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Speech intelligibility with bilateral bone-anchored hearing aids: the Birmingham experience

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Abstract

The Birmingham bone-anchored hearing aid (BAHA) programme, since its inception in 1988, has fitted more than 300 patients with unilateral bone-anchored hearing aids. Recently, some of the patients who benefited extremely well with unilateral aids applied for bilateral amplification. To date, 15 patients have been fitted with bilateral BAHAs. The benefits of bilateral amplification have been compared to unilateral amplification in 11 of these patients who have used their second BAHA for 12 months or longer. Following a subjective analysis in the form of comprehensive questionnaires, objective testing was undertaken to assess specific issues such as 'speech recognition in quiet', 'speech recognition in noise' and a modified 'speech-in-simulated-party-noise' (Plomp) test.

'Speech in quiet' testing revealed a 100 per cent score with both unilateral and bilateral BAHAs. With 'speech in noise' all 11 patients scored marginally better with bilateral aids compared to best unilateral responses. The modified Plomp test demonstrated that bilateral BAHAs provided maximum flexibility when the origin of noise cannot be controlled as in day-to-day situations. In this small case series the results are positive and are comparable to the experience of the Nijmegen BAHA group.

Key words: Hearing Aids; Osseointegration; Speech Intelligibility

Introduction

Three hundred and fifty-one patients have been implanted with bone-anchored hearing aids (BAHA) on the Birmingham BAHA programme since 1988. These include both adults and children. In addition to a high degree of patient satisfaction, a significant improvement in the quality of life has been reported amongst BAHA users. Encouraged by the experience of the Nijmegen BAHA group, the bilateral BAHA implantation programme was started in 1995. A number of patients who had used bilateral conventional aids previously and whose professional needs warranted good binaural hearing, applied for a second side BAHA. Financial constraints and perhaps ignorance of benefit account for the poor practice of bilateral fitting on the NHS in the United Kingdom.[1]

Fifteen patients have been implanted with a second side BAHA on the bilateral BAHA programme. In this study, 11 of these patients who had used their second side BAHA for longer than 12 months have been evaluated objectively. Speech recognition in quiet, in noise and the results of the modified Plomp test are presented.

Patients and methods

A total of 15 patients have been implanted with bilateral BAHAs in Birmingham. To avoid enthusiasm bias and to allow acclimatization with the use of the second BAHA, 12 patients who had used both their BAHAs for 12 months or more were invited to participate in this study on the benefits of bilateral BAHA implantation. Table I provides detailed information of the study group that included nine females and three males. Although not stringent, certain selection criteria were used as follows:

(1) previous knowledge and experience with binaural hearing (conventionally aided or unaided);
(2) bilaterally symmetrical hearing loss (interaural threshold difference of less than 15 dB four-tone-average);
(3) professional needs of the users: e.g. businessmen, teachers and nurses;
(4) motivation – patients voluntarily applied for a second side BAHA;
(5) age – the bilateral implantation facility has not been extended to children yet.

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TABLE I
AGE AND SEX DISTRIBUTION WITH DIAGNOSIS AND DURATION OF BAHA USE

Patient number	Age (in years)	Gender	Diagnosis	I BAHA	II BAHA
1	31	F	Treacher Collins syndrome	10 years	5 years
2	53	M	Bilateral mastoid cavities	10 years	3 years
3	31	F	Bilateral congenital hearing loss	4 years	3 years
4	22	F	Treacher Collins syndrome	10 years	30 months
5	54	F	Bilateral chronic otitis media	5 years	30 months
6	42	M	Bilateral mastoid cavities	12 years	2 years
7	39	M	Goldenhar's syndrome	4 years	2 years
8	45	F	Bilateral microtia	4 years	2 years
9	48	F	Bilateral chronic otitis media	3 years	18 months
10	42	F	Bilateral acquired otosclerosis	4 years	16 months
11	47	F	Bilateral chronic otitis media	5 years	12 months
12	53	F	Bilateral mastoid cavities	5 years	12 months

Following a postal questionnaire study[2] on patient benefit and quality of life using the two BAHAs, the study group was invited to attend the audiology service for objective evaluation of patient benefit.

The objective audiological evaluation (Table II) included unaided soundfield levels (dB A) and aided thresholds with right, left and bilateral BAHAs. Soundfield speech using the Arthur-Boothroyd (A-B) word lists was evaluated with right, left and bilateral-aided situations.[3]

For the evaluation of 'speech-in-quiet' and 'speech-in-noise', Bamford-Koval-Bench (BKB) sentences were used.[4] This included the evaluation of the three individual situations, i.e. right, left and bilateral aiding, at signal-to-noise ratios (SNR) of plus 10 dB, 0 dB and minus 10 dB.

A modification of the Plomp multitalker noise test was used to evaluate 'speech-in-noise' with open-set speech recognition.[5–7] The basic test environment is as shown in Figure 1. BKB sentences are presented to patients from speaker 1 at 70 dBA. Speech babble noise (20 talker/cocktail party noise) is then presented from either speaker, 2 or 3, at a signal to noise ratio of 0 dB. It is then possible to evaluate speech recognition in noise using bilateral, left only and right only BAHA situations. Therefore, there are three basic experimental situations:

TABLE II
AUDIOLOGICAL EVALUTION OF BONE-ANCHORED HEARING

1. Unaided thresholds	Soundfield levels – dB A
2. Aided thresholds	Right BAHA Left BAHA Bilateral BAHA
3. Soundfield speech with Arthur-Boothroyd (AB) word lists	Right BAHA Left BAHA Bilateral BAHA
4. Bamford-Koval-Bench (BKB) sentences (a) In quiet (b) In noise – signal to noise ratios Plus 10 dB Zero dB Minus 10 dB	Right BAHA Left BAHA Bilateral BAHA
5. Modified Plomp Multitalker Noise Test (a) Sound front noise front (SFNF) (b) Sound front noise left (SFNL) (c) Sound front noise right (SFNR)	Right BAHA Left BAHA Bilateral BAHA

(1) sound front/noise front (SFNF);
(2) sound front/noise left (SFNL) and
(3) sound front/noise right (SFNR).

No statistical package has been applied to the results as the number of patients in the study group is small (n = 11) and would make the power of such analysis insignificant. Descriptive data in the form of bar charts, cumulative scores and percentages are presented.

Results

On the bilateral BAHA programme, 15 patients have received a second side BAHA since 1995. Twelve of these patients had used their second BAHA for 12 months or longer (Table I). Patient 10 did not choose to answer the questionnaires or attend the audiological evaluation for personal reasons. During a clinic visit, it was learnt that the patient used her second BAHA for special situations that included social gatherings and supermarkets.

Age and gender distribution and clinical data of these patients are presented in Table I. Of the 12 patients, six had chronic suppurative otitis media or discharging mastoid cavities. Four of these reported dry ears following BAHA use in both ears and two reported occasional otorrhoea in one or the other ear. The group with congenital bilateral conductive deafness included two patients with Treacher Collins syndrome, one Goldenhar's syndrome, one patient with nonsyndromic bilateral microtia and one with

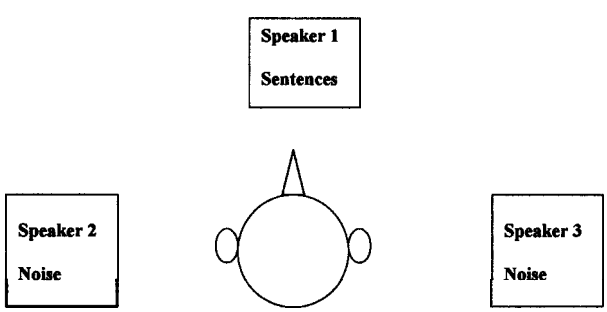

FIG. 1
Configuration standard for the modified Plomp speech-in-noise test.

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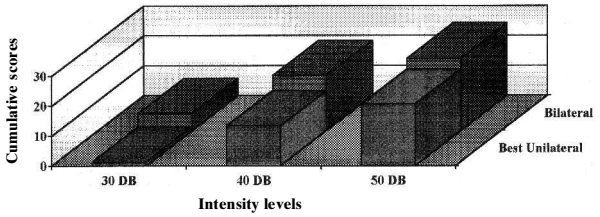

FIG. 2

Comparison of best-unilateral BAHA response with bilateral BAHA response: Cumulative A-B word (30 words) list scores at 30 dB, 40 dB and 50 dB intensity levels.

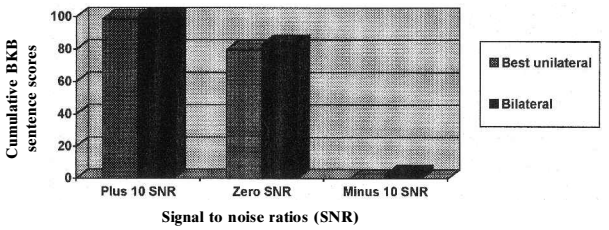

FIG. 4

Comparison of best-unilateral BAHA response with bilateral BAHA response: Cumulative BKB sentence scores at plus 10, Zero and minus 10 signal-to-noise ratios.

congenital bilateral conductive loss consistent with stapes fixation. Four of these with auricular dysplasia benefited with bilateral BAHA and bilateral bone-anchored auricular prostheses, implanted at different stages. The patient with congenital bilateral conductive loss and another patient who had features strongly suggestive of bilateral acquired otosclerosis chose the third option of bilateral BAHA.[8]

The battery of audiological tests that were performed is listed in Table II. Unaided thresholds on all 11 patients showed that they satisfied the audiological selection criteria for BAHA implantation and bilateral provision. Aided thresholds were tested with unilateral and bilateral BAHAs. All 11 patients were tested with their volume controls at position 2, which was the position that they used their BAHAs in and was the most comfortable position.

'Speech in quiet' testing was performed using the BKB sentences. All 11 patients scored 100 per cent scores in all three situations, right, left and bilateral aided conditions. The scores with AB word lists (word lists with 30 words) presented with words at different intensities from 30 dB to 80 dB in a sound field are shown in Figures 2 and 3. The figures clearly demonstrate better scoring with bilateral BAHA compared to the best unilateral response. With speech-recognition in noise, the scores were slightly better with bilateral BAHA compared to the best unilateral BAHA response, either right or left (Figure 4).

The results of the Plomp test are shown in Tables III, IV and V. In the sound front/noise front situation, the performance of the BAHA users was equivocal with unilateral or bilateral aids. Some of the candidates obtained better scores with the unilateral situation that they were most familiar with (Table III). When presenting noise on the same side as the BAHA-in-use (Baffle situation, e.g. noise left for a left only switched-on BAHA), the scores drop dramatically (Tables IV and V). This is largely to be expected as the microphone in the aid is positioned to pick up sounds and noise from the specific side more easily. When noise is presented on the opposite side to the BAHA-in-use (Shadow situation, e.g. noise right for a left only switched-on BAHA), the scores improve dramatically (Tables IV and V). In many cases the scores are even better than the bilateral response.

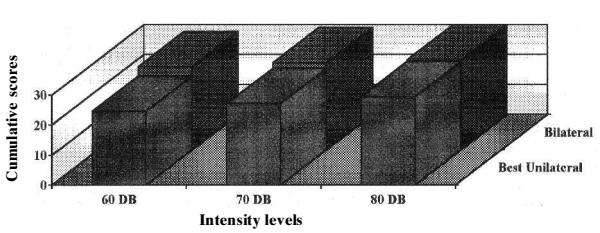

FIG. 3

Comparison of best-unilateral BAHA response with bilateral BAHA response: Cumulative A-B word (30 words) list scores at 60 dB, 70 dB and 80 dB intensity levels.

Discussion

The benefits of binaural hearing include speech intelligibility, sound localization and stereophonic appreciation. These effects have been demonstrated in subjects with normal hearing and with those using bilateral conventional air conduction hearing aids.[9–14]

It is well known that sound amplification by bone conduction stimulates both the cochleae. However, Stenfelt *et al.* have shown that transcranial attenuation of bone conducted sounds may vary between −15 and +40 decibels.[15] In the lower frequencies, stimulation via bone conduction may result in higher stimulus levels at the contralateral cochlea.[15]

In a case series involving 25 patients who received bilateral bone-anchored hearing aids, Bosman *et al.* (Nijmegen group) have unequivocally demonstrated that bilateral amplification restores binaural hearing.[16] However in the United Kingdom, bilateral

TABLE III

PLOMP TEST: SOUND FRONT NOISE FRONT (SFNF) SITUATION

Patient number	Left BAHA only	Right BAHA only	Bilateral BAHAs
1	84	80	82
2	70	83	90
3	63	63	65
4	85	85	87
5	62	61	65
6	76	72	80
7	56	58	60
8	80	84	97
9	83	87	93
10	–	–	–
11	84	87	91
12	93	90	96

Units—percentage correct score

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TABLE IV
PLOMP TEST: SOUND FRONT NOISE LEFT (SFNL) SITUATION

Patient number	Left BAHA only	Right BAHA only	Bilateral BAHAs
1	64	87	80
2	69	94	78
3	3	55	54
4	31	85	83
5	31	82	44
6	27	89	73
7	2	76	62
8	67	87	95
9	71	83	79
10	–	–	–
11	29	97	58
12	47	90	76

Units—percentage correct score

fitting of hearing aids, albeit conventional or bone-anchored, is a practice that appears to be undermined by cost issues and the knowledge and attitudes of local otology teams.[1]

The Nijmegen BAHA team has been the first group to evaluate the benefits of bilateral BAHA. The authors have clearly demonstrated that bilateral fitting of BAHA produces binaural hearing.[16–19] In Nijmegen, the majority of bone-conduction hearing aids was prescribed bilaterally with transducers incorporated in the bows of eyeglasses. With demonstration of binaural benefit using bilateral BAHAs, this now has become the treatment of choice in those that satisfy the selection criteria. The Gothenburg BAHA team has implanted 12 patients with bilateral BAHA and the patients are presently being evaluated (Anders Tjellstrom, personal communication, 2001).

In Birmingham, bilateral implantation with BAHA was started in 1995. This was as a result of requests by some of the patients who had appreciated the benefits of binaural hearing previously with conventional aids. The Nijmegen experience with similar patients was encouraging.[17,18]

The first 11 of the bilateral BAHA users underwent both subjective and objective evaluation. The subjective evaluation strategy included two postal questionnaires that were previously validated. This showed a high degree of patient satisfaction and improved quality of life with the second BAHA, compared to the first.[2]

TABLE V
PLOMP TEST: SOUND FRONT NOISE RIGHT (SFNR) SITUATION

Patient number	Left BAHA only	Right BAHA only	Bilateral BAHAs
1	87	60	80
2	97	61	91
3	82	13	80
4	80	44	85
5	72	30	82
6	97	19	69
7	90	33	71
8	79	60	90
9	100	88	93
10	–	–	–
11	91	37	58
12	95	59	76

Units—percentage correct score

A comprehensive objective strategy has been in practice for evaluation of binaural hearing with conventional hearing aids and BAHAs on the Birmingham implantation otology programme (Table II). This includes evaluation of unaided thresholds, aided thresholds at optimal volume control and speech recognition tests. Both speech-in-quiet and speech-in-noise tests are evaluated at various levels and signal to noise ratios (SNRs). A modified technique of the Plomp multitalker test is also used. The results presented here are positive. We also propose to undertake annual evaluation of binaural hearing to study the process of perceptual habituation and acclimatization. A soundfield laboratory is being set up for evaluation of sound localization with the 12 speaker directional hearing tests. This would enable the team to objectively evaluate the stereophonic benefits of any form of sound amplification including bilateral conventional aids, bilateral BAHAs and bilateral cochlear implants.

Conclusion

Objective evaluation of patients with bilateral bone anchored hearing aids has revealed improved speech intelligibility with bilateral aiding compared to unilateral aiding. This justifies prescription of bilateral BAHAs to patients who satisfy the selection criteria.

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