Critical Review: Is there evidence that Bone Anchored Hearing Aids provide greater benefit in hearing performance than Air Conduction Hearing Aids for conductive or mixed hearing loss patients?

Kim, Y. B. (Sylvia)
M.Cl.Sc. (Aud.) Candidate
School of Communication Sciences and Disorders, U.W.O

This critical review examines the benefit of using Bone Anchored Hearing Aids (BAHA) for conductive and mixed hearing loss patients compared to Air Conduction Hearing Aids (ACHA). Study designs include randomized intervention study and cross sectional survey. Overall, objective measures indicate that BAHA provides equal or slightly better performance than ACHA. Subjective measures show clear patient preference in using BAHA over ACHA. However, factors such as Air Bone Gap should be taken into consideration when counselling patients about BAHA and ACHA.

Introduction

The Bone Anchored Hearing Aid (BAHA), developed by Hakasson vin Sweden in the 1985 (McDermott, Dutt, Reid & Proops, 2002), is a bone conduction hearing aid coupled to an osseointegrated titanium percutaneous implant anchored in the temporal bone. It requires a minor surgical procedure of putting the implant under local anesthetic. Sound is then transferred from the transducer directly vibrating the skull bone, of which the cochlear is an integrated part. Osseointegration affords direct bone conduction along with direct coupling with an integrated implant that allows efficiently transfer of electro-mechanical energy.

The BAHA was designed for patients with conductive and mixed hearing losses who may not be getting maximum benefit from their air conduction hearing aids. Their hearing loss can be further complicated by chronic otitis media and otitis externa and congenital aural atresia, etc. However, lots of conductive and mixed loss patients are usually fitted with either conventional air or bone conduction hearing aids (McDermott et al, 2002). The BAHA device could overcome several of the drawbacks of using conventional air-conduction and bone-conduction hearing aids for patients with conductive or mixed hearing loss. The BAHA does not interfere with the cochlear so there are no risks of damaging the ear or the residual hearing. Recent developments of the BAHA system have made it more user friendly and the device has been further miniaturized. The FDA has cleared the device for both adults and children (from age 5 and up) and also bilateral fitting (Westerkull, 2002).

Objectives

The primary objective of this paper is to critically evaluate existing literature regarding the benefits of using BAHA over ACHA for conductive or mixed hearing loss patients. The secondary objective is to generate recommendations for clinicians and for future research based on evidence-based results.

Methods

Search Strategy

Computerized databases, including Communication Sciences and Disorders Dome (ComDis Dome), PubMed, and Cochrane Library, were searched using the following search strategy:

((Bone Anchored Hearing Aids) OR (BAHA)) AND ((Air Conduction Hearing Aids) OR (ACHA)) OR (Conventional Hearing Aids))

The search was limited to articles written in English between 1995 and 2007.

Selection Criteria

Studies selected for inclusion in this critical review paper were required to investigate the objective performance using pure tone thresholds and speech recognition or subjective performance using outcome measures of the BAHA in comparison to ACHA for conductive or mixed hearing loss patients, both adults and children.

Date Collection and Research Design

Results of the literature search yielded the following types of articles congruent with the selection criteria: Non randomized intervention study (4) including one longitudinal study, and cross sectional survey (2). Five of six studies used 2-tailed paired t test with the overall significant level <0.05. One study used ANOVA using the normal hearing group as the control group. Overall level of evidence hierarchy is 3. Quality of published evidence of each article is summarized in Table 1.

Results

Results of Objective Measures

Threshold comparison using Sound Field Audiometry

Mylanus, van der Pouw, Snik & Cremers (1998) found a significant benefit in favor of BAHA at 1 KHz ($t=3.53$; $p<.01$) and 8 kHz ($t=5.65$; $p<.001$) of 6 and 12 dB respectively in their tests with 34 adults patients with average age 48, while Bance, Abel, Papsin, Wade & Vendramini (2002) found no significant difference between ACHA and BCHA measurements across frequencies in their tests with 15 adult patients age under 48 years old.

The follow up study conducted by Hol, Snik, Mylanus & Cremers (2005) revealed that mean free-field aided BAHA thresholds were 7 dB poorer (number of patients who showed poorer thresholds =23 out of 27), which also resulted in the poorer S/N ratio ($p=.001$). To assess whether the reason for the poorer thresholds is cochlear function being deteriorated over time, not related to aging, age-appropriate P50 values were subtracted from the measured bone conduction thresholds and results were averaged per patient. The comparison between pre-implantation and recent bone conduction thresholds at the frequencies of 0.5, 1,2, and 4 kHz after correction with P50 values according to International Organization of Standardization norms revealed that the cochlear function significantly deteriorated over time, with a mean SD of 13.3 ±4.6 dB (range,8-23 dB).

Perceiving Speech in Quiet and in Noise

Mylanus et al. (1998) showed that the improvement in S/N ratio reflects a small but significant change with the BAHA compared to ACHA ($t=3.17$; $p<.01$). However, Consonants discrimination tests administered in four conditions: contrasting initial consonant in quiet, final consonant in quiet, initial consonants in noise, and final consonant in noise (Bance et al, 2002) indicated that there were no significant difference between the BAHA and the ACHA. A longitudinal study (Hol et al, 2005) found a significant decrease in both speech in quiet ($p<.05$) and in noise ($p=.001$) for BAHA performance compared to the study conducted in 1988. The results reflect the cochlear function deterioration in half of the patients with mean SD 13.3 dB±4.8 dB.

Niparko, Cox & Lustig (2003) conducted a intervention study with 10 adults with profound unilateral hearing loss and compared the HINT results for BAHA with CROS. The results revealed a significant BAHA advantage in speech performance in all five HINT conditions: Ease of Conversation ($p=.007$), Noise Front ($p=<0.001$), Noise better ear ($p=0.152$), Noise worse ear ($p=0.183$), and Composite noise score ($p=0.001$). For every 1 dB change in threshold, there was an approximately 10 dB change in speech intelligibility. However, the HINT in quiet did not show a BAHA advantage ($p=0.18$).

Gap Discrimination and Temporal Acuity

The study conducted by Bance et al. (2002) indicated that there were no significant differences between unaided and aided ears with BAHAs or with ACHAs in the case of the duration of gap difference limen. In tests of temporal acuity the BAHA scores were slightly higher than the ACHA scores, but the difference was not significant.

Sound Localization

Niparko, Cox & Lustig (2003) conducted the Source Azimuth Identification in Noise Test (SAINT) (n=10, all with uni-lateral deafness) to determine the ability to localize sound in the horizontal plane. The subjects were tested in a sound-treated booth in the center of a speaker array, 1 m away from each of the speakers. The summary SAINT scores at baseline (0.307) and for the CROS (0.261) and BAHA (0.285) showed no significant differences indicating poor sound localization in all three conditions in 95% confidence level.

Impact of Air Bone Gap

Based on the fact that hearing by bone conduction is far less effective than by air conduction, the intuitive conclusion is that the performance of the patients with pure sensorinerual hearing loss may be poorer than with an ACHA. However, in patients with an air-bone gap, the amplification via an ACHA to be increased substantially, it has to compensate for the air bone gap. Thus, the air-bone gap was a significant factor with the BAHA. Bance et al. (2002) found that the greater the unaided air bone gap, the higher the discrimination of the initial and final consonants in noise. Mylanus et al. (1998) found that when maximum phoneme score was plotted against the size of air bone gap (average air-bone gap at 0.5, 1,2, and 4 kHz), in patients with an air-bone gap that exceeded 30 dB, the score with the BAHA was equal or better than with the air-conduction hearing aids and15 out of 28 patients whose air-bone gap exceeded 25 dB showed significant improvement of the S/N ratio $r=0.59$, $p<.01$).

Results of Subjective Measures

In the study by Niparko et al. (2003) with 10 adults with unilateral deafness (pure tone average >90 dB) and normal haring (pure tone average < 25 dB) in the opposite ear, the results of the mean standard deviation of the four principal probes of the

Abbreviated Profile of Hearing Aid Benefit (APHAB) survey of hearing benefits scores associated with BAHA (Niparko et al, 2003) reached positive clinical significance in easy of conversation (6.7±14.5), listening in reverberant conditions (21.2±23.1), and listening in background noise (18.5±29.6) compared to previous use of ACHA.

The Glasgow Hearing Aid Benefit Profile (GHABP) questions targeted the listening experience related to watching television, conversation in quiet and in noise, and conversation in a group. In the same study by Niparko et al. (2003), the mean GHABP scores for the probes of time worn, benefits, residual disability and overall satisfaction demonstrated a consistent BAHA advantages compared to the use of ACHA.

Mylanus, Snik, & Cremers (1995) conducted a prospective study (n=65, all current BAHA users who had used conventional hearing aids) with two outcome measures designed to find out qualitative descriptive results and difference scores comparing conventional hearing aids and BAHA. Patients favored the BAHA because they experienced less ear infections and skin irritation, but only slightly for speech recognition and sound quality. For difference questionnaires, more patient preferred the BAHA ($p<.01$). 34 out of 55 patients preferred the BAHA for speech recognition in noise, six patients preferred their previous hearing aids (ACHA), and 15 patients responded they had no preference. On average, more than half of the patients reported that speech recognition and sound quality with the BAHA was better than with the ACHA.

McDermott, Dutt, Reid & Proops (2002) used the Nijmegen group questionnaire collected from 227 patients to directly assess patient satisfaction with their current BAHAs in comparison with their previous won ACHAs. The results revealed that Patients found the BAHAs to be significantly superior in all respects when compared to their previous conventional hearing aids with all parameters listed in the questionnaire: reduced occurrence of ear infection ($p \leq .001$), speech recognition in quiet ($p \leq .001$), speech recognition in noise ($p \leq .005$), sound quality ($p \leq .001$), visibility ($p \leq .001$), handling ($p \leq .001$), feedback problems ($p \leq .001$), and ENT visits ($p \leq .001$). When asked to identify the most satisfying feature of their BAHA, 79% of 227 patients responded sound quality to be the most outstanding feature ($p \leq .001$).

Conclusions

Research has demonstrated the performance with the BAHA was found superior in some patients and inferior in others. Mylanus et al. (1998) found that the aided thresholds with the BAHA were somewhat better in the high frequency region than those obtained with the ACHA. This indicates that patients with BAHA may perform better in perceiving speech in noise. Objective benefits were demonstrated in selected tasks of speech recognition in noise from Niparko et al (2003). Improvements in speech recognition in noise suggest that some degree of spectral information in speech signal is more efficiently conducted via bone across the skull base.

Some studies showed that both BAHA and ACHA seemed to result in very similar audiometric performances. However considering that the electronic circuitry available is more sophisticated and allows for better compression and more programmability with ACHA and sound quality is different with bone conduction and the transmission route is through skull bone vibration with BAHA, it is encouraging the BAHA provides at least the same and sometimes better results with greater subjective satisfaction.

The significant correlation between the air bone gap and speech perception in noise with the BAHA suggests that those with air bone gap more than 25 dB may receive grater benefit from amplification in communication capability.

Studies of subjective measures consistently revealed that the BAHA was found to be better in all areas. The main advantages appeared to be related to sound quality, speech in quiet and in noise and reduced ear infection in comparison to ACHA.

Discussion on limitation of the studies

Of the articles evaluated, many have not provided adequate statistical data in terms of numerical results of testing. A couple of studies used very few charts or tables, and only displayed percentages without mentioning statistical significance. Also, few studies mentioned the specific fitting protocol and testing environment used for the BAHA device. As such, replication of the study results would be impossible for future researchers.

One article conducted ANOVA analysis using normal hearing group as a control group. As a result, it produces a meaningless comparison by showing the performance of the normal group, which is naturally significantly better than the hearing impaired group regardless of type of the hearing aids. More meaningful results could have been produced if the study compare the performance of conductive versus conductive and mixed versus with mixed as the BAHA is recommended for conductive or mixed hearing patient groups.

About comparing the BAHA system with CROS, providing acoustic stimulation from across the median plan to a single cochlear would be unlikely to stimulate the central binaural auditory mechanism normally activated by binaural input. However, it is not certain whether limited partial hearing can be achieved with acclimatization and learning effects over time. More over, these results were achieved with an omni directional microphone in the process-transducer, the use of a directional microphone might possible improve localization.

Some of the subjective measure questionnaires used for surveys such as Qualify of Life and the Sanders Profile questionnaire are not directly relevant to the hearing loss and its impact. Therefore, it is not surprising that results of those tests did not show significant BAHA advantage in comparison to other subjective measures.

Recommendations

In patients with conductive or mixed hearing loss as well as those with chronic ear problems, the BAHA device is an alternative to ACHA. However, for mixed hearing loss patients, pre-operative counseling is imperative based on the size of the air-bone gap because deterioration in speech recognition might happen, especially if the air-bone gap is smaller than 25-30 dB.

Also, for patients with profound unilateral hearing loss (pure tone average>90 dB, Speech discrimination <20%), the BAHA system is a good option over CROS as the BAHA overcomes some of the negative head shadow effects and amplifies signals with no interference with the function of the normal ear.

Patients should be counseled on the operation and special care of the percutaneous implant as well as possible skin reactions, that could be a disadvantage that the BAHA device could cause to the wearers. Also, the condition of the titanium implant and the success of using BAHA device depend heavily upon the meticulous care and cleaning of the abutment.

As the BAHA technology advances toward more powerful and flexible frequency shaping and programmability, further research is necessary on the performances of different advanced BAHA models and on wearing binaural BAHA devices.

References

Note: References marked with an asterisk indicate studies included in the critique.

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TABLE I
Quality of Published Evidence on Comparison of BAHA with ACHA

Reference	Type of Study and Methodology	Cases (Age)	Main Conclusion	Evidence Type
Mylanus et al. (1995)	Cross sectional study with questionnaires	65 patients (10-76 yrs)	Patients with BAHA reported a significant improvement in speech recognition in quiet and noise, and in sound quality (P<.01)	
Mylanus et al. (1998)	Non randomized intervention study: pure tone and speech recognition testing plus questionnaires	34 adults (26-72 yrs)	Speech recognition improvement and better performance with BAHA in high frequencies. The assessment of the size of the air-bone gap can help predict whether speech recognition may improve or deteriorate with the BAHA compared with the ACHA. More air-bone gap than 25 dB may improve the speech recognition.	3
McDermott et al. (2002)	Cross sectional study: Nijemen group questionnaire	227 participants (both adults and children who had won their BAHA for a period of six months to 11 years)	73 percent of participants with ear infections preferred the BAHA for fewer ear infections. 79 percent of the respondents perceived speech better in quiet and 59 percent perceived speech better in noise with the BAHA.	3
Bance et al. (2002)	Non randomized intervention study: pure tone, duration discrimination gap discrimination, consonants discrimination plus questionnaires	17 patients (16-67 yrs)	Overall, the BAHA and the ACHA provided similar audiometric functioning in audiometric tests. The BAHA should be considered for patients with ear drainage.	3
Hol et al. (2005)	Longitudinal non randomized intervention study: pure tone and speech recognition plus Nijemen questionnaire	27 patients (average age: 46 years and 7 months)	The audiometric data showed fairly stable results. Positive patient outcome measures. Preference increased from 81% to 91%.	3
Niparko et al. (2003)	Non randomized intervention study: sound localization and speech discrim. plus APHAB and GHABP scores	10 adults patients with profound unilateral hearing loss, age not stated.	The BAHA, when placed on the side of a deaf ear, yields greater benefit in patients with normal monoaural hearing than does CROS. The performance and survey clearly indicated that BAHA stimulation was more efficacious than CROS. The BAHA advantage in HINT was 3.2 dB in quiet (p=0.007) and 1.5 dB in noise from front (p<.001	3