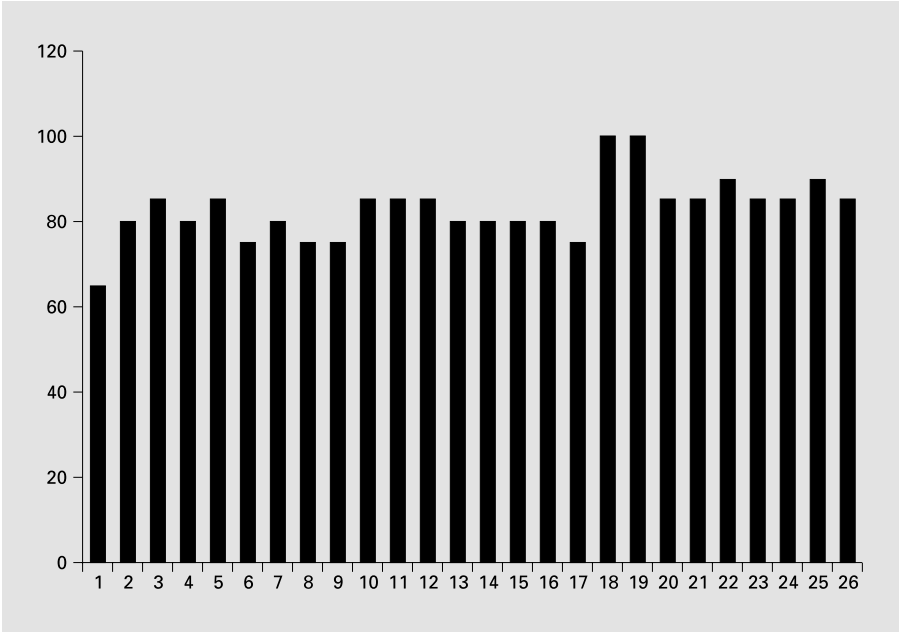

Fig. 2. Pre-operative thresholds (in dB HL) for all patients: 125 Hz.

mechanical damage to the apical end of the cochlear due to full electrode insertion of the Combi 40 and 40+ electrodes (full insertion = 31.3 mm). If no response was obtained at the maximum output level of the audiometer, then 130 dB HL was considered as the threshold for calculation purposes. If subjects indicated a vibratory response, this threshold was not considered as a response for residual hearing but was recorded as 'no response'.

Soft surgery technique was used for the cochlear implantations. Soft surgery technique involves a minimal cochleostomy, maximum electrode insertion, preservation of perilymph and use of Healon® (Pharmacia, Columbus, Ohio, USA) to lubricate the electrode and seal the cochleostomy during insertion [11]. All subjects were implanted with the Med-El Combi 40 (n = 9) or 40+ (n = 17) cochlear implant system. The electrode has a diameter of 0.6 mm and either 8 (Combi 40) or 12 (Combi 40+) electrode contacts over 26.4 mm (fig. 1).

Testing was conducted 1 month after surgery, with the cochlear implant removed from the head. Subjects were tested in the same conditions as the pre-surgery assessment. Subjects were tested under headphones with the cochlear implants switched off. Pure-tone thresholds were re-assessed.

Results

Pre-operative results are shown in figures 2–4. The average hearing loss for 125 Hz was 82.9 dB HL, for 250 Hz 91.5 dB HL and for 500 Hz it was 108.3 dB HL.

Considering the fact that attenuator steps of 5 dB were employed, a minimum of ± 5-dB measurement error was

Fig. 3. Pre-operative thresholds (in dB HL) for all patients: 250 Hz.

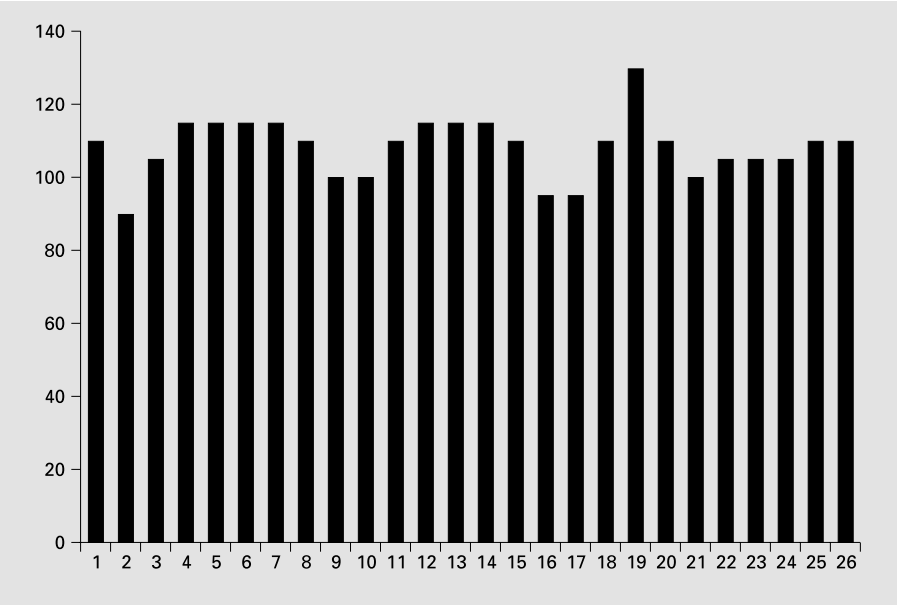

Fig. 4. Pre-operative thresholds (in dB HL) for all patients: 500 Hz.

introduced. Since tolerances contained in ANSI standards are from ± 3 to 5 dB of designated sound pressure levels, the standard error can potentially expand to ± 10 or 15 dB HL, depending on the listener's actual physiologic sensitivity [15]. Therefore, we only considered patients with a negative threshold difference of more than 10 dB as being patients who lost a certain degree of hearing following the cochlear implantation.

The post-surgery changes in auditory threshold for the frequencies 125, 250 and 500 Hz can be seen in figures 5–7. We can see that only 6 out of 26 patients (23%) lost their hearing at 125 Hz. In 77% of the cases, hearing was preserved after inserting a standard Combi 40 or 40+ electrode using soft surgery approach. The same results can be seen at 250 Hz. For 500 Hz, 7 out of 26 patients (26%) lost their hearing.

We can determine an overall loss of hearing by looking at the mean pure-tone audiometry (PTA) scores. The mean PTA decreased by 9 dB HL from 93 dB HL preoperatively to 102 dB HL post-operatively in the im-

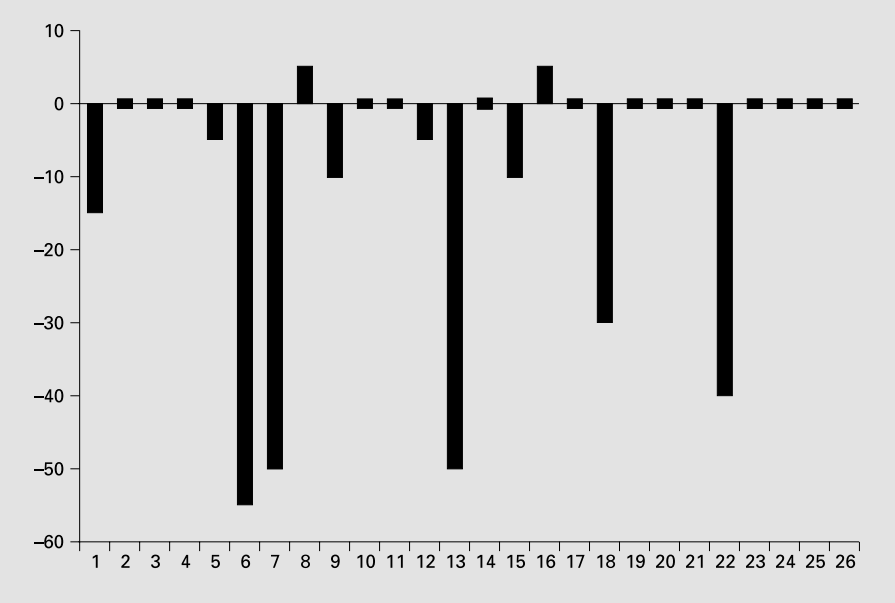

Fig. 5. Post-operative threshold changes for all patients: 125 Hz.

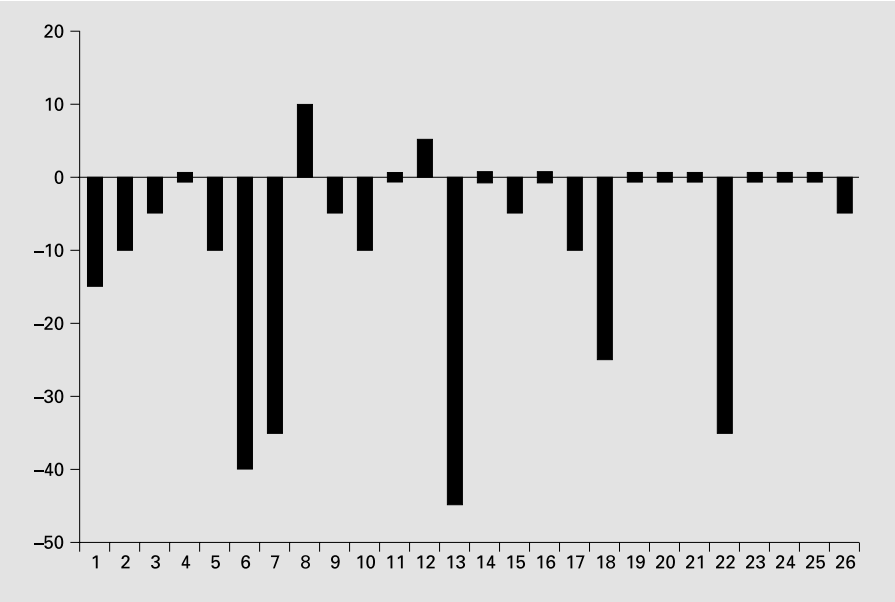

Fig. 6. Post-operative threshold changes for all patients: 250 Hz.

planted ear. This score includes all subjects who exhibited no response at the given average of 130 dB HL. However, as this is an artificial value and biases the result, averages were calculated excluding the 'lost residual hearing' group. The results are striking, with a drop in 3 dB HL from 92 dB HL to 95 dB HL. Interestingly, if one reviews the average PTA score for each patient in table 1, we can see that 16 of 26 patients (62%) retained their residual hearing within 5 dB HL of pre-operative scores, whilst 5 of 26 patients (19%) lost some residual hearing. Only 5 of 26 (19%) patients lost all measurable residual hearing after cochlear implantation.

Statistical analysis revealed no influencing variables when considering age, gender, aetiology or electrode type.

Using the same testing criteria, hearing thresholds showed no improvement post-surgery.

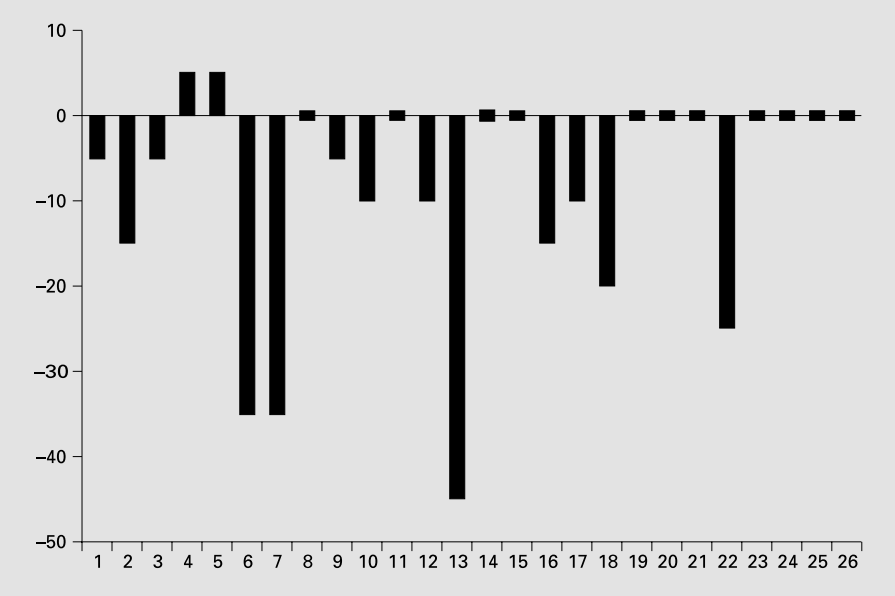

Fig. 7. Post-operative threshold changes for all patients: 500 Hz.

Discussion

Hearing thresholds after cochlear implantation shows a minimal reduction in residual hearing when compared with hearing thresholds pre-implantation. Overall pure-tone average loss was 9 dB HL, while an astounding 62% had conserved hearing after cochlear implantation. These results suggest that by using the Med-El Combi 40 or 40+ electrode array in conjunction with the soft surgery approach, residual hearing can be maintained.

However, we do need to bear in mind that the amount of residual hearing lost due to surgery may be underestimated by a ceiling effect due to the limitation of audiometer output, determined at 130 dB HL. However, this affected only 5 subjects, and results for hearing conservation still hold true. The measurement effect [15] may have had an influence on test results, though these cannot be determined as the individual's physiology has an impact on this. We were aware that some responses to sound may have been tactile; however, adults and older children were asked to indicate if this was the case. If so, they were given a score of 130 dB HL (no response). Obviously, this was more difficult in children, however, most children assessed were old enough to complete this task. There could be further concerns about accuracy of results with children. All children in this study submitted reliable results over time and could be considered 'sophisticated' testees, given that they had experience in test situations.

Interestingly, no influencing variables such as gender, age and duration of deafness influenced the preservation of residual hearing after surgery. Criticisms may arise in that this study considered the impact of surgery on the lower frequencies. Lower frequencies occur at the apical end of the cochlea, a region not frequently damaged during surgery. There may be some concern for this region due to possible damage of the basilar membrane in the cochlea and the resulting changes in the mechanical characteristics of the cochlea. However, our results show that with the Combi 40/40+ electrode and the soft surgery approach, the structures of the cochlea remain intact, resulting in minimal damage to the lower frequencies, despite full electrode insertion up to 31.3 mm.

These test results compare favourably with Dye et al. [11]. Their study utilised a much shorter electrode than the Combi 40 and 40+ electrode, but this study shows that residual hearing may be preserved in most cases using a longer electrode. Results also agree with those of Hodges et al. [7]; however, our study has not considered changes in hearing over time, and this should be a consideration for further research in order to enable more appropriate comparisons. There is a discrepancy between this and other reports where subjects lost residual hearing [2, 9]. Differences may arise from the electrodes used and the surgical approach applied. Interestingly enough, these results are more favourable than those of Lehnhardt [12], who assessed residual hearing in children after soft surgery and found only half the children tested (6 of 12 chil-

dren) had conserved hearing, whereas this study found 5 of 7 children with conserved hearing.

Our paediatric results tend to follow those of Kiefer et al. [1], who found that most children retained residual hearing after surgery. We noted that 5 of 7 children (71%) had retained residual hearing, 1 child had a hearing loss of 7 dB HL and another had lost all hearing. Kiefer et al. [1] postulated that children are more likely to preserve their residual hearing than adults; however, children need to be assessed over time as there may be further degeneration. We noted more adults (58%) with preserved residual hearing, however, this was only at 1 month after the implant, and the time factor still needs to be addressed.

Future research will need to consider the loss of residual hearing over time. Outcomes for implanted individuals with residual hearing need to be taken into consideration. Comparisons between retained residual hearing, lost residual hearing and no residual hearing implantees need to be made in order to prove fully the effectiveness of implanting individuals with residual hearing, both in terms of performance and quality of life.

Considering the fact that hearing was preserved in 62% of our cases, new possibilities could be offered for future implantees. Up to now, not enough is known about long-term effects of inner ear damage caused by traumatic insertions of electrodes (such as perforation of the basilar membrane and damage to the lateral wall). Using the soft surgery approach with the highly a-traumatic Combi 40 or 40+ electrode, it is possible to preserve hearing in the majority of cases. This is an important consideration, because if no damage is caused to the delicate structures of the inner ear, then re-implantation with another electrode or another generation of cochlear implants could be possible without risking a poor outcome.

References

1 Kiefer J, von Ilberg C, Reimer B, et al: Results of cochlear implantation in patients with severe to profound hearing loss – implications for patient selection. Audiology 1998;37:382–395.

2 Brimacombe JA, Arndt PE, Staller SJ, et al: Multichannel cochlear implantation in adults with severe to profound sensori-neural hearing loss; in Hochmair-Desoyer I, Hochmair E (eds): Cochlear Implants. Wien, Manz, 1994, pp 387–392.

3 Snik AF, Vermeulen AM, Brokx JP, et al: Long-term speech perception in children with cochlear implants compared with children with conventional hearing aids. Am J Otol 1997; 18(suppl):S129–S130.

4 Lenarz T: Cochlear implants: Selection criteria and shifting borders. Acta Otorhinolaryngol Belg 1998;52:183–199.

5 Kiefer J, Gall V, Desloovre C, et al: A follow-up study of long-term results after cochlear implantation in children and adolescents. Eur Arch Otorhinolaryngol 1996;253:158–166.

6 Osberger MJ, Maso M, Sam LIC: Speech intelligibility of children with cochlear implants, tactile aids, or hearing aids. J Speech Hear Res 1993;36:186–203.

7 Hodges AV, Schloffman J, Balkany T: Conservation of residual hearing with cochlear implantation. Am J Otol 1997;18:179–183.

8 von Ilberg C, Kiefer J, Tillien J, et al: Electric-acoustic stimulation of the auditory system. New Technology against severe hearing loss. ORL J Otorhinolaryngol Relat Spec 1999;61: 334–340.

9 Rizer FM: Post-operative audiometric evaluation of cochlear implant patients. Otolaryngol Head Neck Surg 1998;98:203–206.

10 Boggess WJ, Baker JE, Balkany TJ: Loss of residual hearing after cochlear implantation. Laryngoscope 1989;99:1002–1005.

11 Dye L, House WF, O'Connor C: Measurable residual hearing following cochlear implantation. Presented at the American Academy of Otolaryngology-Head and Neck Surgery, Chicago, 1987.

12 Lehnhardt E: Intracochlear placement of cochlear implant electrodes in soft surgery technique. HNO 1993;41:356–359. (German)

13 Rogowski M, Reiss G, Lehnhardt E: Morphological study of the guinea pig cochlear after cochlear implantation using the 'soft surgery' technique. Ann Otol Rhinol Laryngol Suppl 1995;166:434–436.

14 Lehnhardt E: Cochlear implants in children – experience in Europe and future aspects. Presented at the First Asia Pacific Symposium on Cochlear Implant and Related Sciences, Kyoto, Japan, April 3–5, 1996.

15 Harris JD: Proem to a quantum leap in audiometric data collection and management. J Aud Res 1978;18:1–29.

16 Lorens A, Geremek A, Walkowiak A, Skarżyński H: Residual acoustic hearing in the ear before and after cochlear implantation; in Jahnke K, Fischer M (eds): 4th European Congress of Oto-Rhino-Laryngology Head and Neck Surgery. Bologna, Monduzzi, 2000, vol.1, pp 135–138.