239b

Bone-anchored hearing aids

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SEARCH STRATEGY

The data in this chapter are supported by Premedline and Medline searches using the key words bone-conduction hearing aids and/or bone-anchored hearing aid.

DEFINITION

Bone-anchored hearing aid (BAHA) is the registered trademark of a bone-conduction hearing aid system currently manufactured by Cochlear™. It consists of a titanium screw that becomes osseointegrated in the skull bone behind the ear. To this a transcutaneous titanium abutment is subsequently fitted and to which a bone-conduction vibrator can be coupled (**Figures 239b.1** and **239b.2**). Since first described by Tjellstrom *et al.* in 1981,[1] the design of the implant and the bone-conduction aid has been modified, but not radically. The ear-level vibrators currently available are more powerful than the previous Superbass HC220 body-level aid.[2] All aids now have a snap coupling to attach it to the abutment, while a loop system has also been developed.

All the alternative commercially available bone-conduction aids require to be fitted to a headband, which is uncomfortable and unsightly. The BAHA can also be fitted to a headband and this is the method recommended in infants with congenital atresias until they are old enough for surgery at about three years of age.

INDICATIONS FOR BONE-CONDUCTION AIDS

There is one absolute indication for a bone-conduction hearing aid; bilateral canal atresia that prevents the

Figure 239b.1 The three-component parts of the BAHA Compact: **(a)** the screw; **(b)** the abutment and **(c)** an ear-level sound vibrator. The design of the snap coupling can be seen. Figure provided by Cochlear Ltd., Lane Cove, Australia.

insertion of a satisfactory ear mould for an air-conduction aid. In the UK, such bilateral atresias occur in around one in 10,000 live births. The majority of bilateral atretic ear canal problems are part of a syndrome complex (e.g. Treacher Collins, Goldenhaar's syndromes).[3] Unilateral atresias are more frequent but do not usually require aiding. Surgical attempts to reconstruct the pinna for cosmetic reasons can sometimes also create a canal into which an ear mould can be fitted. Alternatively, and particularly if a BAHA is being provided, further titanium pegs can be inserted for the attachment of an ear prosthesis.

It is generally accepted that because of their multiple abnormalities, children with congenital pinna abnormalities should be managed by a multidisciplinary team, that in addition to otorhinolaryngology and maxillofacial surgeons includes audiologist, maxillofacial prosthetists and speech therapists.[4, 5] [*]

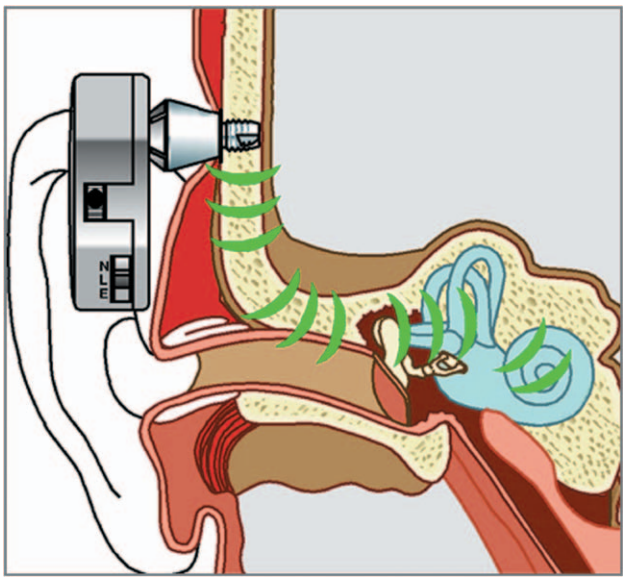

Figure 239b.2 Diagram showing the three-component parts of the BAHA inserted into the skull, which it vibrates to allow sound to be heard by bone conduction. Figure provided by Cochlear Ltd., Lane Cove, Australia.

Bilateral canal atresias can also be acquired (Chapter 236g, Acquired atresia of the external ear), most commonly following chronic otitis externa. Again surgery is an option to make the wearing of an ear mould practicable.

There are several other groups for whom an air-conduction aid is a possibility, but who prefer to use a bone-conduction aid. By far the largest group that have conventionally chosen to do this are those with bilateral discharging ears due to active chronic otitis media. Some prefer to persist with an air-conduction aid, but are troubled by ear mould problems and discharge. Some of these patients have an open mastoid cavity that can make the good fitting of an ear mould without feedback difficult. Here the wearing of an ear mould, particularly with a tight fit to achieve a satisfactory gain, can exacerbate the discharge, with consequent blockage of the mould and social embarrassment. However, in many the active chronic otitis media is unilateral and can be controlled by topical medication, by surgery and/or changing the air-conduction aid to the other ear.

Some clinicians advised individuals with inactive chronic otitis media that they cannot wear an air-conduction aid as this will stimulate activity. There is no evidence to support this advice, but it is often used as a lever to make reconstructive ear surgery more acceptable to the patient. Many patients with inactive chronic otitis media have been fitted with an air-conduction aid without the ear becoming active and even if this does happen they still find an air-conduction aid acceptable.

In most large BAHA series, the proportion of chronic otitis media patients to congenital conductive impairments is 3:1.[4, 6] [*]

Table 239b.1 summarizes the advantages and disadvantages of air-conduction aids, conventional bone-conduction aids and the BAHA.

ELIGIBILITY FOR A BAHA

The prime requirement is that there should be adequate bone-conduction, pure-tone thresholds. The manufacturers

Table 239b.1 Comparison of the advantages and disadvantages of different aids for a conductive hearing impairment.

	AC aid	BC aid with headband	BAHA
Cost	Large range	Modest	Expensive
Cosmesis	Reasonable	Poor	Reasonable
Comfort	Ear blocked	Painful	Very comfortable
Trial of aid	Easy	Easy	Needs another operation
Acoustic modifications available	Multiple	Limited	Limited
Complications	None	None	Infection around abutment

AC, air conduction; BAHA, bone-anchored hearing aids; BC, bone conduction.

state that the bone-conduction averaged over 0.5, 1, 2 and 3 kHz should be equal to or better than 45 dB HL for an ear-level aid and better than 58 dB HL for a body-level aid. These are very general guidelines. More specific, individual frequency guidelines are available for earlier models,[7] but not for the current models. From the information available,[8] the bone-conduction thresholds should be poorer at the high compared with the low frequencies. Fortunately, this is usually the case.

Many centres recommend preoperative speech audiometry to identify those with poor speech comprehension as they consider this to be a contraindication for implantation. Poor comprehension of speech must be rare unless there is a substantial sensorineural element to the impairment and in them the bone-conduction thresholds are unlikely to satisfy the criterion anyway. If the bone-conduction thresholds are adequate, the patient with poor speech discrimination still has to be managed with amplification and there is no reason why a BAHA should be poorer for them than any alternative form of amplification.

SURGICAL TECHNIQUE

Surgery can be performed under local or general anaesthetic. Inserting the titanium screw into the skull (**Figure 239b.3**) is a relatively simple surgical technique,[9] but it does require special instruments, particularly to tap the socket in the bone for the screw. The bone posterosuperior to the ear canal behind the pinna is usually of sufficient thickness over the age of three years to take an implant and allow osseointegration. In adults, but not children, most surgeons now use a one-stage procedure and fit the transcutaneous abutment at the same time rather than wait three months for osseointegration to occur before fitting it at a second operation. If a one-stage procedure is preferred, three months is also usually allowed before fitting the aid. The main surgical problem is to centre the abutment in thin, non-hair-bearing skin. Thin skin is necessary to lessen the risk of inflammation and crusting of exudate around the peg, while the lack of hair makes hygiene easier. Various grafts and flaps have been suggested to resolve this problem.

SURGICAL COMPLICATIONS

These are rare at the time of surgery, with damage to the dura in children with craniofacial abnormalities, especially when multiple abutments are being inserted for a prosthetic pinna, being the most common.

The most common long-term problem is crusting and inflammation around the peg, which sometimes progresses to granulation tissue. This occurs overall in approximately 8 percent of patients, in whom 6 percent are mild and 2 percent require outpatient hospital care.[6] [**] To lessen this potential problem, all patients should be instructed in local toilet techniques. These mirror the techniques for dental hygiene, including the use of floss and toothbrushes. If infection is considered to be a problem, topical antibiotic ointments can be used.

Osseointegration resulting in the screw falling out is uncommon (approximately 0.6 percent).[6] [**] More frequently (approximately 5 percent), the abutment works itself loose from the screw and has to be reattached.[6] [**] Obviously, the longer a patient has an abutment the more likely it is to become loose. Children are more liable to problems partly because many have craniofacial abnormalities that makes their skull bone thinner and also because they are more subject to trauma.[10] Some surgeons implant a reserve, second screw in children as a back up that can be used quickly.

OUTCOMES

Unilateral BAHA for patients with a bilateral conductive impairment

COMPARISON WITH CONVENTIONAL BONE-CONDUCTION AIDS

If a patient has previously used a conventional bone-conduction aid, they almost invariably prefer the BAHA because it is cosmetically more acceptable, more comfortable to wear and gives better, less distorted amplification.[6, 11, 12] [**]

The superior hearing is supported audiometrically by better aided thresholds, particularly at the higher frequencies[13] [***] and by better speech quality and intelligibility in quiet and noise.[14] [***]

COMPARISON WITH AN AIR-CONDUCTION AID

The acoustical benefit of a BAHA over a well-prescribed and fitted air-conduction aid is marginal when assessed both by audiometry[15] [***] and by patient report.[11] [**] In the latter study of 16 patients implanted with a BAHA, 38 percent used their BAHA alone, 31 percent used both their BAHA and their air-conduction aid and 31 percent used their air-conduction aid alone. Those that did not use their BAHA had poorer speech reception thresholds and discrimination with their BAHA. The majority of non-users had a mixed, severe or profound impairment, but there were others in this category who benefited. It has been suggested that those with a small air–bone gap are particularly likely to have a poorer outcome with a BAHA.[15] Though this may be the case on average, there are too many exceptions to support a rule.

Unfortunately, it must be concluded that at present it is not possible to predict preoperatively which patients with an existing air-conduction aid will get poorer benefit from a BAHA. The situation is compounded by the fact

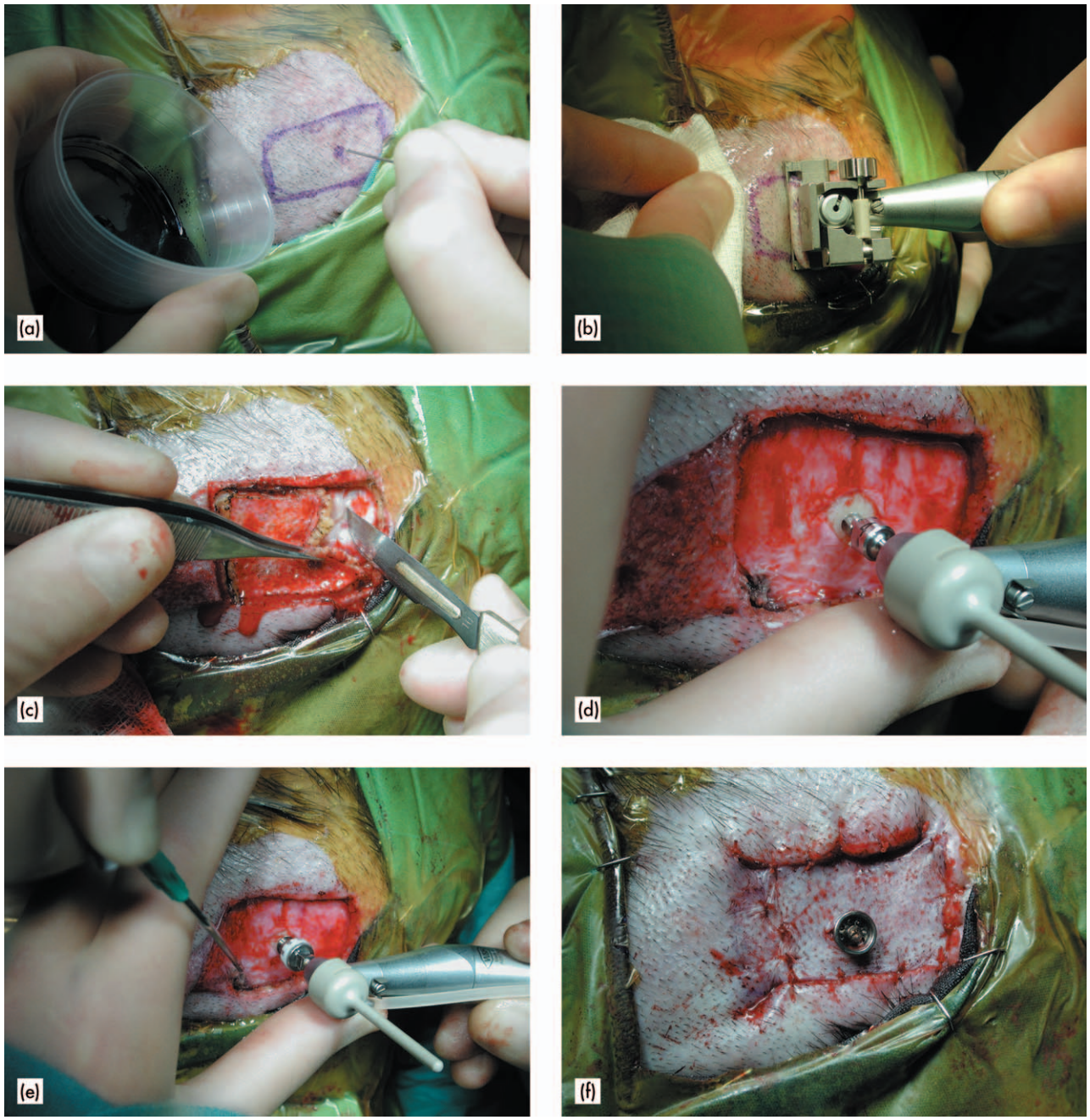

Figure 239b.3 **(a)** The site for the implant is identified behind the ear and marked. **(b)** A split thickness skin graft is raised using a custom-made dermatome. **(c)** The subcutaneous tissue is removed leaving the periosteum intact. **(d)** A countersunk drill is used to prepare the site to receive the implant. **(e)** The titanium implant is slowly inserted under constant irrigation to avoid burning the bone. **(f)** The split skin graft is retuned and fitted over the abutment.

that often patients are being asked to compare a monaural BAHA with binaural, air-conduction aids. In these circumstances, the proportion that report that their BAHA to be poorer is 31 percent for speech in quiet and 38 percent for speech in noise.[16, 17] [**]

Most patients who previously wore an air-conduction aid, but were troubled by a discharge, report that with a BAHA the discharge improved. Of those who previously had an air-conduction aid, 92 percent improved compared with 44 percent of those who previously had a bone-conduction aid.[6] [**] As the discharge would not be expected to lessen in those who previously used a bone-conduction aid, there is obviously a positive halo effect of having had an operation. However, if patients are asked about overall satisfaction with their BAHA in comparison with their air-conduction aid, 50 percent consider the BAHA superior, 25 percent to be no different and 25 percent to be poorer.[4] [**]

It is concluded that if a patient is benefiting acoustically from an air-conduction aid then the disability

from the wearing of an ear-mould has to be sufficiently great for a BAHA to be substituted as this may give poorer acoustical benefit. [Grade C]

Bilateral BAHA for patients with a bilateral conductive impairment

In those with a bilateral hearing impairment, binaural aiding is accepted as the ideal fitting for air-conduction aids because of better sound localization and central loudness summation. This would also appear to be the case with bilateral BAHA (bilateral BAHA compared with unilateral BAHA improved horizontal sound localization from 24 to 45 percent correct and gave central summation of 4 dB).[18] [**] How this relates to clinical benefit is variable with a third of patients using their second aid selectively, but most (approximately 80 percent) use both aids for sound localization tasks.[19] [**] Because a BAHA stimulates both cochlea, bilateral BAHAs will stimulate the auditory system in a very different way from bilateral air-conduction aids. The cues that are used centrally to enable spatial hearing will therefore be materially different with bilateral BAHAs. Whether the central auditory system can adapt to this and gain the same benefit as from binaural air-conduction aids is unlikely.

Unilateral BAHA for patients with a bilateral mixed impairment

Many of the patients with bilateral discharging ears due to chronic otitis media have a bilateral mixed hearing impairment, often with open mastoid cavities. This does not exclude them from being considered for an ear-level BAHA if the bone-conduction eligibility criteria are met, but it is likely that a body-worn sound processor would give greater benefit. If the patient has previously used a conventional bone-conduction aid, a body worn aid will be acceptable. This is less likely to be the case if they have previously used an air-conduction aid. Thus, provided a good acoustic seal can be achieved for the mould of an air-conduction aid, then changing to a BAHA might result in poorer hearing benefit.

Unilateral BAHA for patients with a unilateral conductive impairment

Whilst individuals with a bilateral impairment are those most disabled and request help, those with a unilateral conductive impairment often do report difficulties particularly with listening in noise on their poorer side. If reconstructive middle ear surgery is not acceptable, then an air-conduction aid can be provided. In a small proportion this will be rejected because of difficulties with the ear mould. In them a BAHA is an alternative, albeit it makes the assumption that it will preferentially stimulate the cochlea on the hearing-impaired side and not interfere with the hearing on the other side.

Small case series ($n = 6$ and 9) report audiometric improvement in those with a noncongenital conductive impairment of sound localization and speech recognition in noise with spatial separation of the sound sources.[20, 21] [**] Whether such benefit equates to the alternative of an air-conduction aid has not been shown.

Unilateral BAHA for patients with a bilateral sensorineural impairment

For the extremely rare individual with such severe problems with the ear mould (e.g. otitis externa) that makes it difficult to use an air-conduction aid, then a BAHA is an alternative. Understandably, only a few such patients have been reported and the BAHA does indeed overcome the ear mould problems, but often at the price of lesser audiometric benefit.[22] [**]

Unilateral BAHA for patients with a unilateral total impairment

The traditional way to aid such a patient is with a contralateral routing of sound (CROS) aid, but these give limited benefit because the good ear finds it difficult to separate out the two different sound inputs. A BAHA is likely to be subject to the same problem, albeit the good ear is not occluded with an ear mould. A meta-analysis of four sequential crossover studies[23] [***] suggest that like a CROS aid there is a paucity of good evidence to support the use of a BAHA in acquired unilateral total sensorineural hearing impairments.

Generic outcomes

COMPARISON OF BAHA WITH PREVIOUS HEARING AIDS

Because the fitting of a BAHA entails surgery, there will inevitably be a 'halo' effect when patients report the benefit of this type of aid. Indeed this is confirmed by the lesser report of benefit five to ten years after fitting, that cannot be solely attributed to a deterioration in hearing thresholds.[13] [**]

The generic Glasgow Hearing Aid Benefit Profile has been used to compare the benefit and residual disability between a BAHA and the patient's previous aid.[24] In this study, the proportion of previous bone- to air-conduction aid users was unfortunately not reported. Although the BAHA was reported to be materially superior on both the above outcomes, the benefit from a BAHA was almost certainly overestimated, as the degree of satisfaction expressed was in the upper 95th percentile of the reported benefit for all types of aid.

COMPARISON OF BAHA WITH OTHER OTOLOGICAL PROCEDURES

The Glasgow Benefit Inventory allows the overall value of different otological procedures to be compared. The BAHA mean score[25] of +37 confidence interval (CI 27,48) makes it comparable to the benefit of middle ear surgery and conventional air-conduction hearing aids. The benefit was greatest for those with congenital atresias that had previously used a bone-conduction aid.

Best clinical practice

The following points are made without reference to relative costs.

- ✓ Patients who have previously used a conventional bone-conduction aid on a headband are those most likely to acoustically benefit from a BAHA. This should be considered alongside middle ear surgery or the use of a conventional air-conduction aid in such patients. [Grade B]
- ✓ Acoustical benefit from a BAHA in comparison to a conventional air-conduction aid is variable and cannot be predicted in those with a conductive hearing impairment. Hence, considerable effort should be expended in attempting to solve ear mould problems before considering a BAHA. The disability associated with the ear mould has to be sufficient to make the potential of a lesser audiometric benefit from a BAHA acceptable. [Grade C]
- ✓ Binaural BAHA would appear superior to a monaural BAHA for speech recognition in noise and localization in the laboratory. This does not always translate to reported clinical benefit.
- ✓ For those with a unilateral conductive impairment, a BAHA like a conventional air-conduction aid gives audiometric benefit in laboratory spatial speech reception in noise and sound localization tasks.
- ✓ For those with a single hearing ear, a BAHA gives similar benefit to a CROS aid for directional speech recognition in quiet and noise tasks. [Grade B]

Deficiencies in current knowledge and areas for future research

- ➤ As with other types of hearing aid, considerable research is required to improve the acoustical characteristics of a bone-anchored hearing aid to suit a particular patient's hearing impairment and listening circumstances.
- ➤ Improving the benefit of listening with an aid/s in a background of noise is perhaps the most important requirement needing to be investigated.
- ➤ The reported benefit of binaural hearing aids is likely to be mainly due to a summation of loudness.
- ➤ Because a BAHA will stimulate both cochlea, some listening situations are made worse and some better with bilateral aids.
- ➤ Each of these benefits requires better definition and evaluation.
- ➤ Techniques to study spatial listening are still evolving, but progress is being made.
- ➤ Bone-anchored hearing aids for unilateral, acquired hearing impairments require to be more fully evaluated.

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