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REVIEW ARTICLE

Understanding the low uptake of bone-anchored hearing aids: a review

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Abstract

Background: Bone-anchored hearing aids improve hearing for patients for whom conventional behind-the-ear aids are problematic. However, uptake of bone-anchored hearing aids is low and it is important to understand why this is the case.

Method: A narrative review was conducted. Studies examining why people accept or decline bone-anchored hearing aids and satisfaction levels of people with bone-anchored hearing aids were reviewed.

Results: Reasons for declining bone-anchored hearing aids included limited perceived benefits, concerns about surgery, aesthetic concerns and treatment cost. No studies providing in-depth analysis of the reasons for declining or accepting bone-anchored hearing aids were identified. Studies of patient satisfaction showed that most participants reported benefits with bone-anchored hearing aids. However, most studies used cross-sectional and/or retrospective designs and only included people with bone-anchored hearing aids.

Conclusion: Important avenues for further research are in-depth qualitative research designed to fully understand the decision-making process for bone-anchored hearing aids and rigorous quantitative research comparing satisfaction of people who receive bone-anchored hearing aids with those who receive alternative (or no) treatments.

Key words: Hearing Aids; Bone-Anchored Hearing Aids; Patient Satisfaction; Decision Making; Hearing Loss; Correction of Hearing Impairment

Introduction

Background

Bone-anchored hearing aids (BAHAs) provide hearing improvement for people with hearing loss and for whom conventional behind-the-ear hearing aids are not appropriate.[1] BAHAs comprise a titanium implant that is surgically placed into the skull behind the ear and a detachable sound processor which clips onto the titanium implant. As sound from the BAHA bypasses the middle ear, the devices are effective in the presence of middle-ear pathology.[2] Bone-anchored hearing aids are also used for patients with unilateral sensorineural hearing loss (SNHL): the skull conducts the sound from the side of hearing impairment to the 'good' ear.

Many patients do not take up BAHAs despite their effectiveness, and the reasons for this are not fully understood. It is important to understand why patients decline BAHAs so that healthcare professionals can support patients to make the best decision. If patients decline out of fear or uncertainty, then healthcare professionals can provide appropriate information and support. However, it may be that for some patients, maximum satisfaction and quality of life (QoL) result from not undergoing the procedure, in which case it is helpful to be alert to this.

This review aimed to establish why people choose to have, or not to have, a BAHA fitted, and how satisfied people are with their decisions. Research examining uptake and the possible reasons for not taking up BAHA is considered, and literature addressing patient satisfaction and the perceived benefits to those who have (or have not) opted to receive a BAHA are reviewed. As this review addresses patient decision-making and perspectives, the focus is on patient-reported outcomes related to uptake and satisfaction, rather than to audiometry findings.

Clinical context

National Health Service (NHS) England, UK, funds the fitting of a unilateral BAHA for patients with one of the following conditions: bilateral conductive or mixed hearing loss; unilateral conductive hearing loss unlikely to benefit from other treatments; or profound unilateral SNHL unsuitable for other treatment. Patients must also meet audiological criteria.[3] Thus,

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for many patients in England, cost is not an issue in deciding whether to receive a BAHA. In other countries, patient cost varies according to the particular device, healthcare system and insurance coverage.[4]

Literature review

A narrative review was performed with the aim of exploring the context and scope of literature in this area rather than a systematic review (defined by an a priori protocol). However, the review was conducted in a systematic manner. Initial searches of the Web of Science database were conducted on 31 July 2015, using the search terms: (1) bone anchored hearing aid AND (satisfaction OR psychology OR qualitative OR illness representations OR body image OR anticipated regret); and (2) bone anchored hearing aid AND (uptake OR adherence OR compliance). Empirical studies of uptake and/or decline rates in people offered BAHA, studies describing the reasons for accepting or declining BAHA and studies providing data on patient satisfaction with BAHA were included. Titles and abstracts of retrieved studies were checked for relevance and full texts of all potentially relevant papers were retrieved. The reference lists of all papers included from this search were checked for further relevant papers, and all members of the author team checked the review to ensure that they knew of no additional relevant papers. Only studies published in the English language were included because of resource limitations but the search was not limited by date: the advent of BAHA technology was a date limiter for relevant papers.

Results

Bone-anchored hearing aid uptake

There is a lack of published data indicating the size of the BAHA-eligible population. The NHS Commissioning Board Clinical Reference Group for Specialised Ear Surgery (2013) cites sources stating that the incidence of bilateral chronic suppurative otitis media (a middle-ear infection which could indicate benefit from BAHA) is unknown but that 'clinical observation would suggest this is a considerable problem'.[3]

Few studies report the BAHA acceptance rate, but available data suggest that BAHA uptake is low. Siau *et al*. reviewed data from 90 consecutive adult British patients with unilateral SNHL referred to a BAHA programme between 2008 and 2011.[5] Most ($n = 79$) were deemed audiologically suitable for BAHA and offered a trial of a bone conduction aid attached by a headband. Of these, 24 (30 per cent) accepted a BAHA and 55 (70 per cent) declined, 2 without undertaking the trial. In a study of BAHA-eligible patients with conductive and mixed hearing loss, similar findings were reported: 38 (39 per cent) accepted implantation and 60 (61 per cent) declined. When the sample was divided into patients with unilateral or bilateral hearing problems, acceptance rates were 64.2 per cent ($n = 27$) and 19.6 per cent ($n = 11$) respectively.[6]

A Danish group reported the treatment decisions of adult patients with unilateral SNHL following surgery for acoustic neuroma.[7,8] Of the 52 participants who responded to a question about testing a BAHA, 38 (73 per cent) expressed interest and were invited to a test session. Twenty-six patients (50 per cent of 52) attended the test session and trialled a bone conduction aid on a headband. Fourteen of these decided that they wanted a BAHA, and only 11 (21 per cent of 52) went on to actually receive the implant.

In contrast, a study of 90 new BAHA-eligible patients (68 children, 22 adults) in Montreal, Canada, reported that only 10 patients (11 per cent) declined implantation (2 adults and 8 children).[9] It is unclear why patients found BAHA implantation more acceptable in this study, but there were differences in the study cohort, in particular, most participants were children, so the parents may have made the decision on their behalf. Thus, apart from in this final study, BAHA uptake was lower than might be expected given the effectiveness of the intervention. The next section reviews research into the reasons why some people decline BAHA.

Reasons for declining a bone-anchored hearing aid

In the Canadian study, the most common reason for refusal was cosmetic concerns ($n = 6$).[9] Siau *et al*. reviewed clinical notes of patients with unilateral SNHL to determine patients' reasons for declining a BAHA.[5] Reasons given were perceived limited benefits ($n = 26$); reservations about surgery ($n = 18$); preference for an alternative device (contralateral wireless routing of signals ('CROS'); $n = 13$); and cosmetic reasons ($n = 12$).[5] Of the 55 patients who declined, 32 received wireless contralateral routing of signals devices, but 23 received no device, suggesting that patients chose no hearing support over the BAHA.[5] In another study of a conductive and mixed hearing loss sample, Siau *et al*. found the most common reasons for rejection to be anxiety about the surgery (reported by 27 patients; 45 per cent), cosmetic concerns ($n = 18$; 30 per cent) and insufficient benefit during a softband trial ($n = 16$; 27 per cent).[6] While Siau and colleagues provide some indication of the reasons for declining, neither study was specifically designed to explore the reasons for refusal: instead, these were gleaned from clinical notes. Patients' reasons for declining were noted, but there was limited elaboration or explanation of these reasons. For example, if someone was concerned about surgery, there was no explanation about exactly what worried them.

The Danish study provided no information as to why only 26 of 52 potential participants attended a test session.[7,8] Twelve participants declined after testing a bone conduction aid on a headband. Of these, seven declined because they considered the gains to be 'too

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small or lacking' or for 'other reasons' (not specified). Five had doubts and, after further, extended testing of a conventional bone conduction aid, chose not to have the BAHA (reasons not specified). It is also unclear why 3 of the 14 who did want the BAHA did not receive it.

Patients' records were reviewed at a private otology practice in the USA and appropriate patients were invited for evaluation for BAHA.[10] A letter describing BAHA was sent to 538 potential candidates, of whom 162 (30 per cent) made a consultation appointment and 146 were confirmed as potential candidates. After the BAHA was discussed and shown to individuals, 92 per cent of these patients tried a BAHA on a test band in the office. Patients with single-sided deafness were more likely to try the headband than those with conductive or mixed hearing loss (94 per cent *vs* 83 per cent). Those with conductive or mixed hearing loss who declined tended to have had previously unsuccessful operations and were hesitant about undergoing another procedure, whereas the reasons for not trying the BAHA in patients with single-sided deafness included adaptation to having only one hearing ear, aversion to surgery, cosmetic concerns, lack of insurance coverage and absence of effect on tinnitus. Of the 134 who tried the BAHA test band, most (n = 123) liked the experience; of these, 41 (30.6 per cent of 134) were scheduled for surgery within 1 year. The most important factors in deciding not to have surgery were inadequate insurance or an inability to afford the procedure. Seventy per cent of individuals in this study did not respond positively to the invitation letter, but these were not followed up to determine their reasons for not engaging in the process.

In a prospective study, a Swiss sample of 46 adults with SNHL in 1 ear tested bone conduction aids on headbands for 7–10 days, after which 17 declined and 29 accepted a BAHA.[11] Prior to surgery, participants underwent audiometric tests and rated their perceptions of the benefits of the bone conduction aid. No differences were found between decliners and acceptors in aetiology, deafness duration, transcranial attenuations or air conduction thresholds. However, of the 26 participants who returned the questionnaire, the 10 accepters reported a greater benefit of the test aid compared with decliners in the following contexts: speaker at a distance, speech in noise, group conversation and overall assessment. Thus, understanding patient experiences and satisfaction levels may be more useful than biological, audiometric tests for predicting BAHA acceptance.

This research indicates that a large proportion of patients eligible for BAHA do not receive treatment that could optimise their hearing. However, it is unclear why people decline BAHA. It is important to understand whether people decline because of misunderstanding or fear, which can be addressed with appropriate support, or whether declining is actually the best decision for many people, leading to optimal satisfaction and QoL. The next sections of this review examine satisfaction in patients who have been offered a BAHA. Firstly, studies using cross-sectional and retrospective designs are considered. Most reports identified fall into this group, but such designs are weak and limit conclusions. Secondly, studies using other, more robust designs are discussed.

Patient satisfaction

Cross-sectional and retrospective studies. Many reports of surveys of satisfaction in patients who have received a BAHA were identified. Most were cross-sectional or retrospective studies, with patients completing postal questionnaires or telephone interviews to report their current perceptions of, or change in well-being since, having the BAHA implanted (see Table I for a summary). Generally, satisfaction and usage levels were high. Devices were particularly useful in one-to-one conversations in quiet settings but less so in group conversations in noisy settings. Two studies suggested that the BAHA may be perceived more positively by those with previous experience of bone conduction hearing aids than those who had previously used air conduction hearing aids.[12,13]

It was common for researchers to wait six months between implantation and survey completion to avoid 'enthusiasm bias' owing to the novelty of having a new device. However, it is still possible that people who had undergone invasive surgery were biased towards finding benefits to justify the personal investment of undergoing a surgical procedure. According to cognitive dissonance theory, people are uncomfortable with clashing thoughts and aim to reduce dissonance.[14] Therefore, having made the decision to undergo surgery and having made effortful investment into this decision, people will be reluctant to admit to having made the wrong decision. There is evidence that people show 'confirmation bias', that is, a preference for information that is consistent with decisions they have made.[15,16]

In studies that asked participants to compare their satisfaction or QoL at the time of the questionnaire with how they recall feeling prior to surgery, it is possible for recall to be influenced by a range of factors. A prospective design in which participants are asked about their experiences pre-operatively and then again post-BAHA implantation would provide more reliable data.

Many studies used mixed samples of children and adults. This is problematic because it is unclear who has completed the questionnaire for children, and parents may introduce their own perspectives when helping a child to complete the questionnaire. There also seem to be different issues for adults and children, for example, regarding who makes the decision to have the BAHA and who decides when to stop using it (see Nelissen *et al.*[17]).

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TABLE I
CROSS-SECTIONAL AND RETROSPECTIVE STUDIES INTO PATIENT SATISFACTION WITH BONE-ANCHORED HEARING AIDS

Study (y)	Participants & setting	Measures	Key findings
Badran *et al*. (2006)[36]	Chester, UK: 167 participants received BAHA 1991–2004; participants younger than 16 y & with a BAHA for < 6 mon excluded; questionnaire sent to 152, 117 responses (77%), mean age 57.2 y (range 16–90 y)	EMSQ[30,37] – requires patient to rate hearing aid on a range of factors including how often & for how long they use device; satisfaction with aid in various situations; overall satisfaction	95 (81%) wore aid every day, 78% for > 8 h/day; 82 (70%) had improved QoL after BAHA; 89% rated overall satisfaction as ≥ 6 (median 9); talking to one person – 51% rated as excellent, 34% as very good; talking in groups, poorer – 11% excellent, 34% very good; reported as 'better than previous aid' by > 50% in each subcategory; speech understanding worse, but 46% rated as better than previous aid
Bance *et al*. (2002)[38]	Canada: compared function of BAHA with conventional ACHAs; 16/17 participants aged 16–67 y in hearing aid group had had a BAHA for ≥ 4 mon – 17th recruited before BAHA surgery so had an ACHA only; all had profuse drainage from CSOM	SPQ[39] – measures perceived communicative performance in social, occupational & home environments; MOS SF-36[40] – yields scores for physical functioning, role limitations due to physical & emotional health, energy or fatigue, emotional well-being, social functioning, pain, & general health; asked to complete questionnaires for both ACHA & BAHA at home (so would appear to be retrospective for ACHA)	SPQ, no difference between ACHA & BAHA groups; both, 40% reported difficulty at home when speaker in another room, in social environment when speaker in noisy or reverberant setting, & in occupational environment when noisy site or using phone; MOS SF-36, no differences between ACHA & BAHA groups
Barbara *et al*. (2010)[41]	Italy: 30 participants received a BAHA in 2005–2009 (mean age 52 y, range 12–74 y); 6 excluded, 24 evaluated – 17 bilateral C/MHL, 7 unilateral profound SNHL	Hearing Handicap Inventory – designed to allow clinician to assess patient's difficulty in communicating in domestic, working & social environments; no score given; Client Oriented Scale of Improvement – assesses hearing improvement across five situations; GBI[42] – contains 4 domains (total score, general satisfaction, social benefit, physical benefit); score ranges from −100 (total deterioration) to 100 (total benefit) after surgery; EMSQ	Findings unclear: were the questionnaires presented both pre- & post-implantation, or just post-implantation?
de Wolf *et al*. (2009)[43]	Nijmegen, the Netherlands: questionnaire to 211 BAHA users aged > 18 y with C/MHL; returned by 135; examined by age group, 18–40 y ($n = 29$), 41–60 y ($n = 64$); > 60 y ($n = 42$)	IOI-HA[44] – brief questionnaire; 7 questions on use, benefit, residual limitation in activity, satisfaction, residual participation restriction, impact on others & QoL	Over 80% of 2 younger groups used for > 8 h/day; age > 60 y, 71% used for > 8 h/day; age 18–40 y, 96% at least moderate benefit in situations where 'wanted to hear better' (age 41–60 y, 92%; age > 60 y, 88%); Nearly all participants thought BAHA 'worth the trouble'; > 70%, BAHA did not restrict participation, or only restricted slightly; cumulative IOI-HA score appears negatively affected by age, but seems due to larger SNHL rather than age
de Wolf *et al*. (2010)[45]	Nijmegen, the Netherlands: participants aged ≥ 60 y, fitted with BAHA in 1990–2007; questionnaire sent to 168 participants with bilateral C/MHL who had used BAHA for ≥ 1 y; response rate 80% ($n = 134$), mean age 75 y (range 62–93 y)	GBI, APHAB[23]; APHAB - 3 subscales, speech understanding in various everyday situations; 4th subscale, sound aversiveness; each item rated according to difficulties with & without aid; Nijmegen Cochlear Implant Questionnaire[46] – addresses domains of physical, psychological & social functioning; Hearing Handicap Inventory for the Elderly[29] – assesses emotional & social & situational consequences of hearing loss	Satisfaction shown by recommending BAHA to a peer (90%), willingness to pay for BAHA (71%), choosing BAHA again (92%); GBI – 34%, overall benefit with BAHA compared with previous aid (2%, deterioration; 64%, no difference)
Dutt *et al*. (2002)[47]	Birmingham, UK: 312 participants (242 adults, 109 children) used BAHA for minimum 6 mon; 277 responded; implantation in 1988–2000	GBI + 4 questions related to BAHA success & VAS assessing state of health pre- & post-BAHA	74% 'would encourage others' to have BAHA; all GBI medians for the 18 items were in the 3–5 range (5-point scales used for item responses, pre-transposition to + 100 to −100 scale for overall score); 3 = 'no change', 5 = 'great or moderate success'

Continued

Table I *Continued*

Study (y)	Participants & setting	Measures	Key findings
Dutt *et al*. (2002)[48]	Birmingham, UK: 15 participants with bilateral BAHA	GBI	Bilateral aids improved 'general well-being' & 'state of health'
Dutt *et al*. (2002)[37]	Birmingham, UK: questionnaires sent to 312 people who were implanted in 1988–1999 & had ≥ 6-mon experience with BAHA; responses from 227 (73%) – 187 adults, 40 children (< 16 y)	EMSQ	Majority (93%) found BAHA useful for > 8 h/day, 93% 'for every day of the week'; 81% satisfied with amplification, 76% found BAHA 'quite satisfactory' to 'very satisfactory' when listening to radio or TV; 74% 'pleased with BAHA when listening to music'; 84% high satisfaction for conversation with one person in quiet, 67% high satisfaction for 'conversation with two or three people in quiet surroundings', 25% & 18% reported 'passable' for conversation with one person or a group of people in noise, respectively; 38% 'satisfied with BAHA during conversation with one person in a noisy environment', 50% rated BAHA unsatisfactory for 'speech in noise with a group of people'
McDermott *et al*. (2002)[49] (paper from same study as Dutt *et al*.[37])	See Dutt *et al*.[37]	Nijmegen questionnaire[35] – participants compared BAHA to previous conventional air conduction or bone conduction aid	79% rated sound quality as most outstanding feature of BAHA; 72%, pleased with fewer ear infections; 79%, 'speech in quiet surroundings' improved; 59%, 'speech in noisy environment' improved; 20%, visibility was the most negative aspect; 23%, 'speech in noise' & the number of visits to ENT were the worst aspects
Fuchsmann *et al*. (2010)[50]	Lyon, France: participants with bilateral CHL due to congenital aural atresia with unilateral BAHA; 16 records analysed from 1995 to 2007; average age at fitting, 19.5 y (range 4.5–50 y); average age at study, 23 y (range 8–51 y); of 15 participants still using BAHA, 12 completed questionnaires (80%)	APHAB & 'ease of use', 'daily utilisation period', 'satisfaction rating' regarding 'improvement in QoL', overall satisfaction, 'improvement in sound localisation', aesthetic satisfaction	Average use > 8 h/day for 92% (11); overall satisfaction, excellent (median 9 on 1–10 scale); 'improvement in QoL', excellent (median 9); aesthetics, good (median 7); sound localisation, median 6; all reported 'improvement in comprehension with the BAHA when talking to 1 person in silent conditions; 11 participants, improvement when listening to music, radio & TV; 50% satisfied 'in group situations'
Gardell *et al*. (2015)[51]	Odense, Denmark: participants had BAHA surgery in 1992–2013; 104 of 130 (80%) responded; mean age 60 y (range 6–93 y)	Satisfaction with Amplification in Daily Life questions from the Hearing Aid Research Lab (University of Memphis)[52] & questions developed by Rasmussen *et al*.[53]	9 had implant removed (2 complications, 4 dissatisfaction, 1 did not need after surgery, 2 unknown reasons); 3 had implant but not using – dissatisfied with sound; 91/104 (88%) still used; of the 91, 84% used 7 days/wk, 71 (78%) used for > 8 h/day; 88% 'in best interest' to get BAHA, 63% 'more able to understand the people they spoke to most of the time', 48% 'content with the appearance of BAHA', 80% 'understood always/usually well' one-to-one, 'quiet surroundings', 33% understood always/usually well in one-to-one conversation in noisy surroundings, 25% understood always/usually well in group conversation
Gillett *et al*. (2006)[54]	Kent, UK: participants implanted in 1994–2003; age range at implantation: 6–88 y; commonest indication, CSOM; case note analysis of 63 participants; questionnaire to 59 who had worn for ≥ 6 mon; returned by 41(69%)	GBI; incidence of complications	BAHA improved 'QoL' (GBI scores, $p < 0.001$); provides GBI scores in detail for each item at the Kent site & the large Birmingham centre (data from Proops[55])

Håkansson *et al.* (1990)[12]	Gothenburg, Sweden: 147 participants received BAHA (HC-200) in 1977–1987; none lost to follow-up; mean age 50.8 y (SD 17.4; range 5–82 y); most with C/MHL (CSOM, chronic adhesive otitis media and/or external otitis, 107; external ear canal and/or ossicular malformation, 24; ossicular osteosclerosis, 9); 7, SNHL only; previously, 49 had air conduction aids, 80 had bone conduction aids, 13 had both, 5 had none	Post-surgical assessment of tissue around abutment at 1, 3, 6 mon & every 6 mon thereafter; however, no information about time point for questionnaire measures (& no indication of multiple assessments) so would appear to be assessed at a single time point; participants were asked to rate hearing & comfort when using BAHA compared with their old aid; comfort 'means how pleasant it is, in general terms, to use the device, i.e. including both wearing comfort and sound comfort', hearing 'means, in general terms, how the patients experience the hearing situation in daily life'; asked to rate whether new device better, worse, or no difference compared with old device; also questionnaire asked 'to compare aspects such as sound quality, wearing comfort, status of ear infections, aesthetic appearance, ease of handling … performance of the HC-200 under various listening conditions'	$n = 146$ (1 surgical complication); hearing –improved in 81%, worse in 12%, no difference in 7%; comfort improved in 88%, worse in 5%, no difference in 7%; questionnaire (n appears to be only 51) – 24 previously had an ACHA, 27 previously had a BCHA; > 90% used a BAHA for > 8 h/day; for the BCHA group, significant difference in number of 'improved' compared with number of 'worse' & 'no difference' (sign test, $p < 0.05$) for sound quality, aesthetic appearance, practical handling, wearing comfort; for ACHA group, only significant difference was improvement for ear infection (not significant for BCHA); average overall satisfaction 'slightly above 9' (1, dissatisfaction; 10, satisfaction)
Ho *et al.* (2009)[56]	Birmingham, UK: 50 participants surveyed, mixed deafness, BAHA for > 6 mon; Cordelle device (body worn); 33 responses (response rate 66%), median age 77 y (range 52–95 y)	EMSQ	84% used BAHA every day, 79% for > 8 h/day; happy with device in quiet situations & one-to-one, less so in noisy/group situations
Mace *et al.* (2009)[57]	Glasgow, UK: participants receiving BAHA in 1996–2006; 60 identified, response rate 63% ($n = 38$); mean age 55 y (range 21–82 y)	EMSQ, GBI	33 (87%) used 7 days/wk, 32 (85%) used > 8 h/day; overall satisfaction, excellent (median score 10/10); 91% (35) reported working very well/excellently when talking to 1 person; only 17 (44%) reported working very well/excellently with group; 75%, better than previous aid; 71%, improved QoL; 82%, speech comprehension & sound comfort better with BAHA; 68%, looked better & 'easier to handle' than conventional hearing aid
McLarnon *et al.* (2004)[58]	Newcastle-upon-Tyne, UK: questionnaires sent to 94 participants fitted with BAHA ≥ 3 mon previously; mean age 49 y; responses from 69 (73%); subgroups – 3 acoustic neuroma, 36 discharging mastoid cavity, 9 chronic active otitis media, 3 otosclerosis, 10 congenital atresia, 8 miscellaneous	GBI	Presented findings by subgroup; discussed differences between subgroups but not statistically analysed; all subgroups reported benefit of having BAHA, total GBI scores were at least + 24 for all subgroups
McNeil *et al.* (2011)[59]	Nova Scotia, Canada: 91 of 161 patients who had received BAHA responded (56.5%); 73 had partner; 71 had pre- & post-BAHA audiograms – of these 9 had SSD; analysis focussed on the responses of the partners of these 71 patients	Modified Hearing Handicap Inventory for Adult Screening – partner rated participant's response to particular scenarios before & after the BAHA	Partners reported significant improvement in 'handicap'; over the 710 scenarios (71 partners, 10 scenarios each), pre-BAHA deficit in 548 (77%); where deficit pre-BAHA, noted improvement in 85% (no change in 14.6%, deterioration in 0.4%); most likely to note improvement for listening to radio or TV (84%), in restaurants (75%) & in work environments (75%)
Nelissen *et al.* (2013)[60]	Nijmegen, Netherlands: 31 participants (24 C/MHL, 7 SSD); 25 responded to questionnaire at 2.7–16.5 mon post-implantation; average age at implantation, 55 y (range 18–74 y)	GBI	23/25 (92%) positive overall scores, all mean scores were positive; however, for social & physical domains, median score was 0 (indicates neither benefit nor worsening); for < 6 mon post-surgery ($n = 11$), GBI median 32.4; for ≥ 6 mon post-surgery, GBI median 18.1 (significantly different)

Continued

Table I *Continued*

Study (y)	Participants & setting	Measures	Key findings
Nelissen *et al.* (2015)[17]	Nijmegen, Netherlands: 53 participants (data for 51); congenital unilateral hearing loss, treated with BAHA ('percutaneous bone conduction device') in 1998–2011; all, ≥ 1-y experience with device; mean age at surgery, 17 y (range 4–61 y); phone interviews	SSQ[19] – assesses hearing disability in range of contexts	56.6% still used after mean of 7 y, 23% only used 'sporadically' (generally < 1 day/wk); users, older at implantation than non-users (22 y *vs* 10 y); mean age when stopped, 15 y (after mean time of usage, 4.8 y); reasons for stopping, excess background noise/not receiving enough benefit; 1 stopped for aesthetic reasons; 1 for practical reasons (at sports academy); SSQ sent to 34 participants still using device/stopped in year before interview (23 users, 7 sporadic users, 4 stopped in year before interview); 26 responses; users, significant improvements in speech & spatial domains & non-significant improvement in 'qualities of hearing' domain (aided *vs* non-aided); non-users, no significant differences (aided *vs* unaided) in any domain; suggested that for children BAHAs were chosen by parents who might overestimate problems or aid solves problems in development & when they have only a small 'handicap' they want to fit in with peers
Rasmussen *et al.* (2012)[53]	Denmark: received BAHA in 1989–2007; 57 responses, median age 55.5 y (of 66 possible participants, age range 7–88 y, median age 53.6 y, 6 aged < 18 y); most, mixed CHL & SNHL in both ears/CHL in both ears	'Included were features from … the Nijmegen group questionnaire, the [GBI] & the [EMSQ]'	50 patients (88%) used BAHA 7 days/wk, 46 (81%) used for > 8 h/day; 91% reported usually or always understanding one-to-one conversations in quiet surroundings, 46% in noisy surroundings, 25% could understand conversation in group settings; 86% reported being satisfied or very satisfied with the device overall; when asked whether they would have a BAHA with their current knowledge, 74% said yes (16% 'maybe', 5% 'probably not', 3 'undecided', none said 'no'); most (82.5%) were satisfied with the cosmetic appearance; a primary factor in dissatisfaction was wind noise annoyance (experienced by 70%)
Saroul *et al.* (2011)[61]	France: phone survey, patients implanted in 2005–2008; of 26 potential participants (median age 46.5 y, range 7–77 y), 22 participants – 12 UTD, 10 CHL	Derived from EMSQ	UTD group – 67% used BAHA every day, 75% for > 8 h/day, 17% ($n = 2$) did not use the device; improvement with device reported as moderate–good generally, poorer for group contexts; CHL group – 80% used the device for > 8 h/day (60% used the device every day), 90% rated the BAHA good or excellent in 'one-to-one conversation' *vs* 20% in 'group discussion'; both groups – 76% reported finding the BAHA 'discreet' (none reported being bothered by the appearance – although 19% reported finding it 'not very discreet' & 58% preferred its appearance to a traditional aid
Schrøder *et al.* (2010)[8]	Denmark: 21 of 23 patients with SSD responded; median age 55 y (range 24–66 y); 15 had had acoustic neuroma surgery, 6 had other reasons	Questionnaire appears to have been developed for study, to what extent used BAHA & how it alleviated their 'handicap' in various situations	95% still used after ≥ 6 mon (of these 81% for ≥ 8 h/day); median use, 10 h/day (range 1–24 h/day); 65% considered overall effect to be 'significant' (58% reported hearing significantly improved when 2 people, quiet surroundings; 40% significantly improved in noisy situations); few felt sound localisation 'significantly' improved (20%); 100% of former CROS users preferred BAHA ($n = 12$); all participants would recommend BAHA to others

Snik *et al*. (1992)[13]	12 participants provided with BAHA in Netherlands – 6 Eindhoven, 6 Nijmegen: all, recurrent otorrhoea & mixed hearing loss; 5 previously wore BTE aid, 7 had worn CBCHA; initially given HC200 but rejected for insufficient gain; after ≥ 3 wk, 5 chose Philips S1594, 6 chose Danavox 107–2 (body worn); 1 declined a body-worn aid; HC200 connected to BTE CROS (Oticon E39PL)	Questionnaire: presented after ≥ 4 mon of daily BAHA use; asked about former aid & new BAHA; questions about daily use (h), skin irritation, recognition of speech in quiet & noisy situations, comfort; each rated on 1–10 scale; 3 scores – SQ, SN, comfort score	Presented as change scores (BAHA score minus either CBCHA or BTE score); for previous CBCHA participants, change in SQ & SN was near 0 or positive except for 1 participant, all had change in comfort of 0 or positive; for previous BTE participants, 2 had worse SN & SQ with BAHA (2 had improved SN & SQ, 1 little change), comfort – 3 rated as better, 2 as worse; no statistical tests, very small sample; conclusion – those who previously had CBCHA had 'similar or better' results with BAHA, less clear for those who had BTE previously
Stephens *et al*. (1996)[62]	2 UK sites: Cardiff – 8 participants responded (of 9 invited – 89% response rate), implanted in 1989–1993, mean age 32.4 y (SD 20.2); Birmingham – 61 invited, 31 replied (response rate 51%), mean age 45.9 y (SD 21.0)	Participants were sent the Benefit/Problem Questionnaire[63] – 'please make a list of the benefits which you have had from wearing your [BAHA]. List these in order of importance starting with the biggest benefit. Write down as many as you can think of' & then 'Please make a list of all the problems you have had from wearing your [BAHA]. List these in order of importance starting with the biggest problem. Write down as many as you can think of'	165 benefits & 105 problems listed in total; most common benefits, better hearing (46%), ease of use (38%), better clarity (33%), less noticeable (31%), more confident (28%), more comfortable (21%), fewer infections (18%); most common shortcomings, telephone (23%), wind noise (21%), speech in noise (21%), easily dislodged (21%), size (15%)
Tjellström *et al*. (1995)[64]	Multicentre study – 122 participants from Gothenburg (77), New York (9), Minneapolis (2), Stockholm (10), Skövde (4), Malmö (12), Lund (2), Glostrup (6): 103 CSOM, 19 congenital malformation; average age 53.5 y (SD 14.7), average follow-up time 5.6 y (range 4–14 y)	Completed 3 audiometric tests & a questionnaire – few details provided for questionnaire; included score of overall satisfaction with BAHA from 1 to 10 (1, dissatisfaction; 10, high satisfaction); other items appear to ask about usage time, advantages of BAHA	Average* overall satisfaction score 8.7 (SD 1.72), range 3–10; most (86.6%) used device > 8 h/day; participants reported device offering advantages such as 'improved speech intelligibility, better sound comfort, less pressure on the head, less skin irritation, easy handling, & greater cosmetic acceptability' (unclear what the comparison was – likely to be a traditional bone conduction device); states that 55/67 participants reported the BAHA (HC200) gave improved comfort compared with old bone conduction device (unclear whether only 67 responded or only 67 previously had a bone conduction device)
Tringali *et al*. (2008)[65]	France: 170/ 231 (73.6%) responded; average age at fitting, 56 y; 118 participants with SSD (69.4%), 52 with C/MHL	Questionnaire – ease of use, daily utilisation period, & satisfaction rating (1–10) to evaluate QoL improvement, overall satisfaction, improvement in sound localisation, aesthetic satisfaction	Average* utilisation – > 8 h/day in 48.5%, > 4 h/day in 81.5%; average* QoL – 'very good' (CHL group, 8.16) & 'good' (SSD group, 6.35), group scores significantly different ($p < 0.0001$); general satisfaction – 8.11 for CHL, 6.26 for SSD (significantly different, $p < 0.0001$); aesthetics, good ratings in both groups, not significantly different (CHL, 7.3; SSD, 6.66); localisation, CHL 6.05, SSD 4.85 ($p < 0.01$)
Wazen *et al*. (2008)[66]	USA: identified 218 patients implanted in 1998–2007–114, single-sided deafness; 104, CHL; age range 6–92 y (mean 56.5 y); 106 (49%) completed questionnaire (phone or on-site interview)	'Patient satisfaction questionnaire' – 13 items about usage & level of satisfaction in various contexts	77% were satisfied with the device, 92% used it regularly; on average, used for 10.1 h/day, 5.6 day/wk

*Assumed to indicate the arithmetic mean. Y = years; mon = months; BAHA = bone-anchored hearing aid; EMSQ = Entific Medical Systems (Nobel Biocare) questionnaire; h = hours; QoL = quality of life; ACHA = air conduction hearing aid; CSOM = chronic suppurative otitis media; SPQ = Sanders' Profile Questionnaire; MOS SF-36 = Medical Outcomes Study Short Form 36; C/MHL = conductive/mixed hearing loss; SNHL = sensorineural hearing loss; IOI-HA = International Outcome Inventory for Hearing Aids; GBI = Glasgow Benefit Inventory; APHAB = Abbreviated Profile of Hearing Aid Benefit; VAS = visual analogue scale; CHL = conductive hearing loss; TV = television; wk = weeks; SD = standard deviation; BCHA = bone conduction hearing aid (not bone anchored); SSD = single-sided deafness; SSQ = Speech, Spatial and Qualities of Hearing Scale; UTD = unilateral total deafness; CROS = contralateral wireless routing of signals hearing aid; CBCHA = conventional bone conduction hearing aid; BTE = behind the ear; SQ = speech recognition in quiet; SN = speech recognition in noise

Finally, all of the retrospective studies were limited by only including people who received a BAHA. Thus, no information was gained on patient satisfaction in those who declined a BAHA. It is possible that, despite a high level of satisfaction in those who received a BAHA, patients who decline a BAHA could experience similar or higher satisfaction levels. A comparison of patients with and without a BAHA is therefore needed to control for general levels of satisfaction.

Other study designs. House *et al.* administered postal questionnaires to 126 people with unilateral deafness who had received a BAHA (88 had undergone translabyrinthine craniotomy or another skull procedure, 38 had severe or profound SNHL with other aetiologies) and to 126 control participants who had not received a BAHA after undergoing translabyrinthine craniotomy.[18] Responses were received from 68 participants with a BAHA and 61 controls. In the BAHA group, 83 per cent indicated that they were satisfied (or very satisfied) with the BAHA. However, scores on the Speech, Spatial and Qualities of Hearing Scale,[19] which assesses perceived hearing ability in a range of contexts, did not differ between the two groups.[18] Unfortunately, control participants were not asked how satisfied they were with their hearing.

A small number of prospective studies of patient satisfaction with BAHA were identified. Pai *et al.* compared pre-operative and post-operative (at over 6 months) Speech, Spatial and Qualities of Hearing Scale scores in 25 adults with acquired unilateral profound hearing loss.[20] Participants reported significant improvements across the Speech, Spatial and Qualities of Hearing Scale, and all reported improvements in speech hearing in challenging situations. Twenty-three (92 per cent) reported improved spatial hearing. In a small study of 10 adults with unilateral deafness, participants were first fitted with a contralateral routing of signals hearing aid and assessed after 1 month. All decided that a contralateral wireless routing of signals hearing aid provided insufficient benefit and elected to have a BAHA. One month later, participants reported improvements in 'listening in reverberant conditions,' 'listening in background noise' and 'ease of conversation' with the BAHA compared with the contralateral wireless routing of signals hearing aid, although no statistical tests were performed.[21]

Hol *et al.* (2004) tested 20 patients with unilateral inner ear deafness at baseline, 1 month after being fitted with a conventional contralateral wireless routing of signals hearing aid, and then 1 month after being fitted with a BAHA.[22] Using a Dutch version of the Abbreviated Profile of Hearing Aid Benefit (APHAB),[23] participants scored the BAHA as the most beneficial option. Hol *et al.* (2005) continued this work by adding nine participants to the 2004 sample.[24] Scores on the APHAB domains 'ease of communication', 'background noise' and 'reverberation' remained significantly better than unaided scores at one year. Scores on the Glasgow Hearing Aid Benefit Profile (GHABP)[25] showed that while satisfaction with BAHA declined over one year, there was higher satisfaction with BAHA at six weeks and one year compared with a contralateral wireless routing of signals hearing aid.[24]

The same group administered a prospective postal questionnaire to 56 adult patients who received a BAHA for acquired conductive or mixed hearing loss.[26] Thirty-six of these patients had previously used air conduction hearing aids and 20 had previously used bone conduction hearing aids. While scores on the EuroQol-5 Dimension questionnaire (EQ-5D)[27] and the Medical Outcomes Study 36-Item Short Form Survey ('SF-36')[28] showed little change from pre-surgery to six months post-surgery, significant improvements were seen on both the disability and handicap scales of the Hearing Handicap and Disability Inventory for the Elderly,[29] (effect sizes ≥ 0.79).[26] Before implantation, 78 per cent of air conduction hearing aid users and 90 per cent of bone conduction hearing aid users reported using their aid for 8 or more hours per day; after implantation, all 56 (100 per cent) reported using BAHA for 8 or more hours per day, implying a high satisfaction level. Similarly, in Powell and colleagues' study of 20 paediatric patients in Birmingham, UK, all participants used their BAHA for over 8 hours per day at 6 months after fitting; only 1 participant was less satisfied with the BAHA than with their previous aid.[30]

Two further small prospective studies were reported by Newman *et al.* ($n = 8$) and Wazen *et al.* ($n = 9$).[31,32] In the former, 50 per cent of participants (with unilateral SNHL) reported a significant improvement on the global benefit score of the APHAB at 6 months, rising to 75 per cent at 18 months. While 7 of the 8 participants initially used the BAHA every day, at 18 months daily use was reported by only 2. However, 7 participants said that they would undergo BAHA surgery again.[31] Wazen *et al.* reported that patients with unilateral conductive or mixed hearing loss reported having a lower 'handicap' (i.e. impact of hearing loss) with the BAHA compared with pre-implantation.[32] However, both of these studies have particularly small sample sizes, which limited the statistical analysis and generalisability of findings.

In a study by Mylanus *et al.*, people who had previously used a bone conduction hearing aid were more satisfied with a BAHA at five months post-surgery than those who had previously used an air conduction hearing aid.[33] Participants rated their hearing aid for speech recognition in quiet and noise, quality of sound, and comfort. For the bone conduction hearing aid group ($n = 49$), the BAHA had a higher rating than the previous aid in all categories, whereas differences between ratings did not reach statistical significance for the air conduction hearing aid group ($n = 16$). However, the study may have been underpowered

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to detect a difference in the smaller air conduction hearing aid group. All participants who had previously used a bone conduction hearing aid reported using the BAHA for more than 8 hours per day, as did 15 of the 16 participants who had previously used an air conduction hearing aid. A problem with this study is that scores from the pre-surgery questionnaire were provided to participants at the second completion of the questionnaire, making findings particularly vulnerable to confirmation bias.

Finally, Hol *et al*. conducted long-term follow-up research.[34] In a 1998 study, 33 patients with BAHA completed the Nijmegen questionnaire; 9 years later, this was again presented to 27 of the original cohort.[34,35] In the initial study, 27 (82 per cent of 33) preferred the BAHA to their previous aid; 9 years later, 24 (89 per cent of 27) preferred the BAHA.

Discussion

The evidence reviewed suggests that BAHA uptake by eligible patients is low, and few studies have examined patients' reasons for declining this treatment. Possible reasons for declining BAHA are limited perceived benefits, concerns about surgery, preference for an alternative device, aesthetic concerns and the treatment cost. However, studies primarily aimed at exploring and understanding patients' reasons for declining (or accepting) BAHA were not identified.

In general, the large body of research into patient satisfaction and subjective hearing improvement after receiving BAHA indicates that patients experience benefits with BAHAs and are satisfied with their aids. However, many of these studies had small samples, thus limiting generalisability and possibilities for statistical analysis, and most were conducted retrospectively with people who had opted for BAHAs. This means that the findings depend on patients' recall of their hearing experiences prior to receiving their BAHA, and patients who chose not to have a BAHA tend not to be followed up as a comparison group. It is therefore possible that individuals who do not have a BAHA fitted are just as satisfied with their aid and/or hearing as those who do. In addition, many studies used a mixture of paediatric and adult populations. It is likely that developmental stage will influence responses and children may complete the questionnaires with parental support; in the latter case, the response may not accurately represent the patient's perspective. Mixing paediatric and adult samples therefore makes it difficult to interpret findings.

In the single case–control study identified, there was no significant difference between BAHA users and controls in terms of perceived hearing ability.[18] Nevertheless, findings from prospective studies, in which patients are followed over time (ideally comparing pre- and post-operative scores), suggest that patients do experience benefits with BAHA. However, they may be biased towards perceiving their BAHA positively to avoid cognitive dissonance or their adaptation to their hearing problem may change over time. Prospective research is therefore needed that compares people who received a BAHA with those who chose not to.

There is a suggestion in some studies that people with unilateral impairment had a greater preference for BAHA compared with those with bilateral hearing loss[6] and people with single-sided deafness seemed to be more likely than those with mixed and/or conductive hearing loss to try a bone conduction device.[10] Also, people seemed to be more positive about a BAHA if they had previously used a bone conduction hearing aid rather than an air conduction hearing aid.[12,13] However, there is a need for more rigorous research into these possibilities.

Future research should focus on two areas. Firstly, further quantitative research needs to be conducted to compare satisfaction in patients who receive BAHA and in those who opt for an alternative device or no treatment at all. This would enable health professionals to provide patients with clearer advice about satisfaction levels for people who choose to have, or not to have, a BAHA. Secondly, it is important to conduct research which aims to understand why patients decline (or accept) a BAHA. Qualitative research in which participants are encouraged to talk openly about their experiences, perceptions and reasons for choosing to have, or not to have, a BAHA would be appropriate. A clearer understanding of the issues considered by patients when deciding whether to have a BAHA will enable health professionals to address their uncertainties and concerns.

Conclusion

At present, the evidence base for understanding why people decline BAHAs, and for establishing patient satisfaction with BAHAs, is limited. Where research has been conducted, study designs have generally been weak, so firm conclusions cannot be reached. Good quality research into the reasons for accepting or declining BAHA and establishing patient satisfaction levels in those receiving a BAHA is needed to enable healthcare professionals to provide appropriate support to patients offered a BAHA. In-depth research aimed at understanding the individual reasons for accepting or declining BAHA is necessary, together with good quality prospective studies that include both participants who accept and those who decline a BAHA.

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