Orientation abilities and intelligibility of speech in noise in single sided deaf persons provided with a bone-anchored hearing aid (BAHA)

Susanne Köbler[1], Karin Strömbäck[2], Susan Saeidi[3], Hans Christian Larsen[1], Konrád Konrádsson[1]

[1] *Department of Audiology, Uppsala University Hospital, Sweden*

[2] *Department of Otosurgery, Uppsala University Hospital, Sweden*

[3] *Uppsala Hearing Clinic, Uppsala, Sweden*

The present pilot study describes results for speech intelligibility in noise and localisation abilities of single sided deaf (SSD) persons treated with a bone-anchored hearing aid (BAHA) on the deaf side in order to provide bilateral signals via transcranial contralateral stimulation. Tools in this investigation with five participants were psychoacoustical measurements including presentation of phonemically balanced (PB) words presented from the front in a quasi-free field. Corresponding noise was presented from the front, the normal hearing and the deaf side respectively. Abilities of orientation and speech understanding were measured by presenting sentences from randomly chosen directions (-90°, 0°, or +90° azimuth) in the presence of noise. The patients pointed out the speech-emitting speaker and simultaneously repeated the presented sentence. Preliminary results showed no impact of the BAHA on understanding PB words regardless of the direction of the background noise. There was a tendency for benefit of the BAHA for speech perception with speech from varying directions, but no effect on directionality within this task. The patients also finished three different inquiries dealing with benefit of the BAHA, a health-related and a quality of life instrument.

INTRODUCTION

Patients who suffer from unilateral hearing loss commonly report difficulties hearing signals originating from their deaf side, inability to localise sounds and difficulties to understand speech in background noise. There is evidence, that providing signals from the deaf side to the normal-hearing side through transcranial contralateral stimulation using a bone-anchored hearing aid (BAHA) on the deaf side can treat this condition (Wazen *et al*., 2003; Newman *et al*., 2008; Yuen *et al*., 2009). Thereby, bilateral signals are provided, leading to an improvement of spatial hearing and speech intelligibility in noise in many cases (Wazen *et al*., 2003; Hol *et al*., 2005; Lin *et al*., 2006; Newman *et al*., 2008; Yuen *et al*., 2009). Nevertheless, the importance of more research in the field in order to collect more data and establish a better evidence base of the subject especially regarding spatial hearing has been pointed out (Hol *et al*., 2004; Baguley *et al*., 2006; Dumper *et al*., 2009). Most of the cited studies also emphasise that there might be a difference in objective performance with BAHA

Proceedings of ISAAR 2009: Binaural Processing and Spatial Hearing. 2nd International Symposium on Auditory and Audiological Research. August 2009, Elsinore, Denmark. Edited by J. M. Buchholz, T. Dau, J. Cristensen-Dalsgaard, and T. Poulsen. ISBN: 87-990013-2-2. The Danavox Jubilee Foundation, 2010.

depending on the underlying reason for the single sided deafness as for example sensorineural hearing loss or hearing loss because of vestibular schwanoma tumour excision.

The present pilot study describes outcomes for five unilateral deaf persons implanted with a BAHA in terms of psychoacoustic measurements and inquiries conducted partly before and/or after a test of BAHA with head band, partly after 3, 12 and 18 months use of the implanted BAHA.

MATERIALS AND METHODS

The pilot project includes ten patients who have been provided with BAHA during 2007-2008. Five of the patients have finished the program of the study and the obtained results are presented in this paper.

Participants

The presented results are based on outcomes of BAHA use of two men and three women aged 26-55 years (mean 47, median 51) at the beginning of the treatment. The reason for the single sided deafness of one man (age 55) and one woman (age 53) was vestibular schwanoma tumour excision, the others suffered from sensorineural hearing impairment because of sudden deafness. All patients had a speech discrimination of less than 20% (range 0-18%, mean 3%, median 0%) in the poor ear. In the good ear, bone conduction thresholds measured as mean value of the frequencies 0.5, 1, 2, 3 kHz were better than 15 dB HL (range 1-13 dB HL, mean 6 dB HL, median 5 dB HL).

Subjective assessment, enquiries

Both measures of BAHA-benefit, health-related questions and quality of life assessment were included in the study program.

Inquiries used were Swedish versions of the short form 36 health survey questionnaire (SF-36) (Sullivan *et al*., 1995) and the EQ-5D health-related quality of life instrument (Burström, 2001) as well as a specially designed questionnaire based on questions of the Glasgow Hearing Aid Benefit Profile (Gatehouse, 1999) and basic patient data for BAHA users provided by Entific Medical Systems.

Objective assessment, psychoacoustical measurements

Objective measures used in the study included phonemically balanced one syllable words (PB-words) routinely used in national audiology departments and the Swedish Hearing in Noise Test (HINT) (Hällgren *et al*., 2006). Both tests were used to assess speech perception in noise. Additionally, during the HINT, localisation abilities were tested, see Fig 1 for the experimental set-up.

For the tests with PB-words, the speech material was always presented from a speaker in the front of the patient. Three different conditions of background noise were used: mixed with the speech material from the front, from the poor side, or the good side.

In the front/front condition, the material was presented at a signal-to-noise-ratio (S/N) of 65/61 dB HL; in the other two conditions with an S/N of 61/61 dB HL.

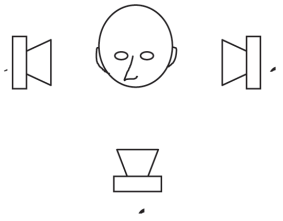

Fig. 1: Experimental set-up, psychoacoustic measurements.

The speech signals of the HINT were presented from a randomised direction with the other two speakers emitting noise. By this, we tried to simulate a situation often encountered in real-life, being forced to detect the source of a conversation one is interested in to follow. The directions were randomised in advance in a way that every speaker was used as 'signal-speaker' 3-4 times during one test-list. The patient was instructed to both point out the signal-emitting speaker as well as to repeat the presented sentence. S/N in this case also was 61/61 dB HL.

All psychoacoustical measurements were conducted without and with BAHA in a balanced way.

Methods

Possible participants for the study were invited from the consecutive lists of patients referred to the audiological department of the Uppsala University Hospital, because of profound unilateral hearing impairment. After the patients' consensus to try BAHA, they were invited to the Uppsala Hearing Clinic to start rehabilitation. After initial measurements (pure tone thresholds, speech-in-noise via headphone), the participants answered the SF-36 and the EQ-5D and were fitted with a BAHA with head band.

After about a month, speech perception in noise (front/front condition only) with and without BAHA with head band was tested and the patient filled in the enquiry measuring experiences with the hearing device. If the patient was satisfied with the trial period, she/he was referred for surgery.

About 2.5 months after surgery, the BAHA was fitted and the patient came back after 3 months to evaluate the device. Measurements at this stage were again speech perception in noise (front/front condition only) with and without BAHA and the patient filled in the inquiry measuring experiences with the hearing device.

After 12 months, the patients answered the three different inquiries. After 18 months, more extensive measurements as described earlier (section 'Objective assessment', 'psychoacoustical measurements') were conducted and the patients answered the three inquiries.

RESULTS

Enquiries: Quality of live

Observations about aspects of the participants' quality of life were monitored with the EQ-5D questionnaire. The most interesting questions in this study were those related to mobility, hygiene, activities, pain and anxiety. For every aspect the patients could chose if they had major, minor or no difficulties at all within these areas. There was almost no variation within time for the 5 persons in this study except for one person within the area 'activities'. The patient, a person who lost hearing on one side because of vestibular schwanoma tumour excision, went from 'huge difficulties' to include various activities in everyday-life preoperatively by 'minor difficulties' after 12 months to 'no difficulties at all' after 18 months.

Enquiries: Health related aspects

Observations about aspects of the participants' general health were monitored with the SF-36. Also within this questionnaire, there was little variation between the preoperative answers and the answers given after 18 months, except for 4 aspects as shown in Fig 2. These questions are dealing with general health during the last year and of feelings of nervousity and calm during the past four weeks prior to the enquiry.

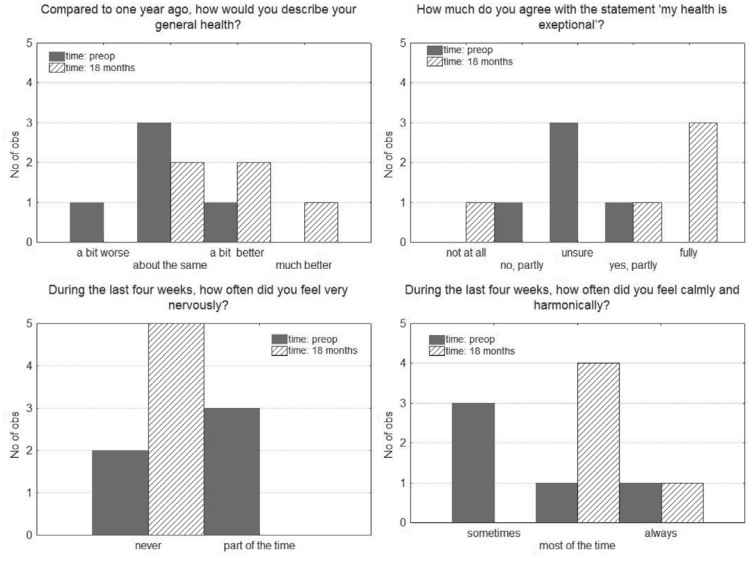

Fig. 2: SF-36, health survey. Described questions: Compared to one year ago, how would you describe your general health? How much do you agree with the statement 'my health is exceptional'? During the last four weeks, how often did you feel very nervously? During the last four weeks, how often did you feel calmly and harmonically? Grey columns indicate results obtained before surgery and diagonally lined columns results 18 months after surgery.

The four described questions show a tendency, that the participants generally felt healthier after than before surgery.

Enquiries: BAHA-benefit

The experienced benefit of the BAHA-device is shown as an extract of 4 questions from the enquiry used for this purpose, see Fig. 3. The overall satisfaction was good and the patients also experienced help in speech understanding and directional hearing.

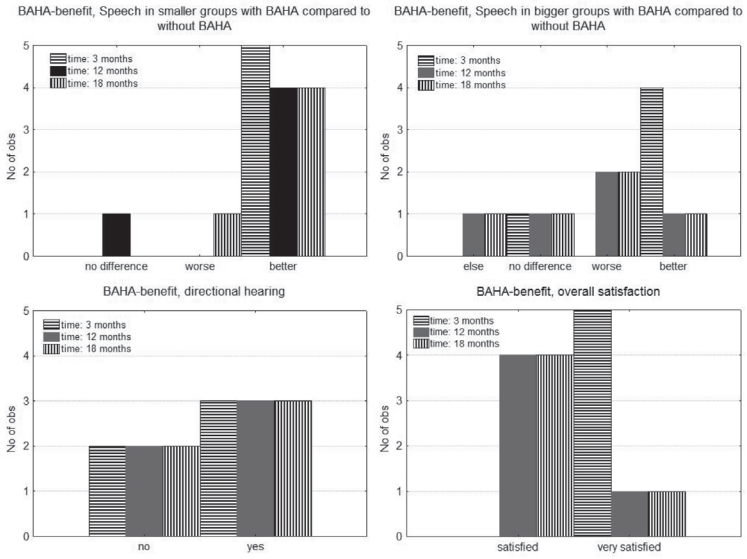

Fig. 3: Enquiry on BAHA-benefit. Horizontally striped columns indicate results obtained 3 months after surgery, grey columns results after 12 months and vertically striped columns results after 18 months. Questions asked were: How do you understand speech in smaller groups (3-6 persons) with BAHA compared to when you do not use the BAHA? How do you understand speech in bigger groups (10 persons or more) with BAHA compared to when you do not use the BAHA? Are you able to judge sound in the distance and decide from which directions you hear sound? How satisfied are you with your hearing aid?

Psychoacoustic measurements: Phonemically balanced words in noise

Speech perception for phonemically balanced words originating from the front were measured under three different background noise situations as described before. One measurement with noise mixed with the signal from the front, one measurement with noise from the poor and one with noise from the good side. All measurements were conducted without and with BAHA. Best results were obtained when the noise was

presented from the poor side, worst when the noise was presented from the front as shown in Fig. 4. We did not find a measurable effect of the BAHA for any of the situations.

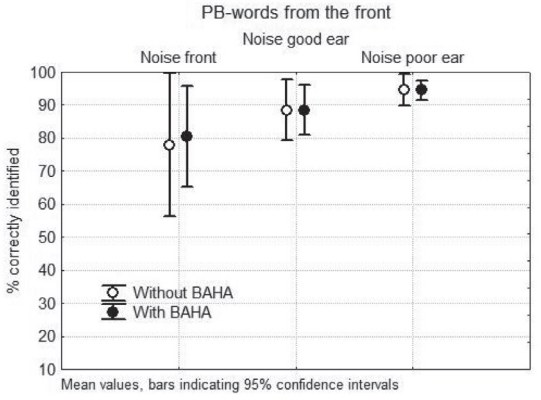

Fig. 4: Results for speech perception measured with PB-words from the front and noise from the front, the good side and the poor side respectively. Open circles indicate results without BAHA, filled circles results with BAHA.

Psychoacoustic measurements: HINT, speech perception and directionality

In order to measure speech perception under conditions with aspects of directionality, the sentences of the Swedish HINT (Hällgren *et al*., 2006) were presented from three different, randomly chosen directions, the front, the right and the left, at a constant S/N (61/61 dB HL). The other two loudspeakers in the experimental set-up (see Fig. 1) emitted noise with the same long-term spectrum as the speech. The patients' task was to identify the location of the speech-emitting loudspeaker and to repeat the sentences presented. Results were proportion of correctly identified key-words of the HINT as well as proportion of correctly identified signal-loudspeakers as shown in Fig. 5. There was a tendency that the BAHA might enhance speech perception under these conditions. The proportion of correctly identified directions was nevertheless on average unaffected by the device.

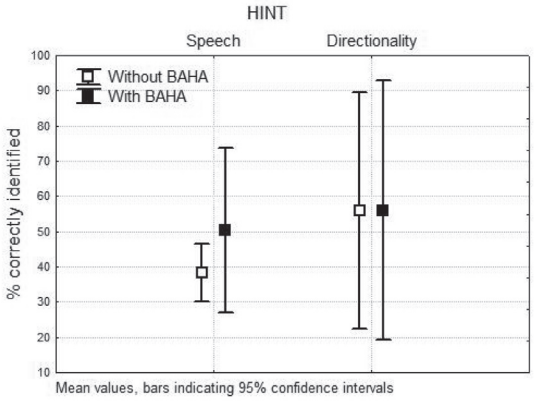

Fig. 5: Results for speech perception and localisation abilities measured with HINT-sentences from three different directions, the front, left and right. Open squares indicate results without BAHA, filled squares results with BAHA.

SUMMARY AND CONCLUSIONS

Some positive effects of the described rehabilitative approach seem to exist regarding self reported health and quality of life as can be seen by the results of the EQ-5D and the SF-36.

In addition, all patients were satisfied with the BAHA as shown by the results for the questionnaire on BAHA-benefit. Satisfaction decreased slightly with time, but none of the patients became dissatisfied with the device. Three out of five also experienced directional hearing with BAHA, even if the psychoacoustic measurements did not support that. There seems to be some self reported benefit of a BAHA for understanding speech in smaller groups. Nevertheless, problems still are present when using the advice in bigger groups.

The psychoacoustic measurements showed on average no impact of the BAHA for phonemically balanced words from the front, regardless if the noise was presented from the front, the normal-hearing or the deaf side of the patient. At least, speech intelligibility generally was not deteriorated by the device. The clearest results for speech intelligibility enhancement with the BAHA were obtained when presenting HINT-sentences in noise from 3 varying directions. Speech intelligibility showed better results with than without BAHA, but the directionality data has a huge spread.

Even though our material is too small to draw valid conclusions, our approach to provide single sided deaf persons with BAHA shows encouraging preliminary results and we will increase the number of participants in this study.

REFERENCES

Baguley, D. M., Bird, J., Humphriss, R. L., and Prevost, A. T. (**2006**). "The evidence base for the application of contralateral bone anchored hearing aids in acquired unilateral sensorineural hearing loss in adults," Clin. Otolaryngol. **31**, 6-14.

Burström, K., Johannesson M., and Diderichsen F. (**2001**). "Swedish population health-related quality of life results using the EQ-5D," Qual Life Res **10**, 621–635.

Dumper, J., Hodgetts, B., Liu, R., and Brandner, N. (**2009**). "Indications for bone-anchored hearing AIDS: a functional outcomes study," J. Otolaryngol Head. Neck. Surg. 38, **96**-105.

Gatehouse, S. (**1999**). "Glasgow Hearing Aid Benefit Profile: Derivation and validation of a client-centered outcome measure for hearing-aid services," J. Am. Acad. Aud., **10**, 80-103.

Hällgren, M., Larsby, B., Arlinger, S. (**2006**). "A Swedish version of the Hearing In Noise Test (HINT) for measurement of speech recognition," Int. J. Audiol. **45**, 227-237.

Hol, M. K., Bosman, A. J., Snik, A. F., Mylanus, E. A., Cremers, C. W. (**2004**). "Bone-anchored hearing aid in unilateral inner ear deafness: a study of 20 patients," Audiol. Neurootol. **9**, 274-281.

Hol, M. K., Bosman, A. J., Snik, A. F., Mylanus, E. A., and Cremers, C. W. (**2005**). "Bone-anchored hearing aids in unilateral inner ear deafness: an evaluation of audiometric and patient outcome measurements," Otol. Neurotol. **26**, 999-1006.

Lin, L. M., Bowditch, S., Anderson, M. J., May, B., Cox, K. M., and Niparko, J. K. (**2006**). "Amplification in the Rehabilitation of Unilateral Deafness: Speech in Noise and Directional Hearing Effects with Bone-Anchored Hearing and Contralateral Routing of Signal Amplification," Otol. Neurotol. **27**, 172-182.

Newman, C. W., Sandridge, S. A., and Wodzisz, L. M. (**2008**). "Longitudinal benefit from and satisfaction with the Baha system for patients with acquired unilateral sensorineural hearing loss," Otol. Neurotol. **29**, 1123-1131.

Sullivan, M., Karlsson, J., and Ware, J. E. Jr. (**1995**). "The Swedish SF-36 Health Survey – I. Evaluation of data quality, scaling assumptions, reliability and construct validity across general populations in Sweden," Soc. Sci. Med., **41**, 1349-1358.

Wazen, J. J., Spitzer, J. B., Ghossaini, S. N., Fayad, J. N., Niparko, J. K., Cox, K., Brackmann, D. E., and Soli, S. D. (**2003**). "Transcranial contralateral cochlear stimulation in unilateral deafness," Otolaryngol Head Neck Surg. **129**, 248-254.

Yuen, H. W., Bodmer, D., Smilsky, K., Nedzelski, J. M., Chen, J. M. (**2009**). "Management of single-sided deafness with the bone-anchored hearing aid," Otolaryngol Head Neck Surg. **141**, 16-23.