B-ENT, 2007, **3**, Suppl. 6, 45-50

Bone Anchored Hearing Aids (BAHA)

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Key-words. BAHA; Bone Anchored Hearing Aid; conductive hearing loss; unilateral deafness

Abstract. *Bone Anchored Hearing Aids (BAHA).* The bone anchored hearing aid or BAHA is a small vibrator that can be reversibly plugged onto a titanium screw that is implanted behind the ear. It transduces sound into vibration of the screw and stimulates the cochleae by means of the bone conduction pathway. The main indications are conductive hearing loss or mixed hearing loss with a moderate perceptive component when classical hearing aids cannot be worn, and rehabilitation of unilateral deafness. The indications, contra-indications, surgical technique and results are discussed in this paper.

Introduction

Most patients with hearing loss can be successfully fitted with a conventional hearing aid which involves the placement of an occlusive ear mould in the external ear canal. For some hearing impaired persons, however, the fitting of a conventional hearing aid is problematic in spite of favourable audiological criteria. For example, in patients with stenosis of the external ear canal due to congenital middle ear malformation or agenesis, an ear mould cannot be placed.[1] Also, hearing impaired persons with chronic suppurative otitis media (CSOM) suffer from ear discharge that often exacerbates when an occlusive ear mould is placed. Another group of patients for whom a conventional hearing aid is often problematic are those with a canal wall down mastoidectomy cavity. They have a wide external ear canal and acoustic feedback frequently occurs. In some otological conditions, thus, the occlusive ear mould of the conventional hearing aid is the major bottleneck in restoring hearing. For these patients, a bone anchored hearing aid (BAHA) does not imply occlusion of the external ear canal and offers a valid alternative to conventional hearing aids.

More recently, the indications for a BAHA have been extended to include unilateral deafness. For these patients, the BAHA is implanted at the deaf side, and bone conduction routes sound to the functional cochlea. Compared to a conventional contralateral routing of sound (CROS) hearing aid, patients report high satisfaction with the BAHA.

Principles

The BAHA stimulates the cochlea through bone conduction, in a similar way as a tuning fork does (see Figure 1). Because the external and middle ear are bypassed, pathological conditions of these structures do not interfere with hearing as they would with a conventional hearing aid.

Bone conduction stimulation of the cochlea results from several physical phenomena:[2]

- sound radiation in the external ear canal (predominantly at high frequencies)
- inertion of the tympano-ossicular chain and the inner ear fluids (predominantly at low frequencies)
- compression of the inner ear spaces (predominantly at mid frequencies)

For bone anchored hearing aids, the latter two phenomena are quantitatively most important and hearing gain will eventually be limited by the amount of sensorineural hearing loss. Sound radiation in the ear canal does occur with a BAHA, but this sound energy reaches the inner ear strongly attenuated due to the pathologic state of the middle ear that indicates the use of the BAHA. As sound waves propagate through the bones of theskull, the contralateral cochlea is stimulated as well, which is a second benefit of the BAHA, as will be discussed forthwith.

By using a percutaneous titanium bone-integrated fixture, the BAHA overcomes the limitations

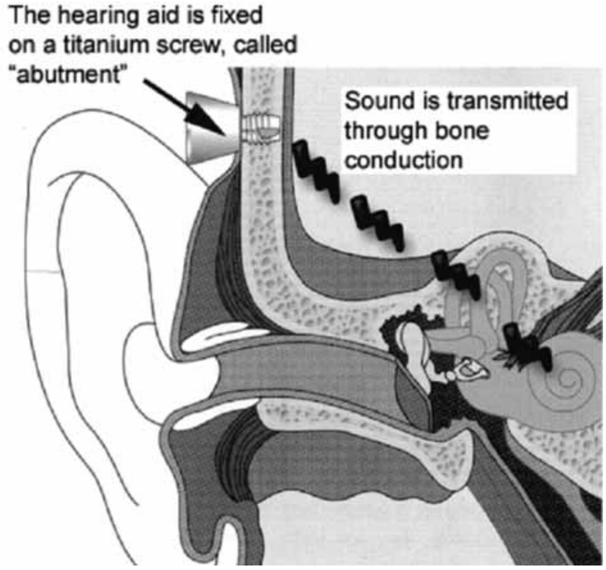

Figure 1
Scheme of BAHA

of transcutaneous devices such as a bone conduction hearing aid incorporated in a headset or spectacles. Most interestingly, acoustic feedback or Larsen's effect does not occur with the BAHA .

Indications and patient selection criteria

1. *Audiological indications*

- A BAHA can be used in all cases of conductive hearing loss,[3] even with an additional sensorineural hearing loss of up to 45 dB HL. For the BAHA Compact, the average bone conduction threshold should be better than or equal to 45 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz). Recently, a BAHA with digital sound processing, the BAHA Divino, has been released. Its maximal amplification is identical to the BAHA Compact, but is has automatic gain control (AGC) capability and two microphones: an omnidirectional microphone and a directional front-facing microphone. The BAHA Cordelle II is a body worn device and has the more powerful K-amp amplifier, which yields an output that is on average 13 dB stronger than the BAHA Classic.
- A maximum speech discrimination score better than 60% (phonetically balanced CVC-words scored on phonemes).
- For single sided deafness,[4,5] the pure tone average air conduction threshold of the hearing ear should be better than or equal to 20-25 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz).
- Using a test band or rod, the candidate can evaluate the sound quality and possible gain of the BAHA device prior to implantation. Pure tone and speech audiometry can be carried out and thus realistic expectations are obtained.

2. *Otological indications*

- Congenital malformations with agenesis or atresia of the middle or external ear. In cases of microtia or a completely absent pinna, an epithesis can be provided with two additional fixation points.[3]
- Chronically draining ears that do not allow use of an air conduction hearing aid, such as mastoidectomy cases with poor sound transmission and recurrent problems of humidity, discharge or infection in case of occlusion by a hearing aid or recurrent external otitis.[3]
- Patients with unilateral conductive hearing loss (and not appropriate for or refusing surgical correction) or unable to be aided by conventional air conduction hearing devices.[3]
- Congenital or acquired unilateral total deafness,[5,6,7] e.g. after acoustic neurinoma surgery where preservation of hearing was not possible.

3. *Contraindications*

- An average bone conduction threshold worse than 60 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz).
- Mentally retarded or uncooperative patients; drug addicts…
- Very small children (<2 years). In the USA, the lower age limit is 5 years.

Surgery

Since Anders Tjellström performed the first three screw implantations in 1977, the surgical procedure and the equipment have evolved significantly. The operation nowadays usually consists of a one-stage procedure, carried out under general or local anaesthesia in the outpatient clinic. Currently, two types of incisions and surgical approaches are used, though the

Figure 2
Horseshoe-shaped incision with elevated and thinned skin flap. Fixture screw in place.

details of the actual implantation are identical in both procedures.[8]

The first approach uses a horseshoe-shaped skin flap that is mobilized somewhat posterosuperior to the pinna (see Figure 2). The flap is elevated and thinned as much as possible before closure. When available, a dermatome can be used for thinning the skin. No subcutaneous fat tissue or hair follicles may remain. The second approach uses a single, straight incision via which the surrounding skin is undermined and thinned. We observed faster wound healing with the straight incision and abandonned the horseshoe-shaped skin flap.

The actual drilling site has to be chosen carefully, especially in small children or in post-radiotherapy cases. Detailed spiral CT studies can be helpful in these particular cases, where sometimes a two-stage procedure is preferred. There are two types of self-tapping fixation screws: their lengths are 3 and 4 mm respectively. After drilling a 3 mm deep hole, the presence of solid bone is assessed. If there is solid bone, then the drilling continues to a depth of 4 mm and the 4 mm fixture is used. This is usually the case.

During the second stage, after osseo-integration of the screw, the skin is again incised and thinned and, subsequently, the abutment is screwed onto the fixation screw.

The so-called osseo-integration takes about 3 to 4 months in healthy individuals, but in most centers, the fixture screw is loaded for the first time approximately two months after surgery. In cases of very thin bone or after radiotherapy, a longer waiting time is warranted.

Results

When reporting the outcome of a BAHA, several issues have to be considered: implantation success, skin tolerance, audiometric performance, and finally, overall patient satisfaction. Most studies report high success rate of osseointegration (>90%). As to complications, they are rare and generally limited to skin reactions. Loss of the fixture is reported to happen sporadically. Previously irradiated bone, bone disease and very thin cortical bone are a negative prognostic factor, but not a contraindication.[8,9]

Several clinical studies comparing the audiometric performance of the Bone Anchored Hearing Aid to those of air conduction hearing aids have been carried out. Especially patients with a pure conductive hearing loss and a limited sensorineural loss up to 45 dB (0.5–3 kHz) are very satisfied, although sensorineural losses up to 60 dB (0.5–3 kHz) can be fitted using a body-worn device connected to the transducer (Cordelle II). If not otherwise stated, the conclusions of these studies are mainly based on data from patients suffering from CSOM. All studies almost unanimously agree on a number of facts:

1. Neither conventional air conduction hearing aids, nor bone anchored hearing aids rehabilitate hearing impaired patients to the level of normal hearing people. Although this might seem an obvious observation, it is important to convey this message to the patient prior to implantation to ensure they have realistic expectations.[10]
2. Both air conduction hearing aids and bone anchored hearing aids yield very similar audiometric performances. Both were effective in improving aided free field hearing thresholds. The best improvement in hearing was observed between 1 and 2 kHz. In tests of temporal acuity, the BAHA scored slightly better, though not statistically significant.[10,11]
3. In terms of subjective improvement using validated question-

naires, the BAHA scored better. Almost all patients preferred their BAHA to the air conduction device they used beforehand. Of course, one has to take into account that the problems these patients had with their conventional hearing aids encompass the indication for switching to BAHA.[11,12]

4. Ninety-seven percent of all patients confirmed reduced occurrence of ear discharge and discomfort.[1]
5. In cases of single sided deafness, studies demonstrate strongly positive patient reactions to the BAHA system. Although source localization was not improved, subjective benefit (quality of life) was reported consistently. Also, an objective improvement in speech recognition in noise was reported (except for the condition where the talker is at the side of the hearing ear). This suggests that reducing the head shadow by use of a BAHA has overall postive effects on hearing, compared to uniloateral hearing. The results with BAHA were also consistently better than those with conventional CROS devices.[4-7,13] One recent review, however, comments on the validity of these studies, since they invariably consist of small numbers of patients, who have not always tried CROS devices for a long enough period according to the authors.[14]
6. Bilateral fitting of BAHA has been carried out on a limited scale. The results show that sound localization, speech recognition in quiet and in noise is significantly better compared to the monaural BAHA group.[15-17]

To our opinion, the recommendations formulated regarding the indications for BAHA surgery are based on good and consistent scientific evidence and can therefore be considered as grade A.

Conclusion

The Bone Anchored Hearing Aid is a valuable solution for a selected group of patients who cannot be satisfactorily helped by either functional surgery or a conventional hearing aid. Level A scientific evidence is at hand illustrating the effectiveness and safety of the procedure, as well as a significant improvement of speech discrimination and quality of life. Although an elegant and minimally invasive procedure, an operation is nonetheless required. Belgian social security reimburses the costs of the operation and the titanium implants. Furthermore, a partial reimbursement of the sound processor is provided, similar to a classic bone conduction hearing aid. The gain in quality of life significantly outweighs the inconveniences associated with this type of hearing aid.

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CME questions

1. BAHA is not indicated for:

   A – Unilateral radical cavity with large conductive hearing loss
   B – Bilateral agnesia of the outer ear canal
   C – Bilateral mild to moderate sensorineural hearing loss
   D – Unilateral deafness

2. In cases of normal healing, the patient can start wearing the hearing aid on the abutment after:

   A – Two weeks
   B – Eight weeks
   C – Six months
   D – Immediately

3. Which of the statements are correct?

   A – A BAHA does not improve speech-in-noise discrimination
   B – A BAHA partly eliminates the head shadow and conveys spectral and temporal information by transcranial sound transmission to the contralateral ear in case of an only hearing ear, thus improving speech-in-noise.
   C – A BAHA is much less efficient than a conventional hearing aid in cases of unilateral deafness
   D – A BAHA needs a mobile stapes in order to work properly

4. Which contra-indication is correct?

   A – An average bone conduction threshold worse than 90 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)
   B – An average bone conduction threshold better than 60 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)
   C – Unilateral deafness
   D – An average bone conduction threshold worse than 60 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)

5. Which statement is correct?

   A – BAHA patients are generally more happy with conventional hearing aids
   B – Larsen’s effect remains an important problem with BAHA
   C – BAHA patients almost unanimously prefer the BAHA to their conventional hearing aid
   D – BAHA patients often complain about vibrations in their ear

Answers: 1C; 2B; 3B; 4D; 5C