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Hearing and Patient Satisfaction Among 19 Patients Who Received Implants Intended for Hybrid Hearing: A Two-Year Follow-Up

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Objectives: To measure patient satisfaction and correlate to hearing results in partially deaf patients, after hearing preservation cochlear implant surgery with hybrid hearing strategy, and to evaluate the stability of residual low-frequency hearing (LFH) over time.

Design: A patient satisfaction survey and a retrospective, 2-year follow-up journal study. Nineteen partially deaf patients intended for hybrid hearing responded to a questionnaire when they had used their cochlear implants for at least a year. The questionnaire consisted of the International Outcome Inventory for Hearing Aids, EuroQol Group visual analogue scale and nine questions about hybrid hearing. Pure-tone audiometry, monosyllables, and hearing in noise test results from the patients' medical records were evaluated and compared with the results from the patient satisfaction survey.

Results: All of the patients were satisfied with their CIs. The mean International Outcome Inventory for Hearing Aids score was 29. The CIs provided a major contribution to the speech comprehension of these partially deaf patients. Two years after surgery, the patients' mean binaural score on tests of monosyllables was 58%, and the mean signal to noise ratio was 4.6 dB. We observed ongoing deteriorations in the residual hearing of the operated ears that surpassed the deteriorations observed in the contralateral ears. One month after surgery, the LFH loss (125–500 Hz) was 17 dB, and after 2 years, this loss was 24 dB compared with 5 dB in the nonoperated ear. There were no significant correlations between preserved LFH and patient satisfaction or speech perception results.

Conclusions: Electric stimulation provided a major contribution to speech comprehension of partially deaf patients. The gain reached in speech understanding widely exceeded the downside in losing some residual hearing. All the patients showed a high degree of satisfaction with their CIs regardless of varying hearing preservation.

Key Words: Children, Cochlear implant, EAS, EQ-5D, Hearing preservation, Hybrid hearing, IOI-HA, Partial deafness, Quality of life, Questionnaire, Residual hearing.

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INTRODUCTION

Von Ilberg et al. (1999) showed that it is possible to combine the electrical stimulation of a cochlear implant (CI) device with the acoustic stimulation of a hearing aid (HA). Initially, this technique was used for patients with pure-tone thresholds of more than 60 dB in the low frequencies, but it is currently possible for partially deaf patients with normal low-frequency hearing (LFH) to receive implants. These patients do not need ipsilateral HA amplification in the low frequencies. They only need complementary electrical hearing in the middle and high frequencies.

Patients with residual hearing benefit considerably from CIs alone compared with conventional HAs (Cullen et al. 2004; Dowell et al. 2004; Gantz & Turner 2004; Adunka et al. 2008). The advantages of hybrid hearing compared with CI only have been demonstrated by von Ilberg et al. (1999), Helbig et al. (2008), Lorens et al. (2008), and Gstoettner et al. (2009). Music perception (Gfeller et al. 2006, 2007) and hearing in complex listening situations (Gifford et al. 2013) seems to improve to a greater extent with hybrid hearing than with conventional CI. To date, only a few studies have investigated the quality of life and subjective ratings from hybrid hearing patients (Lenarz et al. 2013; Santa Maria et al. 2013).

Hybrid hearing requires preserved LFH. Typically, a shorter electrode that is inserted around one turn is used. This procedure minimizes the trauma to the low frequency region in the apical portion the cochlea. The extent of hearing preservation varies and has been presented in different manner. Some studies have indicated delayed hearing loss after surgery (Gstoettner et al. 2006; Luetje et al. 2007), whereas other studies have reported stable hearing in the operated ear (Skarzynski et al. 2007; Lenarz et al. 2009). Nevertheless, the follow-up periods after surgery of these studies have generally been short.

Potential candidates for hybrid hearing can be categorized into two groups. The first category includes those with natural LFH who are not supposed to need amplification. The second category includes people with LFH requiring HA amplification. Both categories of people will, if their LFH is preserved, use CI hearing in the middle and high frequencies, which is called cut off frequency CI (the stimulation is in the range of approximately 500–8500 Hz). Some patients will lose more residual hearing than intended during surgery. Some patients will display little use of their residual hearing. The devices used by these patients will be switched to include LFH and are called conventional CIs or full frequency CIs (125–8500 Hz). After surgery, depending on the extent of surgery-induced hearing loss, the patients who are intended for hybrid hearing can be divided into the following three groups: a natural LFH with cut off frequency CI group, a HA-amplified LFH with cut off frequency CI group, and a full frequency conventional CI group. Only the two first groups are hybrid-hearing patients. It can be assumed that hybrid-hearing patients with natural LFH have better quality hearing than hybrid-hearing patients with HA-amplified LFH. Thus, these groups are assessed separately. Skarzynski et al. (2012) called the first group

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TABLE 1. Age, sex, age of hearing loss, surgery ear, date of activation, mode of fitting, and usage of contralateral hearing aid

No	Age	Sex	Debut Age	Ear	Date of Activation	Frequency Range (Hz)	HA contra
1	53	F	10	L	Oct 2008	100–8500 + HA	N
2	70	M	30	L	Nov 2009	571–8500 + HA	A
3	82	F	50	R	Jan 2010	100–8500	A
4	69	M	50	L	Jan 2010	496–8500 + natural	S
5	48	M	10	L	April 2010	70–8500	S
6	68	F	40	L	May 2010	350–8500 + HA	A
7	70	M	50	L	June 2010	594–8500 + HA	A
8	72	M	20	L	June 2010	250–8500 + HA	A
9	57	M	20	L	Aug 2010	350–8500 + HA	A
10	73	F	50	L	Oct 2010	393–8500 + HA	N
11	28	F	C	L	Nov 2010	350–8500 + HA	A
12	73	M	30	L	March 2011	100–8500	A
13	15	F	C	R	March 2011	70–8500 + natural	A
14	67	F	40	R	April 2011	393–8500 + natural	N
15	53	F	20	R	May 2011	333–8500 + HA	S
16	10	F	C	R	May 2011	450–8500 + natural	S
17	67	M	20	R	June 2011	458–8500 + natural	A
18	65	M	40	R	Nov 2011	250–8500 + natural	A
19	69	F	40	R	Nov 2011	100–8500	A
Min	10	9 M	C	8 R	Oct 2008	9 CI + HA	3 N
Max	82	10 F	50	11 L	Nov 2011	6 CI + natural	4 S
						4 full frequency CI	12 A

Age: age (years) at the activation of the processor. F, female; M, male. Debut age: age at the approximate debut of hearing loss, and C indicated hearing loss since birth or early childhood. Ear, operated ear; L, left; R, right. Date of activation of the processor (typically 4 weeks after the surgery). Frequency range: Frequency range of the processor in hertz at the two-year follow up. HA, hearing aid. Natural: sufficient natural hearing in the operated ear such that HA amplification was not needed. HA contra, hearing aid use in the contralateral ear at the time of the patient satisfaction survey; A, always; S, sometimes; N, never.

electrical complement patients and the second group electro-acoustic stimulation patients. Other authors have used electro-acoustic stimulation and hybrid hearing as synonyms.

The aims of this study were as follows:

1. evaluate patient satisfaction among patients intended for hybrid hearing and the relationship of patient satisfaction with hybrid hearing;
2. relate hearing results in quiet and noisy conditions to subjective experiences and residual hearing;
3. evaluate whether ongoing deterioration of residual hearing occurred in the hybrid-hearing patients.

MATERIALS AND METHODS

The study group consisted of 19 patients who were intended for hybrid hearing (Table 1). Two of these patients were children. The ages at implantation ranged from 10 to 82 years and the study group consisted of 10 female and nine male patients.

From September 2008 to November 2011, the first 24 consecutive, partially deaf patients intended for hybrid hearing underwent hearing preservation surgery in our department. The preoperative candidacy criteria were an unaided pure-tone threshold ≤65 dB HL at frequencies ≤500 Hz and >80 dB HL at frequencies ≥2000 Hz in the ear that was intended for surgery, nearly symmetrical hearing in the contralateral ear (i.e., the better ear), and aided monosyllabic word scores below 60% in each ear. In January 2013, after all patients had used their device for at least 1 year, the patients were asked to participate in the study. The study was approved by the Regional Ethical Review Board in Uppsala (2012/473). Nineteen patients provided written informed consent and responded to the questionnaire survey. The hearing results of these patients were assessed based on their medical records. The pure-tone audiograms of five of these patients have earlier been presented by Erixon et al. (2012).

The patient questionnaire survey consisted of the following three parts:

1. The International Outcome Inventory for Hearing Aids-Swedish (IOI-HA), which was translated into Swedish in 2005 and provided by the International Collegium of Rehabilitative Audiology. The IOI-HA is a questionnaire that targets seven different domains via questions about the following seven topics: (1) HA use, (2) HA benefit, (3) residual activity limitations, (4) satisfaction, (5) residual participation restriction, (6) effect on others, and (7) quality of life. Each item is scored from 1–5, and higher scores indicate more favorable outcomes. The outcome measures can be divided into two subscales. Factor 1 is the sum of items 1, 2, 4, and 7 and represents CI satisfaction, and factor 2 is the sum of items 3, 5, and 6 and represents participation restriction (Kramer et al. 2002; Stephens 2002; Öberg et al. 2007). The questionnaire has been validated and was initially developed for the assessment of HA outcomes (Cox et al. 2000, 2003). We replaced "present HA(s)" with CI.
2. The EQ-5D of the EuroQol Group is a standardized instrument for measuring health outcomes. This instrument consists of two parts, and we used the part that involved a visual analog scale with endpoints that are labeled "Best imaginable health state" (100 points) and "Worst imaginable health state" (0 points).

TABLE 2. Low-frequency hearing losses in the operated and contralateral ears after surgery (125, 250, and 500 Hz)

Time After Surgery	Mean Loss (dB)	Max (dB)	Min (dB)	SD	Mean loss (dB)	SD
		Operated Ear			Contralateral Ear	
1 Month	-17	-40	3	11		
1 Year	-19	-58	7	14	-2	6
2 Years	-24	-57	3	16	-5	6
3 Years (8 patients)	-29	-58	-8	19	-9	7

The differences (in decibels) in the low-frequency pure-tone averages (at 125, 250, and 500 Hz) before surgery and at the specified follow-up periods.

3. A survey containing nine questions concerning the use of residual hearing. This survey was added to scrutinize residual hearing and increase the relevance of the results across different listening situations, such as listening in noisy condition and listening to music. Interested readers can access the nine-question survey in the Appendix, Supplemental digital content (http://links.lww.com/EANDH/A188).

Audiometry

The patients were evaluated with conventional pure-tone audiograms. The audiograms were performed according to the international standards. Speech discrimination tests involving phonemically balanced monosyllabic words (MS) were performed with and without the HAs uni- and bilaterally at a comfortable level (65–85 dB sound pressure level; Svensk Talaudiometri, C-A Tegnér AB: 1998). The Hearing In Noise Test (HINT), a speech recognition test in which everyday sentences are presented with noise, was performed for patients with sufficient hearing (Hällgren et al. 2006). At the follow-up, we evaluated the pure-tone audiograms and best-aided MS and HINT scores.

Surgery and Fitting

All patients in the study were operated on by a single surgeon. A round window approach was used, and the electrode was inserted slowly in steps that were interrupted by instillations of corticosteroids into the middle ear (Kenacort-T or triamcinolone solution, 40 mg/mL). A 24-mm long flexible electrode (MED-EL FLEXEAS) was used in all cases with the exception of one patient who received a custom-made electrode (20 mm) from MED-EL. One month after surgery, a postoperative audiogram was taken, and the patients were fitted with CI processors (Opus 2), and if needed, most of the patients were fitted with an ipsilateral HA at the same time (Duet 2). The patients visited our clinic on 4 days during the first 2 weeks for adjustment and training and then visited at 5 weeks and 3, 6, and 12 months after the fittings. Subsequent annual visits followed.

Statistics

Group means and alterations in pure-tone thresholds, MS, HINT, and patient satisfaction scores were assessed. The parameters were plotted, and the correlations were evaluated using Excel (Microsoft). The levels of significance (i.e., *p* values) were calculated using Wilcoxon's matched pairs signed rank test.

RESULTS

Before surgery, seven patients were intended to use unamplified LFH and a CI, and 12 patients were intended to use an ipsilateral HA and a CI. At the time of the patient survey, six patients were using unamplified LFH and a CI. Nine patients were using amplified LFH and a CI, and four patients were using a conventional full-frequency CI (Table 1). There were no surgical complications and no persistent increases in tinnitus or dizziness; however, one patient suffered a persistent loss of chorda tympani function.

Patient Satisfaction

The mean IOI-HA score was 29 out of the possible 35 (SD 3.4, range 22–35). The individual results are shown in Table 3. All items are presented in Table 4 separately for the hybrid hearing and nonhybrid hearing groups.

The groups exhibited nearly identical results on all questions with the exception of question number 5 (residual activity limitations) for which the nonhybrid patients indicated greater limitations. This difference was not statistically significant ($p = 0.71$).

The EQ-5D visual analog scale was not completed by two patients (Table 3). The mean value across the 17 responders was 78 (SD = 18.9, range: 27–100). The patients with natural LFH scored 87 (SD = 9.7). The group with an ipsilateral HA scored 79 (SD = 20.2), and the nonhybrid group scored 67 (SD = 21.2). The difference between the hybrid and nonhybrid patients was not statistically significant ($p = 0.51$).

According to the nine-question survey, 18 patients were "very satisfied" with their CI, and one patient was "satisfied." All of the patients responded that they would recommend a CI to a person in a situation similar to their own. Seventeen patients used their CI for more than 8 hr per day. One patient used the CI for 4 to 8 hr per day, and one patient used the CI for 1 to 4 hr per day. Table 3 illustrates the results of the hearing in silence, hearing in noisy conditions, and hearing music tests. One patient heard less than expected. Three patients heard "about the same," seven heard "better," and eight heard "much better" than they expected.

Comparison of the patients with useful LFH and the full-frequency stimulation group revealed a trend toward higher scores in the former group. Regarding hearing in noisy conditions, the hybrid-hearing patients scored 3.3 (SD = 0.9) compared with 2.5 (SD = 1.0) for the full-frequency stimulation group. A similar difference was found in the hearing in silence test (4 [SD = 0] compared with 3.5 [SD = 0.6], respectively). There were no differences in general satisfaction, time of use, contralateral

TABLE 3. Patient satisfaction, experience, and speech discrimination separately for the patients with natural low-frequency hearing, the patients with hearing aids in the low frequencies and the patients with a conventional CI

No	Frequency Range (Hz)	VAS	IOI-HA	Silence	Noise	Music	Residual Hearing	LF PTA dB	MS % (Gain)	HINT dB (Gain)
4	496–8500 + n	87	28	Much better	Same	Not well	Great benefit	37	68 (60)	4 (18)
13	70–8500 + n		27	Much better	Much better	Very well	Great benefit	-2	60 (2)	-1.6 (12)
14	393–8500 + n	80	33	Much better	Better	Not well	Beneficial	50	22 (18)	10.6
16	450–8500 + n	100	30	Much better	Much better	Very well	Beneficial	18		0.1 (11)
17	458–8500 + n	79	25	Much better	Same	Well	Great benefit	40		8.9 (11)
18	250–8500 + n		33	Much better	Much better	Well	Great benefit	45	12 (8)	5.4 (6)
1	100–8500 + HA	95	29	Much better	Much better	Very well	Great benefit	63	60 (36)	5.4
2	571–8500 + HA	27	30	Much better	Better	Well	Sometimes	48	64 (22)	0.5 (13)
6	350–8500 + HA	80	29	Much better	Same	Well	Great benefit	75	60 (60)	3.3
7	594–8500 + HA	85	34	Much better	Much better	Very well	Great benefit	35	80 (38)	0.4
8	594–8500 + HA	90	28	Much better	Much better	Well	Great benefit	57	76 (68)	
9	250–8500 + HA	80	29	Much better	Much better	Not well	Great benefit	60	68 (34)	0.2
10	393–8500 + HA	90	25	Much better	Better	Not well	Beneficial	52	44 (22)	4.9 (15)
11	350–8500 + HA	80	29	Much better	Same	Well	Great benefit	57	52 (4)	4.1 (8)
15	333–8500 + HA	85	29	Much better	Much better	Well	Beneficial	60	50 (38)	4 (9)
3	100–8500	48	22	Better	Same	Not well	Beneficial	50	60 (56)	5.2
5	70–8500	80	28	Much better	Same	Not well	No benefit	67	48 (48)	6.1
12	100–8500	50	23	Better	Same	Not well		78	46 (34)	3.3
19	100–8500	90	35	Much better	Much better	Not well	No benefit	65	20 (12)	10.3

Frequency range: frequency range of the processor in hertz at the 2-year follow up. HA, hearing aid; n, sufficient natural hearing in the operated ear such that HA amplification was not needed. VAS, EQ-5D™ visual analogue scale; IOI-HA, International Outcome Inventory-Hearing Aids, total results. Silence: patient responses to a question about hearing in silent conditions (question no. 5). Noise: patient responses to a question about hearing in noisy conditions (question no. 6). Music: patient responses to a question about how music sounds (question no. 7). Residual hearing: patient responses to a question about residual hearing (question no. 9). LF PTA, low-frequency pure-tone average in decibels (125 – 500 Hz) at one year; MS, percentage of correctly recognized monosyllabic words in the best-aided condition in the operated ear at one year. The gain is shown in brackets. HINT, hearing in noise test (binaural) in the best-aided condition at 1 year. The gain is shown brackets, and a lack of brackets indicates that the hearing was too poor to perform a preoperative HINT.

HA use, or expected hearing. Eleven of the 15 hybrid-hearing patients claimed that music "sounded good or very good." All the nonhybrid patients and four of the hybrid patients did not appreciate music. All the hybrid-hearing patients benefited from residual hearing. Ten of 15 patients claimed that they were benefited greatly. Two of four patients who used the full-frequency stimulation claimed that they experienced no benefit from their residual hearing. One patient did not respond, and one patient with a 50 dB LF PTA claimed a benefit.

The children were very satisfied in the silent, noisy, and music conditions. One child stated that "a fog lifted from her ears and everything went clear" when she heard the high frequencies for the first time in her life. Both children desired a second implant.

Hearing Preservation

There was no incidence of total residual hearing loss in any of the patients. All patients exhibited hearing levels within the limits of the audiometer (120 dB) within the range of 125–500 Hz. We calculated the LF PTAs at frequencies of 125, 250, and 500 Hz. Preoperatively, the mean LF PTAs were 31 dB HL (SD = 17, min = -5, max = 67) in the ears that underwent surgery and 30 dB HL (SD = 16, min = 0, max = 63) in the contralateral ears. The LF PTAs of each patient before surgery and at the follow-up are presented in Figure 1. The mean changes of residual hearing at different frequencies after surgery are shown in Figure 2. The mean LF PTA losses at different times are presented in Table 2. There was significant ($p < 0.05$) hearing loss in the operated ears 1 month after the surgeries. There was an additional significant loss between the first and second years. The contralateral ears displayed no significant loss during the first year but did exhibit a significant loss between the first and second year.

Eight of the patients attended a 3-year follow-up visit. Among these patients, the mean LF PTA loss in the operated ear was -29 dB (SD = 19, max = -8, min = -58), and the loss in the contralateral ear was -9 dB (SD = 7, max = 2, min = -17) 3 years after fitting. Two years after fitting, the mean LF PTA losses across these eight patients were -21 dB (SD = 17, max = 3, min = -50) in the operated ear and -7 dB (SD = 5, max = 2, min = -13) in the contralateral ear. Among these eight patients, there was a significant loss in the operated ear during the 3rd year after surgery. A similar deterioration in hearing did not occur in the contralateral ear.

In two children, hearing was well preserved. LFH was normal (<20 dB) up to 500 Hz in one child and up to 750 Hz in the other child. After 2 years, the LF PTA losses in two children were 7 and 22 dB. The child who experienced the 22 dB loss also experienced a deterioration of 8 dB in her contralateral ear.

Speech Recognition

Before surgery, the patients displayed performances of 20% MS recognition (SD = 19, max = 58, min = 0) in the ear intended for surgery and 35% (SD = 17, max = 64, min = 6) in the other ear in their best-aided conditions. The MSs were presented at a mean sound intensity of 72 dB (SD = 5, max = 85, min = 65). Binaurally, the patients displayed 39% MS recognition (SD = 17, max = 70, min = 10) at the mean sound intensity of 70 dB (SD = 4, max = 80, min = 65). At 1-year follow-up (data from two patients were missing), the patients displayed 52% MS recognition performance (SD = 19, max = 80, min = 12) in the implanted ear in their best-aided condition.

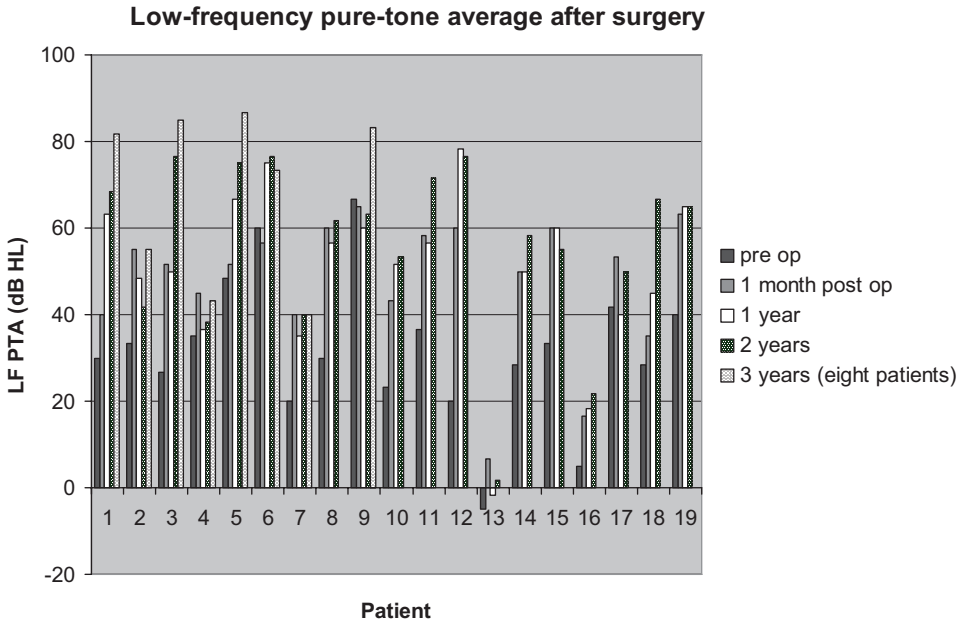

Fig. 1. The low-frequency pure-tone averages (125, 250, and 500 Hz) in decibels are presented for each patient before the operation, 1 month postoperatively and 1 and 2 years after fitting. The 3-year results for eight patients are presented.

The MSs were presented at a mean sound intensity of 69 dB (SD = 3, max = 75, min = 65). Table 3 illustrates the individual results after 1 year. Binaurally, the patients (data from three patients were missing) displayed 63% MS recognition performance (SD = 16, max = 88, min = 34) at a mean sound intensity of 69 dB (SD = 3, max = 75, min = 65).

At the 2-year follow-up (the data from one patient was missing), the patients displayed 45% MS recognition performance (SD = 27, max = 82, min = 0) in the operated ear. The MSs were presented at a mean sound intensity of 68 dB (SD = 4.2, max = 80, min = 65). Binaurally, the patients (all patients) exhibited 58% MS recognition (SD = 17, max = 90, min = 22) at the mean sound intensity of 67 dB (SD = 3, max = 75, min = 65).

Nine patients were unable to perform the HINT test before surgery due to poor hearing. Ten patients presented with a mean HINT result of a 15 dB signal to noise ratio (SNR) in the binaural best-aided listening situation (SD = 4, max = 10, min = 22). In the ear that was intended for surgery (nine patients), the SNR was 16 dB (SD = 6, max = 21, min = 3). At 1-year follow-up (18 patients), the mean binaural SNR was 4.2 dB (SD = 4, max = -1.6, min = 10.6), and in the operated ear (14 patients), the SNR was 6.0 dB (SD = 5, max = 17, min = 0). The individual results after 1 year are illustrated in Table 3. In the nine patients with preoperative HINT scores, the binaural gain in the SNR was 11 dB after 1 year. A mean gain of 11 dB was observed in the operated ears of the five patients as measured monaurally. After 2 years, HINT scores were assessed bilaterally in all of the

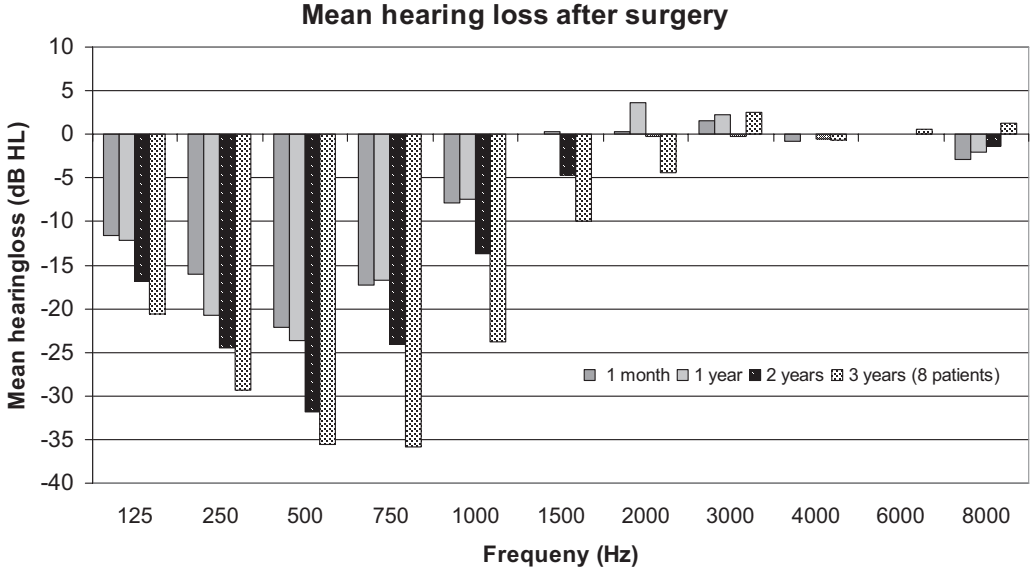

Fig. 2. The mean changes in residual hearing for each frequency 1 month after surgery, 1 and 2 years after fitting, and after 3 years for eight patients.

TABLE 4. International outcome inventory for hearing aids results

	Natural LFH (6)	CI + HA (9)	Full CI (4)	All Patients (19)
Use	5.0 (±0.0)	4.8 (±0.7)	4.8 (±0.5)	4.8 (±0.5)
Benefit	4.5 (±0.8)	4.4 (±0.7)	4.3 (±0.5)	4.4 (±0.7)
RAL	3.2 (±1.5)	3.0 (±0.8)	3.0 (±1.7)	3.1 (±1.1)
Satisfaction	4.8 (±0.4)	5.0 (±0.0)	4.6 (±0.5)	4.9 (±0.3)
RPR	4.4 (±0.5)	3.6 (±0.7)	3.0 (±1.4)	3.7 (±1.0)
Impact on others	3.8 (±0.4)	4.0 (±0.9)	3.8 (±1.3)	3.9 (±0.8)
QoL	4.3 (±0.8)	4.7 (±0.5)	4.5 (±0.6)	4.5 (±0.6)
Factor 1	18.7 (±1.9)	18.9 (±1.3)	18.1 (±1.8)	18.7 (±1.5)
Factor 2	10.7 (±2.1)	10.2 (±1.6)	9.0 (±4.2)	10.1 (±2.4)
Global score	29.3 (±3.3)	29.1 (±2.3)	27.0 (±5.9)	28.8 (±3.4)

Mean scores (SD in brackets) for the IOI-HA. The results are separately presented for the patients with natural low-frequency hearing (LHF), CI+HA, patients with cochlear implant plus hearing aid-amplified LFH and patients with full frequency CIs (the numbers of subjects are in brackets). The maximum score for each item was 5. Use, hearing aid use; benefit, cochlear implant benefit; RAL, residual activity limitations; RPR, residual participation restriction; QoL, quality of life. Factor 1 is the sum of items 1, 2, 4, and 7 and represents CI satisfaction. Factor 2 is the sum of items 3, 5, and 6 and represents participation restrictions. The global score is the total score for the seven items.

patients, and the SNR was 4.6 dB (SD = 3.4, max = -1.7, min 12.= 5). For the operated ear alone (14 patients), the SNR was 5.8 dB (SD = 3, max = 11.5, min = 0).

The two children did quite well in the silent condition before surgery (one performed an easier test designed for children). After surgery, the children's hearing was approximately the same as it was before surgery. On the HINT test, the children exhibited a gain of 11–12 dB and presented with SNRs of -1.6 and 0.1 dB after 1 year.

Correlations

There were tendencies for the hybrid-hearing patients to experience better hearing and be more satisfied, but these trends were not statistically significant for any of the questions.

There were no correlations between residual hearing and the MS or HINT scores. Both the patients who scored the best and worst on the MS and HINT were found in the hybrid-hearing group. The patients' perceptions of improved hearing in silence and noise were not correlated with the postoperative MS or HINT scores or with the MS or HINT gains. All patients with a SNR ratio below 1 dB in the HINT experienced better or much better hearing in noisy environments after implantation. All of these patients had hybrid hearing.

DISCUSSION

In this study, we evaluate patient satisfaction among patients intended for hybrid hearing and relate hearing results in quiet and noisy conditions to subjective experiences and residual hearing. Results showed that electric stimulation provides a major contribution to speech comprehension in partially deaf patients and that all of the patients were satisfied with their CIs regardless of the variation in the extent of hearing preservation.

All of our patients reported that they would recommend a CI to a person in a situation similar to theirs, and this is a major sign of patient satisfaction. The overall benefits in high-frequency hearing seemed to outweigh the possible benefits of preserved LFH. Because only four patients lost the possibility of hybrid hearing, the cohort was too limited to assess the possible advantages of hybrid hearing. A control group lacking usable LFH in the ipsilateral ear could not be obtained because the majority of conventional CI patients have profound bilateral hearing loss across all frequencies. Within-subject comparisons were not possible because earplugs and ear defenders are estimated to mask only approximately 30 dB in the lower frequencies, which is insufficient when LFH is normal. Such comparisons would be too time consuming to routinely perform. Plugging of the operated ear was performed in a few patients to evaluate LFH when considering full-frequency CI stimulation or HA. Lenarz et al. (2013) performed within-subject comparisons and showed that hybrid hearing is superior to nonhybrid hearing. The patient satisfaction survey employed by these authors only compared hybrid hearing with preoperative HA hearing.

Because it can be assumed that patients with natural unamplified LFH might hear better than those with HA-amplified LFH, we found it useful to separate the results based on three CI groups. A disadvantage is that patients with similar LFH might choose different fitting strategies, which may include ipsilateral HAs. Thus, we compared the levels of satisfaction related to the actual LFH and those related to the different groups. We found no correlations. Santa Maria et al. (2013) analyzed a fairly small patient sample and also found no differences in patient satisfaction between the hybrid and nonhybrid patients. The IOI-HA scores of our patients were nearly identical to those reported by Redfors et al. (2013) for patients suffering from otosclerosis who received HAs. These authors also claimed that the patients with mixed hearing loss scored better than did the patients with only sensorineural hearing loss using a HA.

Our results indicate that music perception was better among the hybrid-hearing patients than the nonhybrid patients. Contralateral hearing might also have contributed to the musical experiences because the patients with minimal LFH predominantly had similar situations in their contralateral ears. The preoperative musical experiences differed. Some of the patients had normal hearing since birth, and others had limited memories of high-frequency hearing. These differences raise a problem concerning relative patient satisfaction. Some of the patients were very satisfied by relatively small improvements, particularly if they had experienced a long-lasting period of profound hearing loss with limited hearing experiences.

There are several methods to for examining hearing loss related to hearing preservation surgeries (Incerti et al. 2013). Because all of our patients exhibited ski-slope shaped audiograms and because all of our patients had measurable hearing in the 125–500 Hz range postoperatively, we found our selected method to be practical and easy to use every day in the clinic. Lenarz et al. (2013) characterized hearing preservation either as complete (≤10 dB) or partial (≤30 dB). In this study, among the 66 patients, 43% exhibited complete preservation, and 74% exhibited partial preservation after 1 year. (The group of partial preservation includes the patients with complete preservation. The rest of the patients 26% have no preserved hearing according to the criteria). In this investigation, 32% of our patients exhibited complete preservation, and 95% exhibited partial preservation after 1 month. At 1 year, the corresponding values were 21% and 89%, respectively; at 2 years, the values were 26% and 63%, respectively. These results indicate that the number of patients with completely preserved hearing was less in our study than in the study by Lenarz et al., but the number

of patients with partially preserved hearing was higher in our study. A loss of 30 dB could be the difference between using and not using an acoustic complement.

Despite the ubiquitous hearing preservation after round window surgery, deteriorations in the LFH of the operated ears were observed during the 1st years. The finding that the loss was more advanced in the operated ear suggests that this loss might have been induced by the electrode array. The explanation for the less severe hearing loss that was observed in the nonoperated ears might be related to the etiologies of the hearing impairments of our patients (Usami et al. 2012).

We did not find a way to predict hearing deterioration immediately after surgery or thereafter. A better understanding of the etiology of hearing loss might contribute to such predictions in the future. Because the loss of residual hearing could not be predicted, the progression of LFH loss should always be considered and discussed in patient consultations, but this should not be considered a contraindication for implantation because patients will benefit from CIs.

If the LF PTA is 50 dB before surgery, the patients will likely not use ipsilateral HAs. The patients who switched from the hybrid hearing strategy to the full frequency program due to greater LFH loss did not complain, likely because they gained full-frequency CI hearing and maintained LFH in the contralateral ear. These patients were pleased with the easier handling of the processor, which did not obstruct the ear canal. The patients with initial unaided LFH, who deteriorated after fitting abandoned the hybrid-hearing strategy and used full-frequency CIs. One patient preferred the full-frequency stimulation despite having normal LFH, and another patient chose to use a full-frequency CI stimulation and a HA during 2 years. These results indicate the remarkable potential of the "listening" brain and demonstrate the complexity of identifying the best-aided condition. Because our patients had natural LFH in their contralateral ears, they likely suffered less from the ipsilateral LFH loss. This needs to be carefully considered before bilateral implantations for hybrid hearing. Further studies are necessary before standard indications for bilateral hybrid hearing implantations can be established.

One year after surgery, the patients displayed a mean performance of 52% in the MS test in the operated ear. This finding is in accordance with those of earlier studies (Hamzavi et al. 2003; Skarzinsky et al. 2012; Lundin et al. 2013). The HINT results after 1 year are in accordance with those of Gifford et al. (2013). After 2 years, slight reductions in the MS and HINT scores were observed. When asked, the majority of the patients responded that they experienced stable or improved hearing.

In many patients, the speech test results were not consistent with the patients' subjective experiences. Factors, such as preoperative hearing ability, individual expectations, and environmental needs might explain these inconsistencies. These findings illustrate the value of assessing both patient satisfaction scores and audiological to understand the actual hearing situation.

The two children included in this report were described separately because they seemed to exhibit the possibility for successful CI rehabilitation despite profound high-frequency deafness since childhood. Such children may benefit from receiving high-frequency CIs early and experiencing improved hearing at a critical time of their lives. High-frequency hearing seems to facilitate learning and cognitive development. Because both of the children in our study had normal preoperative LFH, they might benefit from hybrid hearing for many years despite the ongoing deteriorations of their residual hearing. Such benefits of hybrid hearing might be found to be important for the optimal education and social development of these children.

CONCLUSIONS

Electric stimulation provides a major contribution to speech comprehension in partially deaf patients. All of the patients were satisfied with their CIs regardless of the variation in the extent of hearing preservation. The preservation of hearing constitutes an additional benefit that might improve hearing in noisy situations and music perception. This effect had only a minor influence on the patients' overall satisfaction. We observed ongoing deterioration of the residual hearing of the operated ear that surpassed the deterioration of the contralateral ear. The gains achieved in speech comprehension vastly outweighed the loss of some LFH. Based on our findings, we propose that most people with partial deafness should be offered hybrid hearing. Evaluations of patient satisfaction should be used with conventional hearing tests to increase our knowledge of CI hearing.

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