Critical Review:

Does the BAHA hearing system provide subjective and objective benefit compared to the unaided condition in adults with unilateral deafness?

Lauren Vannus
M.Cl.Sc (AUD) Candidate
University of Western Ontario: School of Communication Sciences and Disorders

This critical review examined the subjective and objective benefits associated with the BAHA hearing system in adults with unilateral deafness. Study designs included: survey research and case series (1), meta-analysis (1), cross-sectional cohort design (1), prospective within group (repeated measures) design (2), prospective mixed between and within groups (repeated measures) design (1), case series pre-post test design (1). The current research reviewed did not provide sufficient support for recommending the BAHA hearing system to all adults with unilateral deafness. Some positive subjective and objective results have been demonstrated, but these results should be taken with caution. Additional studies investigating this treatment should investigate the impact of microphone directionality and the characteristics of successful BAHA users in this population.

Introduction

Unilateral deafness can result in difficulty understanding speech in noise, poor localization ability, loss of binaural summation and integration and difficulty hearing sounds from the deaf side (Newman, Sandridge and Wodzisz, 2008).

The conventional treatment for this condition is a Contralateral Routing of Signal CROS system. A CROS aid transfers sound from a microphone placed the deaf side to a hearing aid positioned on the ear with normal hearing thresholds connected by either a cable or wireless technology (Dillon, 2001). Several studies have suggested limited success with CROS system (Bosman, Hol, Snik, Mylanus, and Cremers, 2003 & Andersen, Schroder, and Bonding, 2006).

The Bone Anchored Hearing Aid (BAHA) has been suggested as another possible treatment for this population (Bosman, Hol, Snik, Mylanus, and Cremers, 2003; Snik, Mylanus, Proops, Wolfaardt, et al., 2005; Spitzer, Ghossaini, and Wazen, 2002). This device was approved by Health Canada for unilateral deafness in 2002 (Yeun, Bodmer, Smilsky, Nedzelskiand Chen, 2009). BAHAs produce a mechanical vibration that is transmitted to the skull via a titanium screw embedded and osseointegrated into the mastoid. This is referred to as a percutaneous coupling. This device is able to bypass the outer and middle ear and stimulate both cochleae (Dillon, 2001). This allows sound from the impaired (deaf) side to be transmitted to the normal functioning cochlea.

The studies reviewed in this analysis used similar subjective and objective outcome measures of benefit. All studies administered a speech in noise measurement of some form including the Hearing In Noise Test (HINT) and the revised Speech Perception in Noise (SPIN-R) test. The administration of the speech in noise tests varied across the studies as several different speaker configurations were used to present the speech and noise signals.

Subjective outcome measures commonly administered included the Abbreviated Profile of Hearing Aid Benefit (APHAB), the Single-Sided Deafness Questionnaire (SSDQ), the Glasgow Hearing Aid Benefit Profile (GHABP), and the Hearing Handicap Inventory for Adults (HHIA).

Objectives

The primary objective of this review is to critically evaluate the existing literature surrounding the objective and subjective benefit provided by the BAHA hearing system compared to the unaided condition in adults with unilateral deafness. A second objective is to examine speech in noise test results with consideration given to test conditions related to the location of the speech and noise signals.

Methods

Search Strategy

Computerized databases including PubMed, Medline, CINAHL, and Scopus were searched using the following search strategy: [(BAHA) OR (bone anchored hearing aid)] AND [(unilateral deafness) OR (single sided deafness)]. The search was limited to the English language and adults.

Selection Criteria

Studies included in this review were required to investigate benefit associated with the BAHA hearing system using both objective and subjective measures and include the unaided condition as one of the controls

used. To avoid redundancy, studies with the same subjects used in another, similar study, were omitted.

Data Collection

Results of the literature search yielded seven studies: survey research and case series (1), meta-analysis (1), cross-sectional cohort design (1), prospective within group (repeated measures) design (2), prospective mixed between and within groups (repeated measures) design (1), case series pre-post test design (1).

Results

Survey Research and Case Series:

Andersen, Schroder, and Bonding (2006) approached fifty-nine patients with unilateral deafness as a result of removal of an acoustic neuroma to complete a short subjective questionnaire that investigated handicap associated with unilateral deafness using a visual analogue scale. Fifty-three patients responded and were invited to try a BAHA device attached to a test band. Twenty-six of the patients participated in the BAHA trial. Speech discrimination in quiet and in noise was measured with the BAHA test band and in the unaided condition. After this testing patients walked around in various sound environments and were subsequently interviewed about their experience and satisfaction with the BAHA.

The initial questionnaire revealed high variability within the subject population. Of the fifty-three subjects, fifty-two thought they had a hearing handicap, 45% perceived it as being significant, 38% perceived that it was moderate and 15% thought it was a minor problem. Thirty-eight patients indicated that they were interested in trying the BAHA test band; this was correlated with their subjective hearing handicap. Twenty-six of the questionnaire respondents actually participated in the BAHA test band trial.

The speech in noise results showed significant improvement in the BAHA test-band condition compared to the unaided condition.

After wearing the BAHA test band for one hour the participants were interviewed about their experiences. Approximately 65% thought it was a satisfactory aid, 20/26 found it easier to hear sounds from the deaf side, 16/26 found it helpful for hearing speech in noise, 23/26 found the sound quality as being pleasant and natural. 5/6 existing conventional CROS users wanted treatment with the BAHA instead of their current CROS system. Approximately half the patients tried conventional CROS hearing aids but only a small number still used the aid and none of the patients found the system to be satisfactory.

Only 54% of the 26 decided they wanted to proceed with an implanted BAHA device, There was a trend to correlation between patients interested in the BAHA treatment and a high handicap score on the visual analogue scale but the correlation was not significant.

Statistical analysis to determine significance was not completed. Characteristics that defined individuals who decided to proceed with the BAHA surgery were not investigated although it was reported that the most frequent reason for not getting a BAHA device was that the benefit was too small. The researchers also suggested that the patients may have been hesitant about undergoing another surgery.

Cross-sectional Cohort Design:

Dumper, Hodgetts, Liu, and Brandner (2009) evaluated fifty patients who currently wear BAHA hearing systems. The patients were divided into four categories of hearing loss: bilateral conductive hearing loss, unilateral conductive hearing loss, unilateral mixed hearing loss, and unilateral deafness. The unilateral deafness group consisted of fifteen participants. The HINT was administered in the aided and unaided condition for all subjects in a variety of speaker configurations. The APHAB and SSQ were also administered to all subjects. The SSQ was used to make a comparison across the test groups and is therefore not relevant to the present analysis.

A 2x4x4 mixed ANOVA was run on the HINT data. The results revealed no significant improvement in the unilateral deafness test group.

The APHAB is able to provide a comparison of results between the unaided and aided with the BAHA. A 4x4 mixed ANOVA showed significant subjective improvement in patients with unilateral deafness in the BAHA-aided condition. These results were similar to the other test groups.

Although there is little objective improvement for the unilateral deafness test group, Dumper, et al. (2009) suggest that the objective tests used may not be sensitive enough to detect the benefit shown in the subjective results, that is the test may not be representative of real world listening conditions. The researchers believe it is unlikely related to the placebo effect because this test group regularly uses their devices and improvements have been reported years after their initial surgery.

Case Series Pre-Post Test Design:
Yuen, Bodmer, Smilsky, Nedzelski, and Chen (2009) evaluated twenty-one adults with unilateral deafness who were recently fit with a BAHA hearing system. HINT scores were obtained for the unaided and aided conditions with two speaker paradigms. The APHAB and the GHABP were administered pre-fitting and post-fitting via mail.

BAHA-aided condition resulted in significantly poorer abilities compared to the unaided condition when noise was presented from behind the participant while speech was presented from the front. The SNR increased on average by 1.6 dB SPL (range 0-5dB) in the aided condition.

The HINT scores showed a significant BAHA benefit when noise was presented to their normal hearing ear and speech was presented to the BAHA side. The mean decrease in SNR was 5.5 dB SPL (range 2-11 dB) when the BAHA was turned on compared to turned off.

Only sixteen of the twenty-one participants completed both the APHAB and GHABP questionnaires (a response rate of 67%). The APHAB showed the BAHA condition resulted in significant improvement compared to the unaided condition for the ease of communication, reverberation and background noise domains. The positive impact on aversiveness to sound has borderline significance. Yuen, et al. (2009) summarized results of the GHABP as being positive for the BAHA condition, however no statistical support founded these claims. The scores showed that subjective benefit was highly variable across individuals.

Meta-Analysis:
Baguley, Bird, and Prevost (2006) evaluated the evidence base for fitting BAHA hearing systems in adults with acquired unilateral sensorineural hearing loss. A Medline search was conducted (1960-2005) using the terms “unilateral”, and “hearing loss”. 238 abstracts were screened for relevance to the efficacy of BAHA hearing systems for adults with unilateral SNHL. Four controlled studies were identified and reviewed, observational and non-peer reviewed studies were identified and also discussed.

HINT results across the studies showed favourable results for the BAHA aided condition compared to both the conventional CROS and the unaided conditions.

The pooled mean difference with a confidence interval of 95% was calculated for the BAHA and conventional CROS for the APHAB domains. APHAB and speech discrimination results of the four studies showed a BAHA advantage compared to the conventional CROS system and the unaided condition, however several study design flaws were outlined Baguely, et al. (2006) suggesting that these results be taken with caution.

For example, no technical details regarding the CROS fitting were provided by the authors of these studies, there was subject overlap in some of the studies reported, and the BAHA device was always fitted last. It was also stated that these results were from patients who sought out the intervention and were likely experiencing significant handicap. This limits the generalization of the findings as they may not apply to all individuals with unilateral deafness.

Prospective Within Group (Repeated Measures) Design Study 1
Hol, Kunst, Snik and Cremers (2009) contributed to some of the studies reviewed by Baguley, et al. (2006). They acknowledged some of the short-comings outlined in the meta-analysis by Baguley, et al. (2006) in the pilot study outlined as follows.

This study evaluated the effectiveness of three contralateral routing of sound (CROS) hearing aids in adults with unilateral deafness. The CROS aids evaluated included the conventional CROS hearing aid, the completely in the canal hearing aid and the BAHA system (attached to a headband).

Ten patients with unilateral deafness and normal hearing in the contralateral ear had an 8-week trial with each of the three CROS hearing aids in random order. Localization and speech perception in noise were evaluated at the baseline and after each amplification trial. The APHAB, SSQ and SSDQ were also measured at the baseline and after each amplification trial.

The randomized cross-over design addressed one of the concerns expressed by Baguley, et al. (2006) in their previous studies, although it is important to note that the implanted BAHA hearing system has a 10 dB advantage over transcutaneous delivery of the signal. The participants were patients recruited from their out-patient clinic although they had not necessarily visited the clinic to obtain information about hearing aids, which reduced some patient selection bias. The authors acknowledge the need for a larger study to determine treatment efficacy for this population, as they obtained only 7 complete sets of test results. The conventional CROS and CIC models and settings were outlined. No statistical analysis of the data was performed.

The APHAB showed greatest benefit for the BAHA, intermediate scores for the CROS and the poorest scores for the CIC although the CROS had the best overall

APHAB scores. The SSQ showed the BAHA and CROS provided the most benefit

The SSDQ showed the CIC had the best scores for wearing comfort, ease of use, rustle, whistle and failure; the items related to quality of sound were best for the conventional CROS and worst for the CIC. Localization was found to be at chance levels for all conditions. Speech recognition in noise showed poorer results for the BAHA aided condition compared to the unaided condition.

Not one of the three treatment conditions seemed to have an overall advantage. At the end of this study six out of the ten patients did not choose any of the unilateral amplification methods they tried in this study. One patient chose an FM CROS (instead of the wired CROS trialed), two have received a BAHA implant and one is waiting for the surgery.

Prospective Within Group (Repeated Measures) Design Study #2

Newman, Sandridge, and Wodzisz (2008) evaluated the short, medium and long-term benefits and satisfaction of the BAHA system in adults with unilateral deafness. Eight adults with unilateral deafness were evaluated unaided, 1, 3, 6, 9, 12, and 18 months after the BAHA fitting. The measures used include: the SPIN-R test, the HINT, localization testing, the APHAB, the HHIA, the SSDQ, and the Medical Outcomes Study SF-36 Health Survey was used to assess health-related quality of life.

The SPIN-R showed consistent aided advantage at each time interval compared to the unaided baseline in mean and individual data and was statistically significant. The HINT showed significant variability in the participants' performance over time with a BAHA advantage shown up to the 18-month time interval. Localization did not improve over time and were not above chance levels.

The APHAB showed significant improvement in the BAHA-aided condition compared to baseline except for one and twelve months post-fitting for the ease of communication subscale. The aversiveness to sound subscale was not analyzed because it is not used in the calculation of global benefit. This is interesting because some of the above studies found this subscale to be less favourable for the BAHA treatment. Seventy-five percent of participants showed significant improvement by 18 months. Consistent improvement over time was seen in the reverberation and background noise subscales while changes in the ease of communication subscale were the least noticeable.

The HHIA revealed that on average, the perceived activity/participation restriction was significantly reduced. The HHIA showed significant improvements in psychological function at each time interval although scores did not fall within the normal range (they ranged from 34 to 47 points) indicating the patients had residual mild to moderate handicap despite having the BAHA aid.

The SSDQ revealed that most participants reported that the BAHA improved their quality of life. When asked at the 18-month session if they would be willing to have the surgery again if given the chance seven of the eight participants reported that they would. It is interesting to note however that seven of the eight participants used the BAHA everyday initially, but by the 18-month session one participant no longer used the device and only two of the participants reported daily use. The SSDQ showed that this did not affect the long-term satisfaction with the device.

The general health-related quality of life assessment failed to demonstrate positive effects unlike the other specific questionnaires (APHAB and HHIA). This tool may not have been specific enough to show an effect.

Prospective Mixed Between and Within Groups (Repeated Measures) Design:

Linstrom, et al. (2009) evaluated seven adults with unilateral deafness and normal hearing in their contralateral ear. The original study group consisted of eight participants, but one participant was excluded due to lack of device use. Outcome measures included HINT, APHAB, and SSQ at one, six and twelve months post BAHA fitting. The results of the HINT were compared to a normally hearing control group.

All patients were implanted with the BAHA Compact with a class D amplifier, output compression, and a switch that allowed both omindirectional and directional microphone settings.

HINT benefit was found when speech was presented to the BAHA side and noise presented from the front. This was significantly better in the omnidirectional microphone setting than in the directional setting. When speech was presented from the front and noise presented to the BAHA side the SNR mean was significantly worse although directional microphone condition helped slightly. The BAHA aided condition never approximated the control group SNR for any condition.

The APHAB revealed background noise, ease of communication, reverberation and the global scores were significantly better in the BAHA condition than the unaided condition. A statistical difference was not found for the aversiveness subscale although results showed a trend toward more aversiveness to sound in

the BAHA-aided condition. The SSDQ showed a positive BAHA impact on each item and time had no statistically significant influence on the scores.

Discussion

Overall, these studies were well designed and used reasonable outcome measures, however statistical analysis was lacking in several of the studies. The speech in noise test results varied across studies and are difficult to compare because the location of the speech and noise signal also varied substantially.

It appears as though the BAHA provides benefit understanding speech in noise in a common real-world listening environment where the speech is presented from the front in the presences of diffuse noise (Andersen, et al., 2006 & Newman et al., 2008).

Yuen et al. (2009) and Newman, et al. (2008) found speech in noise scores showed a significant BAHA benefit when noise was presented to the participants' normal hearing ear and speech was presented to the BAHA aided side. Linstrom, et al. (2009) also showed a BAHA benefit when speech was presented to the BAHA aided side and noise was presented from the front.

Yuen, et al. (2009) did not perform the HINT in the condition with noise presented to the BAHA side and speech to the normal hearing ear because they stated the individual could down or turn off the device in this challenging listening condition.

When speech was presented from the front and noise presented to the BAHA side the SNR mean was significantly worse (Newman, et al., 2008 & Linstrom, et al., 2009). Dumper, et al. (2009) found similar results for this configuration, although they were not statistically significant.

Hol, et al. (2009) found poorer results for the BAHA aided condition when noise was presented from the front and speech was presented to the BAHA aided side and to the normal hearing ear. Yuen, et al. (2009) also demonstrated significantly poorer results for the BAHA-aided condition compared to the unaided condition when noise was presented from behind the participant while speech was presented from the front.

The studies reviewed by Baguley, et al. (2006) showed a BAHA benefit for speech in noise tests. These studies used a variety of configurations such as noise presented from the front and speech presented separately to the BAHA aided and the normal hearing sides or speech presented from the front with noise presented from the front and two sides. The meta-analysis (Baguley et al., 2006) did not analyze the results separately across the presentation conditions, so it is unclear how the signal presentation locations impact these results.

It is interesting to note that the HINT results varied across time intervals (Hol, et al., 2009 & Newman, et al. 2008) and subjects (Newman et al., 2008) while Linstrom, et al. (2009) found the results did not change over time.

Overall subjective results appeared to be favourable for the BAHA aided condition compared to the unaided condition across the various test measures. Although the GHABP showed highly variable range of reported experiences associated with the BAHA (Yuen, et al., 2009). Localization abilities did not differ between the BAHA aided and unaided conditions.

Conclusions and Clinical Implications

Results from these studies show overall subjective benefit associated with BAHA systems for individuals with unilateral deafness, but the objective data is less conclusive. However, hearing in noise does appear to be improved in a common real-world listening condition (speech from the front in a diffuse noise field).

Less invasive CROS systems should be initially trialed, such as the conventional CROS system. The majority of the studies had subject populations that consisted of current BAHA users, many of whom trialed a conventional CROS system but received inadequate benefit. This suggests that global recommendations for all patients with unilateral deafness based on the discussed studies are inappropriate. BAHA implantation should be done on a case-by-case basis. This is highlighted by findings from Andersen, et al. (2006) that approximately only 25% of the individuals in their study wished to pursue a BAHA hearing system after a trial with a BAHA attached to a test band.

It would be reasonable for an individual who is unsatisfied with the conventional CROS system to pursue a BAHA hearing system (with a test band trial first), as they may obtain some subjective and possibly objective benefits. Many of the studies had small subject populations, which is to be expected given the low incidence of unilateral deafness. However, it is interesting to note that several subjects were excluded from the analyses because they did not complete the necessary tests or did not wear the BAHA device for more than one hour a day.

Prospective BAHA patients should be cautioned about the magnitude of benefit they should expect. This is

especially true as Linstrom et al. (2009) showed that HINT results were not as good as the normal-hearing control group for either the BAHA-aided or unaided conditions. It is also interesting to note that Newman, et al. (2008) found residual hearing handicap after BAHA treatment and decreased use of the device eighteen months after the initial fitting although satisfaction with the device was reported as being high.

Further investigation should be done to distinguish between individuals with unilateral deafness who are successful BAHA candidates and those who may not be interested in or benefit from the device. Additional studies investigating the effects of microphone directionality are also recommended.

References

Andersen, H. T., Schroder, S. A., & Bonding, P. (2006). Unilateral deafness after acoustic neuroma surgery: Subjective hearing handicap and the effect of the bone-anchored hearing aid. *Otology & Neurotology, 27*, 809-814.

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

Bosman A.J., Hol M.K.S., Snik A.F.M., Mylanus E.A.M., Cremers C.W.R.J. (2003).Bone-anchored hearing aids in unilateral inner ear deafness. *Acta Otolaryngol.* 123, 258–260.

Dillon, H. (2001). Chapter sixteen: CROS, bone-conduction, and implanted hearing aids. *Hearing aids* (pp. 434-450). Turramurra, Australia: Boomerang Press.

Dumper, J., Hodgetts, B., Liu, R., & Brandner, N. (2009). Indications for bone-anchored hearing aids: A functional outcomes study. Otolaryngology–Head and Neck Surgery, 38(1), 96-105.

Hol, M. K. S., Kunst, S. J. W., Snik, A. F. M., & Cremers, Cor W. R. J. (2009). Pilot study on the effectiveness of the conventional CROS, the transcranial CROS and the BAHA transcranial CROS in adults with unilateral inner ear deafness. *European Archives of Oto-Rhino-Laryngology*

Linstrom, C., J., Silverman, C. A., & Yu, G. (2009). Efficacy of the bone-anchored hearing aid for single-sided deafness. *The Laryngoscope, 119*, 713-720.

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

Snik A.F.M Mylanus E.A.M., Proops D.W., Wolfaardt J.F., et. al (2005). Consensus statement on the BAHA system: Where do we stand at present? *The Annals of Otology, Rhinology & Laryngology. 114*, 1-12.

Spitzer J., Ghossaini S., Wazen J. (2002) Evolving Applications in the Use of Bone-Anchored Hearing Aids. *American Journal of Audiology. 11*, 96-103

Yuen, H., Bodmer, D., Smilsky, K., Nedzelski, J. M., & Chen, J. M. (2009). Management of single-sided deafness with the bone-anchored hearing aid. *Otolaryngology–Head and Neck Surgery, 141*, 16-23.