Fitting Strategies for Patients with Conductive or Mixed Hearing Loss

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Introduction

Surgical correction of conductive hearing loss (CHL) is the principal and preferred treatment by most patients. Surgical therapy is successful in the majority of cases, but not all patients are candidates for surgery because of medical, anatomic, or personal reasons. Although most who undergo an otologic operation achieve socially adequate hearing [i.e., speech recognition threshold (SRT) of 25-dB hearing level (HL) or less], some do not, and these patients can generally obtain additional benefit from amplification. In cases of CHL in only hearing ear, the surgeon recommends amplification to avoid the risk of surgical complications that might increase the hearing loss, provided that the CHL is not the result of a progressive disorder, such as a cholesteatoma. Thus, amplification for CHL remains a topic of great interest to audiologists, otologists, and patients alike.

This chapter discusses the types of CHL for which amplification is the primary treatment method, those for which amplification is fitted secondarily following recovery from surgery, and those for which combined surgical-audiologic treatment (i.e., implantable hearing device) is warranted.

Bone conduction aids were once the mainstay of amplification technology for CHL. These bone conduction devices, however, have been superseded by newer technology [i.e., bone-anchored hearing aid (BAHA®)]. The use of conventional or programmable air-conduction aids and implantable bone-conduction hearing devices is emphasized in this chapter.

There are a variety of causes of hearing loss. It is important for all members of the hearing health care team (otolaryngologists, audiologists, and aural rehabilitation specialists) to fully understand the mechanisms of both conductive and sensorineural components in each individual case and develop an optimal rehabilitative strategy. In cases with a significant conductive component, many factors must be weighed. Certain physical findings such as persistent otorrhea, cholesteatoma, and mass lesions of the external and middle ear require aggressive medical and surgical therapy regardless of the degree of conductive impairment. In other cases with congenital or progressive disorders resulting in CHL, the main issues are the degree of hearing impairment, the age of the patient, the status of the other ear, and the probable success of surgery versus amplification.
This chapter first outlines the various causes of CHL and then reviews the medical, surgical, and rehabilitative options.

**Lesions of the External Auditory Canal**

Any process that obstructs the external auditory canal (EAC) can result in a CHL up to 40-dB HL. These lesions can be separated into congenital or acquired etiologies. Congenital stenosis (narrowing) or atresia (failure to develop) of the EAC may be partial or complete and is frequently accompanied by deformities of the pinna, ossicles, middle ear cavity, and otic capsule, resulting in a wide range of hearing loss from mild conductive loss to severe mixed loss. High-resolution computed tomography (CT) scan of the temporal bone is necessary to evaluate the extent of bony versus soft tissue stenosis, the shape of the ossicular chain, and the presence or absence of an aerated (air-containing) middle ear space. Surgical reconstruction of the EAC and ossicular chain is warranted as early as possible in cases of bilateral stenosis with CT evidence of middle ear aeration and normal otic capsule anatomy (Chandrasekhar et al, 1995). In cases of unilateral disease, patients are usually advised to reach adulthood before making a decision regarding surgery. Amplification strategies include bone-conduction hearing aids and bone-anchored hearing aids (BAHAs) in cases where reconstruction of the EAC and ossicular chain is impossible. These two treatment plans are discussed later in this chapter.

Acquired obstruction of the EAC is commonly caused by cerumen impaction, collection of squamous (skin) debris, tumors, or chronic external otitis (infection) with stenosis. Periodic cerumen removal in the office under direct vision is required in certain patients with excessive cerumen production or small, tortuous external canals. Self-manipulation of the canal (i.e., cotton swabs) is not recommended due to the possibility of injury to the canal skin or tympanic membrane. This problem is especially bothersome in patients wearing hearing aids that occlude the canal and prevent the normal migration of cerumen. Some patients suffer from excessive collections of squamous debris that forms a plug or cast of the EAC. If the process does not erode the skin or bone of the EAC, the term keratosis obturans applies. In cases of canal erosion, a canal wall cholesteatoma is suspected. Periodic removal of the debris is indicated and possible surgical widening and grafting of the EAC is performed in severe cases (Farrior, 1990).

Tumors of the external canal may be either malignant or benign and either soft tissue or bony. Keratinous cysts of the EAC are common and warrant surgical removal if they obstruct the canal. Malignant tumors include squamous cell, basal cell, melanoma, ceruminoma, and tumors of the parotid gland invading the EAC. Surgical therapy is the main treatment for these lesions. Acquired bony lesions include exostoses and osteomas, which are also removed when they obstruct the canal or trap wax and debris (Fisher and McManus, 1994).

Chronic external otitis may lead to progressive narrowing of the external canal with subsequent hearing loss. Aggressive topical steroid and antimicrobial therapy is necessary, with surgical treatment reserved for cases of soft tissue stenosis (Parisier and Levinson, 1991). The use of hearing aids in these cases is contraindicated because of the aggravation of the inflammation caused by the device in the EAC.

**Lesions of the Tympanic Membrane**

**Tympanic Membrane Perforation**

Perforations of the tympanic membrane cause a variable amount of CHL based on the size and location of the perforation and the presence or absence of otorrhea. Small (1 to 2 mm) dry perforations generally cause minimal hearing loss (in fact, this is essentially identical to the placement of a pressure-equalizing tube). Larger perforations with chronic mucoid otorrhea centered more posteriorly tend to cause more CHL in the 25- to 35-dB HL range. Total tympanic membrane perforations can result in CHL of
40-dB HL or greater. When the perforation is posterosuperior, extends to the margin of the tympanic membrane, and collects squamous debris, a cholesteatoma is suspected that may cause ossicular erosion and hearing loss as great as 60-dB HL.

In most cases, surgical repair of the perforation is recommended and is successful in about 90% of cases with near-complete closure of the air-bone gap (Glasscock, 1973). In a small percentage of cases, surgical failure or late reperforation occurs due to poor eustachian tube function. In such cases, amplification is indicated as long as the perforation is dry.

**Tympanosclerosis**

Tympanosclerosis is the accumulation of dense hyaline-like material in the fibrous layer of the tympanic membrane. This results in stiffening of the tympanic membrane and may impede sound transmission. In severe cases, the ossicular chain is also involved. Surgical management is warranted when a perforation is also present; otherwise, amplification is recommended to overcome the CHL.

**Adhesive Otitis Media**

In certain cases of severe eustachian tube dysfunction, the tympanic membrane (TM) collapses into the middle ear space. A moderate conductive loss is common and surgical attempts to graft the TM with fascia or cartilage and placement of a pressure equalization (PE) tube are variably successful. In such cases, amplification is recommended to rehabilitate the ear.

**Lesions of the Middle Ear and Mastoid**

**Chronic Otitis Media**

Chronic infections of the middle ear can result in damage to the tympanic membrane, ossicular chain, and even cochlear hearing via the round window. In cases of chronic otitis media with effusion (COME), a tenacious mucoid effusion persists that causes a moderate CHL. Placement of long-standing PE tubes for ventilation is the mainstay of therapy (Mandel et al, 1989). Chronic otorrhea via a TM perforation is common and precludes the use of a hearing aid until the drainage is stopped via medication or tympanomastoid surgery. Finally, ossicular continuity is frequently disrupted at the incudostapedial joint, resulting in CHL from 15- to 50-dB HL. In these cases, ossiculoplasty with bone or synthetic prostheses is indicated with variable success (Brackmann et al, 1984). In many instances, amplification is necessary due to a persistent conductive loss or an accompanying sensorineural component.

**Cholesteatoma**

As mentioned above, cholesteatoma is an aggressive invasion of squamous epithelium into the middle ear and mastoid spaces. Although not truly neoplastic, the squamous cells incite a cascade of inflammatory mediators that trigger bony resorption involving the ossicles, mastoid cells, and even the otic capsule. In all cases, surgical removal or exteriorization of all cholesteatoma matrices is necessary to achieve a dry ear (Parisier et al, 1991). When this is done, then either surgical reconstruction of the ossicular chain or amplification can be achieved. Cholesteatoma is an aggressive process with serious complications and therefore must be treated aggressively.

**Otosclerosis**

Otosclerosis is a progressive osteodystrophy (abnormal bone growth) of the otic capsule that most frequently involves the anterior stapedial footplate, causing fixation and progressive CHL. The disease is thought to be inherited in an autosomal-dominant pattern with variable penetrance, although alternative theories implicating viral infections have been reported. The disease usually becomes evident in the third decade of life and may be bilateral. Audiometric findings include a low- to midfrequency conductive loss from 10- to 50-dB HL, elevation of the 2000-Hz bone threshold (Carhart notch), normal or
stiff tympanogram, and absent stapedial reflexes. Options for therapy include observation and serial audiometry, surgery, or amplification. Observation is warranted if the CHL is slight (<20-dB HL) and the patient is fully functional in his or her environment. Surgery consists of either total removal of the stapes (stapedectomy) or partial footplate fenestration (stapedotomy) and piston reconstruction of the ossicular chain (Rizer and Lippy, 1993). The decision of stapedectomy versus amplification is based on a combination of severity of loss, age and occupation of the patient, and discussion of the risks of surgical intervention. In general, younger, active patients desire surgical treatment, whereas the elderly patient frequently decides to pursue amplification. Surgery is contraindicated in an only-hearing ear or in patients with severe vertigo. Success rates up to 95% are reported for closure of the 500 to 2000 Hz air-bone gap to within 10-dB HL (Rizer and Lippy, 1993). In patients who are undecided, a trial with amplification is useful, reserving surgery for those patients who fail.

**Tumors of the Middle Ear and Mastoid**

A variety of benign and malignant tumors can affect the middle ear and mastoid, resulting in a conductive hearing loss. A thorough workup, including CT scan imaging, magnetic resonance imaging (MRI), angiography, and surgical exploration, is necessary to eliminate these lesions. Amplification is reserved to rehabilitate the resultant conductive loss produced by the lesion and its removal.

**Inflammatory Diseases of the Middle Ear and Mastoid**

Because the middle ear and mastoid are lined with respiratory epithelium, these spaces are also prone to systemic inflammatory processes that affect the entire respiratory tract. Examples of such diseases include Wegener’s granulomatosis, sarcoidosis, and amyloidosis. These diseases can cause a clinical picture similar to chronic otitis media and should be suspected in any cases of persistent otorrhea unresponsive to antimicrobial therapy. A mixed hearing loss can result if untreated and amplification may be unsuccessful in severe cases.

**Surgery to Provide Amplification**

Surgery for providing amplification is an emerging area of interest. As mentioned, surgical modification of the external auditory canal for congenital or acquired atresia is a standard procedure. In recent years, electromagnetic devices have been developed that are either coupled to the ossicular chain directly or vibrate the skull, thereby eliminating the mechanical issues of sound transduction via the air through the external canal and tympanic membrane. Such devices are desirable in patients with (1) atresia not amenable to surgical reconstruction, (2) persistent otorrhea due to chronic supplicative otitis media resistant to medical and surgical therapy, (3) uncorrectable ossicular abnormalities, or (4) intolerance or allergy to earmolds. Suitable candidates meeting the medical and audiologic criteria for such devices should have realistic motivation and understanding of the benefits and limitations. Contraindications include (1) the absence of suitable ossicular or squamous temporal bone in which to place the device and lack of adequate skin cover, (2) active infection in the implantation site, and (3) systemic disease that might affect wound healing. Some of these fitting options are discussed later in this chapter. The option of middle ear implants (MEIs) are covered in great detail in Chapter 11.

**Overall Strategies for Amplification**

The optimal strategy for hearing restoration requires an individualized approach based on many factors. Active infection of the external canal, tympanic membrane, or middle ear must be medically or surgically controlled before amplification is prescribed. Surgical correction of dry tympanic membrane perforations, ossicular discontinuity, or ossicular
fixation is recommended with amplification reserved for residual conductive or mixed losses after surgery. One exception would be the poor surgical candidate where amplification is the only alternative. In cases of severe aural atresia or uncontrolled chronic otitis media with an open mastoid cavity, surgical implantation of electromagnetic bone-anchored devices may be warranted. In many instances patients may progress through stages in their disease process that include all medical, surgical, and rehabilitative options.

**Implantable Bone-Conduction Hearing Device**

In the first edition of this textbook, the authors included information on the Xomed Audiant implantable hearing aid as a treatment option for patients with conductive or mixed hearing loss. Unfortunately, this product was removed from the market in the late 1990s due to its inability to provide adequate gain/output for many patients with conductive or mixed hearing loss. Since the first edition was published, the BAHA® has been introduced. It has been approved by the Food and Drug Administration (FDA) as a treatment option for patients with conductive or mixed hearing loss where the bone-conduction pure-tone average (BCPTA at 500, 1000, 2000, and 3000 Hz) is 45-dB HL or better and who are at least 5 years old.

Currently, the BAHA® is available in the Classic 300 (upper drawing in Fig. 10–1) and Cordelle II (lower drawing in Fig. 10–1). Recently, the BAHA® became available as a Compact smaller device (i.e., 35% smaller than the Classic 300). All three processors are available in beige, black, and gray. The Cordelle II provides about 13 dB greater output than the Classic 300 and the Compact and is typically utilized for those patients who report that the gain provided by the Classic 300 or Compact is insufficient. The Classic 300 operates on a 675 battery and has a volume control/on/off switch and tone control switch [N (normal-frequency response), L (high-frequency attenuation), and E (disconnects the microphone so the 300 can be directly coupled to external equipment)]. The Classic 300 is capable of connecting directly to assistive-listening devices (FM, infrared, Walkman devices, etc.) via direct auditory input (DAI). Finally, the Classic 300 can be ordered with a telecoil, auditory adapter, and directional microphone. The Compact operates on a 13 battery and has a volume control/on/off switch, tone control [N (normal-frequency response), L (high-frequency attenuation), and E (disconnects the microphone so the Compact can be directly coupled to external equipment)] switch. The Compact is capable of connecting directly to assistive listening devices (FM, infrared, Walkman devices, etc.) via DAI. Finally, the Compact can be ordered with a telecoil and auditory adapter. The Cordelle II operates on a rechargeable 9V battery and, as mentioned earlier, provides about 13 dB greater gain than the Classic 300. This unit has a built-in telecoil (M/T/MT switch), tone switch for low- and high-frequency attenuation, and K-Amp™ signal processing where the compression kneepoint and loudness boost can be adjusted.

These devices transmit amplified sound directly to the skull without interference from the intermediate tissue. The BAHA® consists of a titanium fixture that is anchored into the skull and a percutaneous titanium abutment that is attached to the titanium fixture and penetrates the skin (Fig. 10–2). Finally, a processor is connected to the protruding part of the abutment (Fig. 10–2). With the BAHA®, no tissue is present to impede the transmission of the amplified sound, and the processor does not press against the skin and cause irritation.

**Surgical Considerations**

The titanium screw and abutment is typically implanted using general anesthesia on an outpatient basis. A skin flap is elevated and thinned to the appropriate thickness as necessary. A suitable location on the skull above and behind the pinna is chosen. Drilling begins with a 3-mm and then 4-mm fixed-depth guide drill. A larger center hole is drilled with a countersink drill in prepara-
tion for threading. The internal device is a titanium fixture (Fig. 10–2) that is mounted in the bone behind the ear where it osseointegrates. The vibrations from the sound processor are transmitted to the fixture via a percutaneous abutment (Fig. 10–2). The sound processor (Classic 300, Compact, or Cordelle II) can be connected and disconnected at will via an abutment snap [items 7 (upper) and 15 (lower) in Fig. 10–1] on the Classic 300 or Cordelle II. The bone screw becomes osseointegrated over 3 (for adults) to 6 months (for children) and becomes rigidly coupled with the skull. The external

Figure 10–1. Drawing of the bone-anchored hearing aid (BAHA®) Classic 300 (upper) and Cordelle II (lower) sound processors. Upper: (1) volume control; (2) tone switch; (3) electrical input; (4) battery compartment; (5) battery cover; (6) microphone; (7) abutment snap; (8) attachment for safety line; (9) gain control; (10) tone control (bass cut); (11) serial number. Lower: (1) transducer; (2) body worn unit; (3) cord; (4) M-MT-T switch; (5) electrical input; (6) tone switch; (7) volume control; (8) microphone; (9) electrical output; (10) trim controls; (11) clip; (12) battery cover; (13) battery compartment; (14) serial number; (15) abutment snap; (16) electrical input; (17) serial number. (From Entific Medical Systems, with permission.)
sound processor is typically fit 8 to 10 weeks postoperatively. The sound processor transforms vibrational energy in the skull, causing the cochlea to vibrate. Because of the rigid coupling, the sound transfer is excellent, especially at the higher frequencies, where speech understanding occurs.

Postoperative Care
Postoperative care is minimal. In the immediate postoperative period, antibiotic ointment and dressing changes are done. Once the sutures are removed and wound healing is complete, no continuing attention is necessary. Patients are advised to examine the area periodically for evidence of irritation. Routine assessment after healing is typically unnecessary. Daily cleaning is essential after healing to maintain proper healing. Ninety-eight percent of problems with the BAHA® are due to recurring infections of the skin.

Audiologic Criteria for the BAHA®
Patients for whom no better alternative treatment exists may be considered candidates for the BAHA® if the aided ear:

1. Has a BCPTA at 500, 1000, 2000, and 3000 that is equal to or better than 45-dB HL.

Patients with bone conduction thresholds between 25- and 45-dB HL can expect improvement, but may not achieve aided levels within in the normal range of hearing. Patients who bone conduction thresholds are less than 25-dB HL could have restored aided hearing levels within the normal range.

2. Has an air-conduction word recognition score in quiet [at 30-dB sound level (SL) or at a most comfortable loudness level] of greater than 60%.

3. Is free from a generalized disease process that could result in poor wound healing.

4. Is unwilling or unable to be a candidate for reconstructive surgery.

5. Is unable to use conventional air- or bone-conduction hearing aids because of chronic otitis media, congenital malformation of the external/middle ear, or other acquired malformations of the external or middle ear that preclude wearing conventional air-conduction aid.

6. Is strongly motivated toward this surgical procedure.

7. Is able to understand the objectives and expectations of this method of amplification.

8. Is psychologically and emotionally stable to maintain the hygiene of the percutaneous titanium abutment.

9. Is at least 5 years old.
Examples of pathologies or conditions that may lend themselves to the BAHA® include:

1. Congenital or acquired atresia of external canal or middle ear that is not amenable to surgical reconstruction.
2. Stenosis of the ear canal.
3. Chronic suppurrative otitis media that is resistant to medical-surgical therapy.
4. Complications from radical mastoidectomies.
5. Congenital or acquired ossicular malformations.
7. Postoperative mastoid cavity with chronic otorrhea.
8. History of intolerance or allergy to earmolds.

Advantages of the BAHA® over the Bone-Conduction Hearing Aid

Prior to the introduction of implantable hearing aids, bone-conduction hearing aids (to be described later in this chapter) were the hearing aids typically fit on patients with conductive or mixed hearing loss. Advantages of the BAHA® over a bone-conduction hearing aid include the absence of pressure on the skin from the headband, elimination of feedback, reduced distortion, and improved high-frequency hearing through more direct bone conduction. Another advantage is stable bone vibrator placement through surgical implantation rather than external placement of the bone vibrator on the skin over the mastoid, which is subject to movement.

Fitting Strategies for the BAHA®

If the results of the audiometric examination establish that a patient meets the selection criteria described above, then the patient should be counseled about the BAHA® and referred to the otolaryngologist. Assuming that all criteria have been met, the audiologist and otolaryngologist would determine the processor (Classic 300, Compact, or Cordelle II) that appears most appropriate. As discussed earlier, this decision would depend primarily on the bone-conduction thresholds and the subjective judgments of the patient. A test headband (Fig. 10–3) is available to determine which ear would be the best candidate for surgical placement of the titanium fixture. All three processors can be attached to the headband. The headband can be useful to determine on which side the titanium fixture should be implanted. Additional information may include onset of the hearing loss (i.e., congenital vs. acquired) and prior experience with amplification.

Figure 10–3. BAHA® test headband. (From Entific Medical Systems, with permission.)
According to manufacturer guidelines, the processor is fit after 3 to 4 months in adults and 6 months in children. This allows for complete osseointegration of the titanium fixture and abutment. At approximately 6 months postimplant (2 to 3 months after the initial fitting), the audiologist would evaluate the performance of the BAHA® by having the patient face a loudspeaker at 1 m at 0-degree azimuth. Now, the audiologist would assess the unaided performance as well as the aided performance of the BAHA® and the patient’s air- and/or bone-conduction aids. Measures would include:

1. Warble tone thresholds at 500, 1000, 2000, 3000, and 4000 Hz.
2. Word recognition for monosyllabic words presented at 63-dB SPL and speech-shaped noise presented at 57-dB SPL [a +6 dB signal-to-noise ratio (SNR)].
3. Completion of the preoperative [12 questions about the performance of the patient’s current aid(s)] and postoperative (eight questions about the performance of the BAHA®) questionnaires.

Expected performance with the BAHA® is improving the aided warble tone thresholds to within normal limits if the unaided bone-conduction thresholds were better than 25-dB HL and close to the normal range if the bone conduction thresholds were between 26- and 45-dB HL. In addition, the speech recognition in noise performance with the BAHA® should be significantly better than unaided and with the patient’s current aid(s). Finally, the subjective preference for BAHA® should be rated significantly better than the patient’s current aid(s). Optimally, patients will also report improved fidelity and reduced feedback relative to the performance of their air- and/or bone-conduction hearing aid.

Research Findings Using the BAHA®

Surgical Outcomes

Tjellstrom and Granstrom (1977) reviewed over 100 BAHA® cases from 1977 and found that over 68% reported no skin reactions (e.g., swelling or redness around the abutment; granulation; removal/revision). An additional 21% had one or two episodes of adverse reactions. Five of the patients lost their abutment due to direct trauma (e.g., hitting a doorway; blow to the ear; taking off an apron), and an additional five patients lost osseointegration of the implant. That is, in 90% of the patients (90/100), the BAHA® was still intact following surgery over an 8-year time frame. Tjellstrom and Granstrom (1995) reported on 214 patients who were followed over a 5-year period using a two-stage (titanium screw implanted first and then titanium abutment attached at a second surgery) or one-stage (titanium screw and titanium abutment implanted at the same time) surgical procedure. These authors reported that the success rates for both procedures were the same. In the two-stage group, nearly 68% had no adverse reactions to the implant, and the number increased to nearly 75% of the one-stage group. Tjellstrom and Hakansson (1995) reported that in 806 observations, 96.4% of the cases indicated no adverse reaction to the surgical procedure.

Subjective Outcomes

Hakansson et al (1990) reported that 22 of 24 subjects reported fewer ear infections with the BAHA® than their previous air-conduction hearing aids (ACHAs). Also, 16 of 24 (67%) subjects reported better sound quality with the BAHA® in comparison to their AC hearing aids, and 19/27 (70%) other subjects who were experienced bone-conduction hearing aid (BCHA) users reported greater comfort with the BAHA® (four reported no difference and four reported poorer comfort with the BAHA®).

Tjellstrom and Hakansson (1995) reported on 122 cases from nine sites on a questionnaire for unaided, BAHA®, and BCHA listening conditions. On the questionnaire, 86.6% reported they use the BAHA® 8 or more hours/day. The subjects also reported that the BAHA® resulted in improved speech intelligibility, better sound comfort,
less pressure on the head, less skin irritation, easier handling, and greater cosmetic acceptance than the BCHA. In addition, 44 of 51 subjects (86%) reported a general improvement of their ear infections after they switched to the BAHA® in comparison to those who previously had worn air conduction hearing aids. Finally, 55 of 67 subjects (82%) reported improved wearing comfort in comparison to their previous BCHA.

**Objective Outcomes**

Tjellstrom and Hakansson (1995) reported on 122 cases from nine sites using sound-field warble tone thresholds (500 to 3000 Hz), SRTs, and word recognition at +6-dB SPL (signal at 63-dB SPL; speech noise at 57-dB SPL). The mean improvement for the BAHA® over the unaided hearing was 29.4-dB HL (range of 26.0- to 36.3-dB HL), whereas the mean improvement for the BCHA was 27.3-dB HL. The advantage of the BAHA® over the BCHA ranged between 1.6 and 9.1 dB, where the mean improvement for the BCHA was better than the BAHA® at 500 Hz. For the SRT, the BAHA® and the BCHA reported a mean improvement over unaided performance by 26.5-dB HL. For word recognition in noise, the BAHA® improved word recognition, on average by 41.8%, whereas the BCHA improved word recognition, on average, by 35.5% (i.e., BAHA® better than the BCHAs by 6.2% and found to be statistically significant, \( p < 0.001 \)).

See the additional readings at the end of this chapter for more references on the surgical, subjective, and objective outcomes reported with the BAHA®.

**Hearing Aid Selection and Fitting for Conventional Hearing Aids**

Options for selecting and fitting hearing aids for conductive or mixed hearing loss can generally be divided into three categories. As illustrated in Figure 10–4, patients can be fitted with air conduction in-the-canal (ITC, left), in-the-ear (ITE, center), or behind-the-ear (BTE, right) hearing aids. Patients can be fit with eyeglass-, body-, or bone-conduction hearing aid(s). Finally, patients can receive

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**Figure 10–4.** Examples of three air conduction hearing aids. Left: In-the-canal (ITC) hearing aid. Middle: In-the-ear (ITE) hearing aid. Right: Behind-the-ear (BTE) hearing aid.
an implanted bone-conduction hearing device as was discussed in the previous section.

**Air-Conduction Hearing Aids**

Determining which air-conduction hearing aid is most appropriate is usually based on (1) the magnitude of hearing loss, (2) the magnitude of the air-bone gap, and (3) patient preference. As a general rule, as the hearing loss and magnitude of the air-bone gap increases, the need to fit a BTE or body hearing aid increases. Finally, air-conduction hearing aids should be considered the most appropriate fitting for chronic conductive hearing loss when medical contraindications have been ruled out.

**Fitting Strategies for Air-Conduction Hearing Aids**

Regardless of the type of air-conduction hearing aid, the appropriate real-ear gain for patients with conductive or mixed hearing loss can be determined by using many of the prescriptive procedures reported in Chapters 1 and 3. That is, prescribed real-ear gain for hearing aids providing linear amplification is based on the air-conduction threshold with additional gain prescribed to compensate for the magnitude of the air-bone gap. Lybarger (1955, 1963), Byrne (1983), and Byrne and Dillon (1986) recommend that 25% of the air-bone gap should be added to the amplification requirements for patients with sensorineural hearing loss. On the other hand, Berger et al (1984) recommend that 20% of the air-bone gap should be added with the maximum additional gain limited to 8 dB at any frequency.

Other than Berger et al (1984) and Byrne and Dillon (1986), no prescriptive formulas described in Chapters 1 and 3 specify guidelines for providing additional gain to compensate for the air-bone gap. The authors feel that audiologists should always consider adding between 20% and 25% of the air-bone gap to the prescribed gain even if the selected prescriptive procedure (Cox, 1983, 1988; McCandless and Lyregaard, 1983; Libby, 1986) does not specifically provide such guidelines. For example, if a patient has a 65 dB sensorineural hearing loss at 2000 Hz, the National Acoustic Laboratories revised (NAL-R) procedure advocated by Byrne and Dillon (1986) prescribes 26 dB of real-ear gain. If the patient had a mixed hearing loss at 2000 Hz with an air-bone gap of 45 dB, the prescribed gain would be increased to 37 dB (i.e., 26-dB sensorineural hearing loss and 11 dB to compensate for 25% of the 45-dB air-bone gap). If the audiologist, however, were fitting to the Berger et al formula, the recommended gain would be 50 dB (i.e., 42 dB for the 65-dB sensorineural loss and 9 dB to compensate for 20% of the 45-dB air-bone gap with a maximum of 8 dB).

**Verification Strategies for Air-Conduction Hearing Aids**

The verification process for air-conduction hearing aids can either be real-ear gain using probe tube or functional gain measures (see Chapter 3), paired comparisons (see Chapter 4), and/or subjective evaluations (see Chapter 5).

**Bone-Conduction Hearing Aid**

Bone-conduction hearing aids are available in BTE and in eyeglass (Fig 10–5) and body (Fig. 10–6) configurations. Bone-conduction aids are the most appropriate hearing aid fitting when it is physically impossible to use air-conduction hearing aids. Examples of such circumstances may be atresia, severe stenosis of the ear canal, chronic middle ear drainage, and chronic allergic reaction to the materials used to manufacture earmolds. In addition, it is important that bone-conduction thresholds are within normal limits or only slightly reduced in order to achieve success with this type of amplification. Finally, it is important to remember that conventional bone-conduction hearing aids should be evaluated and fitted on at least a trial basis prior to fitting an implantable bone-conduction hearing device.

Bone-conduction hearing aids deliver the amplified sound to a bone vibrator that is
Figure 10–5. Example of an eyeglass bone-conduction hearing aid.

Figure 10–6. Example of bone conduction vibrator attached to a headband and body hearing aid.
placed over the mastoid process. The vibrator is held in place by a headband or eyeglass frame. The most frequently used bone-conduction hearing aids are eyeglass and body designs. The eyeglass arrangement is typically preferred for cosmetic reasons and should be initially recommended even if the patient has normal vision and will use non-prescription lenses. The use of bone-conduction hearing aids is limited due to both minimal available gain at 3000 to 4000 Hz and difficulties involved in achieving the precise placement and tension of the vibrator on the mastoid process. In addition, many patients using bone-conduction hearing aids complain of headaches and soreness around the mastoid process due to the pressure of the bone vibrator on the mastoid process. Despite these drawbacks, successful bone-conduction fittings have been achieved by the authors because of our access to optometrists and opticians who have experience in the proper placement of the bone vibrator. To the best of the authors’ knowledge, only Starkey Laboratories have eyeglass bone-conduction hearing aids available for dispensing to patients with conductive or mixed hearing loss.

**Fitting Strategies**

Lybarger (1955, 1963) provides guidelines that suggest that if the air-bone gap is <25-dB HL, then a conventional air-conduction hearing aid is the appropriate fitting. If the air-bone gap is between 25- and 40-dB HL, then either an air-conduction or bone-conduction fitting may be appropriate. Finally, if the air-bone gap is >40-dB HL, then a bone-conduction fitting may be the most appropriate. To the authors’ knowledge, however, Lybarger’s recommendations have never been evaluated clinically, and the guidelines do not consider cases in which the air-bone gap may be different at different frequencies within the same ear. In view of recent advances in earmold and hearing aid technology (improved isolation between transducers within the hearing aid case, for example), it is now possible to achieve greater gain without feedback. The reader is referred to Chapter 2 in *Hearing Aids: Standards, Options and Limitations*, 2nd edition (Thieme Medical Publishers) for a comprehensive overview of the improved isolation currently available in hearing aids. The audiologist is urged to view these previous guidelines with some skepticism and to evaluate, at least on a trial basis, air-conduction hearing aids for patients in whom air-bone gaps exceed 40 dB HL.

As with air-conduction hearing aids, the primary strategy for bone-conduction hearing aids in cases of conductive and/or mixed hearing loss is to reduce or eliminate the air-bone gap. Again, the most appropriate fitting strategy is to determine the prescribed real-ear gain using many of the prescriptive procedures outlined in Chapters 1 and 3 with additional gain to compensate for the air-bone gap. Finally, like conventional air-conduction hearing aids, bone-conduction hearing aids should be fit bilaterally when appropriate (see Chapter 7).

**Verification Strategies**

The verification process for bone-conduction fitting is primarily limited to measures of functional gain (see Chapters 1 and 3). Recently, paired comparisons (see Chapter 4) and subjective evaluations (see Chapter 5) have become increasingly popular to verify the fitting of hearing aids for patients with sensorineural hearing loss. The use of paired comparisons and subjective evaluations could be extended to fittings for patients with conductive or mixed hearing loss. Real-ear probe tube measures are not commonly used as a means to verify bone-conduction fittings.

**Summary**

Surgical correction of most conditions causing conductive hearing loss provides satisfactory results. Amplification plays an important role in cases in which the postoperative hearing level is suboptimal and in cases in which surgery is not possible or appropriate. The various otologic conditions causing con-
ductive hearing loss were reviewed, and the interaction of surgery and amplification were discussed.

Depending on the circumstances, air conduction, bone conduction, or the BAHA® may be used. The indications, contraindications, and criteria for their use were discussed.

References
Cox R. Using UCL measures to find frequency/gain and SSPL90. Hear Instrum 1983;34:17–22.

Additional Readings: BAHA®
STRATEGIES FOR SELECTING AND VERIFYING HEARING AID FITTINGS


