If you're a regular reader of Page Ten, you know that just last month Anne Marie Tharpe discussed unilateral hearing loss, and reviewed its potential negative consequences. As Dr. Tharpe mentioned, an important factor to consider for these patients is whether or not some type of amplification will be beneficial. This month, we're going to talk more specifically about hearing aid treatments for the most severe category of unilateral hearing loss, the case when the damaged ear is not aidable.

Even the beginning student of hearing aid dispensing is familiar with the "CROS" hearing aid—the style commonly used for patients with unilateral hearing loss. After the early work with traditional CROS amplification in the mid-1960s, we were soon bombarded with all types of options from the CROS family: BiCROS, IROS, powerCROS, miniCROS, multiCROS, highCROS, and focalCROS. There was even a doubleCROS and a crisCROS. While these fun 1970s acronyms possibly could prompt Shirley Ellis to rewrite the lyrics of *The Name Game* song, selecting a CROS option for our patients is not so much fun, and nothing to sing about. That's because we have even more options today, at least one of which requires the patient to undergo surgery, and picking the best is not an easy task.

We're fortunate to always have good authors on Page Ten, and that certainly was true back in 1995 when **Michael Valente**, PhD, joined us and reviewed amplification options for unilateral hearing loss. Things have changed significantly in the CROS world since then, so we thought it was time to bring Mike back for an update on the topic.

Dr. Valente is clinical professor of otolaryngology and the director of adult audiology at Washington University School of Medicine in St. Louis. He also serves on the AuD faculty for the program in audiology and communication sciences. He is an internationally known editor and author, currently serving as the section editor for amplification for *JAAA*. We're all familiar with the many books Dr. Valente has edited—keep your eye out for three more of his audiology texts to be released this fall.

Mike, whose wife, Maureen, is also an audiologist, is known among colleagues to be a big "family man." While this applies mostly to the Valente clan, it also carries over to the Cardinals during the summer. And, while the love might not be the same, I think you'll find his knowledge about the CROS family to also be quite impressive.

GUS MUELLER
Page Ten Editor

Fitting options for adults with unilateral hearing loss

By Michael Valente

Valente

1 Didn't you write a Page Ten on fitting options for unilateral hearing loss once before? If so, has anything changed on this topic since then?

You have a good memory—that Page Ten was published in 1995! That was 12 years ago, and, yes, there have been significant advances since then.

2 Do we really need expensive technology for people with a minimal problem such as this?

You sound like many professionals who believe that patients with unilateral hearing loss (UHL) don't have major problems. The notion is that such people only need to be counseled to make sure their good ear is facing the wanted signal. It's true that preferential seating can resolve some of these patients' listening problems. However, being required to "scan" the environment constantly is difficult and tiring and these patients cannot always do this successfully.

In addition, patients with UHL still have problems with: (1) localizing, (2) understanding speech arriving at the poorer ear, and (3) understanding speech in background noise, especially when the noise arrives at the better ear. For these patients, audiologists often recommend Contralateral Routing Of the Signal (CROS) amplification to the better ear. Recently, several new fitting options have become available for these patients.

3 I'm interested in hearing what's new, but, before that, can you can tell me exactly what you mean by UHL? There seem to be differing opinions.

Here is my definition, which I think is pretty common: UHL is unaidable hearing in one ear and normal hearing (20 dB HL or better) in the opposite ear. "Unaidable" can mean profound sensorineural hearing loss, very poor word recognition, and/or marked intolerance for amplified sounds. Often, it is a combination of these conditions.

4 You're known as a stickler for details. Are there any more definitions you want to share with us before we go on?

Details are a good thing! Yes, there are several definitions that are important for you to understand.

First, there is "*conventional CROS*," in which the signal from the unaidable side is sent to the better ear via an air-conducted (AC) signal (e.g., wired-analog, wired-programmable, wireless-analog, or digital).

Second, there is "*quasi-transcranial CROS*," in which the signal from the unaidable side is sent to the cochlea of the better ear via vibration of the skull using an AC signal (e.g., transcranial CROS).

Finally, "*true transcranial CROS*" is a fitting in which the signal is sent from the unaidable side to the cochlea of the better ear via vibration of the skull using a bone-conducted (BC) signal (e.g., eyeglass BC, bone-anchored hearing aid (BAHA), or TransEar).

5 Isn't the traditional CROS the "gold standard" for treating these patients?

Probably, but that doesn't mean it's always the best thing to do. Sometimes a profession becomes accustomed to doing things one way and is reluctant to change.

For example, when fitting CROS, the audiologist should consider the communication strategies the patient has developed. Typically, many UHL patients have been communicating with one normal and one unaidable ear for some time. Over the years, they develop strategies to situate themselves so the wanted signal is on their good side. When they are able to do this, they perform quite well.

On the other hand, these patients try to avoid situations where the noise is on their good side and the signal is on their poor side. As one can imagine, constantly "scanning" the environment so their good ear is toward the signal and their poor ear is toward the noise can be tiring. Also, typically the signal is mixed with the noise and is not only on one side or the other.

6 So what's wrong with all that? Sounds like good listening strategies to me.

Well, consider that when we fit a CROS hearing aid, we place a microphone over or in the poor ear to capture the wanted signal the patient was missing. However, there is a strong likelihood that noise will arrive on that side as well. This noise, which in the past was attenuated by the patient's poor hearing, is now amplified and sent to the better ear. Thus, the well-intentioned practitioner has reversed the patient's unaided world. What was "difficult" without amplification becomes "easier" (i.e., speech on the poor side), but what was "easier" without amplification now becomes more difficult (i.e., noise on the poor side). Thus, the use of amplification has reversed the patient's world by making "easy listening" difficult and "difficult listening" easy.

7 I see. So, is there really any patient benefit?

That's difficult to say. The question really is what have you done to improve the patient's overall listening between unaided and aided? The answer is "probably little."

That's especially true if the patient frequently listens in background noise. This may explain, at least in my experience, the higher rate of dissatisfaction among patients fitted with CROS instruments than those using other forms of hearing aids. Some of these anticipated problems (e.g., the "reversed listening world") can be addressed with extensive counseling, but in many cases patients remain dissatisfied.

8 You've made a compelling argument about the problems associated with CROS amplification. Do you have any solutions?

Yes, I have two. One solution is currently available and the other is something to ponder for future development.

First, it may seem unconventional, but consideration should be given to dispensing a bilateral contralateral routing of the signal (BICROS) type of fit so a volume control is available on the microphone side and there is an open earmold in the better ear. This arrangement allows the patient to reduce amplification from the microphone on the poor side if he or she perceives noise, yet still achieve the benefits of the open earmold fit to the normal ear. A similar outcome can be achieved with an on/off switch.

A second solution, which has not yet been investigated, is to use DSP noise-reduction algorithms. For example, what if a CROS/BICROS aid could be developed in which the noise-reduction algorithm in the aid on the poor ear would shut the aid off (or significantly attenuate amplification) when an unmodulated signal (noise) was detected? This type of fitting could resolve one of the problems presented above because the offside microphone would be active only when the processor detected a modulated signal (speech). In this manner, what was "easier" unaided would remain "easier" aided (signal on the better side; noise on the poor side) and what was "difficult" unaided (signal on the poor side; noise on the good side) would become "easier" aided because the noise would not be amplified as it is in current CROS/BICROS aids. This strategy could improve user satisfaction with amplification.

9 So, do I take it you're not a big fan of CROS? That's sort of a problem, because we're only on Question 9!

It's not that I'm not a fan of CROS, it's just that I think it can present obstacles and is typically not a fitting that results in user satisfaction or benefit. But, in many cases, it's the best we have to offer, so let me give you a quick run down on what's available. As you know, "conventional" CROS is available as *wired-analog, wired-programmable with directional microphones, wireless-analog,* and *wireless-digital*.

We talked about the early attempts to improve communication for UHL patients in my last Page Ten.[1-4] One of the major drawbacks of the earlier CROS systems was the need for a wire connecting the output from the microphone on the impaired ear to the receiver on the better ear.

To solve this problem, Telex introduced a wireless BTE to ITE CROS. an instrument now available from Phonak. Other models included a BTE to BTE version. This wireless CROS used an amplitude-modulated carrier frequency to transmit signals from the microphone on the side of the impaired ear to the receiver placed in the better ear.

Distance between the transmitter and receiver is critical. It is typically about 6.5 inches, and for every half-inch increase in this distance, gain *decreases* by 3-4 dB. Clinically, a major drawback of these wireless CROS systems was the limited ability to shape the frequency-gain response to provide the prescribed gain to the aided ear. Most of these models were non-programmable, and were delivered with only a low-frequency tone control or low *and* high-frequency tone controls as a means to shape the frequency response.

In the past several years, several manufacturers have re-introduced wireless BTE to BTE, BTE to custom, and custom to custom CROS aids with directional-microphone technology and *multichannel digital signal processing*. Due to significant advances in digital signal processing (DSP) over the past decade, these models have eliminated most of the shortcomings cited above for the original wireless models.

An example of a wireless DSP CROS system is one that uses a CROSLink FM transmitter and an FM receiver attached to a direct auditory input (DAI) boot. This can be coupled to BTEs from more than 30 manufacturers. The reader can go to www.phonak.com/croslink for BTE compatibility, audio shoe order numbers, CROSLink pin orientation, and DPAI (designated programmable audio input) status.

10 You mentioned earlier that there are some more unconventional CROS-type fittings. Can you tell us about them?

Certainly. One of the more unconventional fittings is the quasi-transcranial CROS, which several authors have advocated.[5-9] These authors suggested the unthinkable! That is, to fit a high-output AC hearing aid in the impaired ear to take advantage of the fact that the cochleas of each ear are not acoustically isolated. That is, if an AC signal of high output is presented to the cochlea of an impaired ear, the signal will eventually be heard in the cochlea of the better ear because it will be intense enough to overcome the acoustic isolation (interaural attenuation-IA) between the cochleas. Because the signal picked up by a microphone placed in the impaired ear is transferred to the cochlea of the better ear through the cranial structures of the temporal bone, the authors refer to this as *transcranial CROS*.

I prefer to call it "*quasi-transcranial*" because the mode of transmission to the cochlea of the better ear is via AC and not via the more efficient method of BC that is used with other fittings. In an effort to determine if quasi-transcranial fittings had merit, back in the mid-1990s we evaluated 12 patients who had one unaidable ear and normal hearing in the opposite ear.[10] We fitted the impaired ear of each patient with a strong ITE hearing aid (maximum saturation sound pressure level of 120 dB; full-on gain of 55-65 dB) with a long canal and pressure vent. At the end of 4 weeks, half the patients believed that the ITE quasi-transcranial CROS provided significant benefit, while the other half noted little benefit and decided to continue using their current hearing aids or not pursue amplification.

It is important to remember that the acceptance rate at Washington University at that time for conventional CROS fittings for this population (normal hearing in the better ear) was approximately 10%, while the acceptance rate for the quasi-transcranial CROS was 50%. The reasons that many patients rejected the quasi-transcranial CROS were related to feedback or to a sensation of vibration generated from the hearing aid. The results of this study were encouraging. Interestingly, and of some clinical value, was that the patients who preferred the quasi-transcranial fit were those with the lowest interaural attenuation values (i.e., greater ease for the amplified signal to reach the normal ear).

11 Didn't you once write about a probe-mic method for fitting transcranial instruments?

It's good to know that at least one person read those articles![10-11] Yes, we detailed a method whereby probe-mic testing was used to measure the transcranial thresholds (in dB SPL) of the poor ear by placing a probe microphone in the poor ear while measuring thresholds at 250-8000 Hz. This value (in dB SPL) was coined "transcranial threshold (TCT)" and represented the lowest level by which the real-ear aided response (REAR) in the poor ear had to exceed TCT in order to verify that the output from the hearing aid provided sufficient amplification to be heard in the cochlea of the better ear. In this way, you actually have a "prescriptive target" for your transcranial fitting.

12 I might try that. But, the bigger issue seems to be that not many of your subjects believed the quasi-transcranial fit solved their listening problems. Also, doesn't the idea of putting a hearing aid into a "dead" ear almost seem unethical?

Yes, on the surface, it might appear that placing a hearing aid into a "dead" ear is unethical. But you must remember that this approach is not aiding the "dead" ear but rather using it as a conduit to apply amplification to the normal ear on the opposite side. It's really not any different in concept from placing a piece of tubing into a normal ear and applying amplification to a normal ear, as we do routinely in traditional CROS fits.

13 It seems that advances in DSP might help us address some of the shortcomings you mention. Have you given any thought to re-visiting quasi-transcranial fits using DSP technology?

Oh, great minds think alike! Yes, I've recently revisited quasi-transcranial because of advances in DSP. The greatest potential advantage of DSP is the availability of feedback management and noise reduction. Remember, one limiting factor preventing success with the analog version was that feedback did not allow sufficient output for the measured REAR to exceed the transcranial threshold (TCT in dB SPL) in the poor ear.

We're currently completing a pilot project on four single-sided deafness (SDD) patients using a high-power DSP BTE aid with excellent feedback management. If successful, this project will be expanded to a larger subject pool and communication will begin with interested hearing aid manufacturers to determine the feasibility of interacting noise reduction to reduce the output of the aid if noise is detected on the poor side as described above.

14 Earlier, you mentioned a "true-transcranial." How does this differ from a quasi-transcranial"?

Actually, there are three options of "true-transcranial." The first is a straightforward bone-conduction fitting in which a bone vibrator is placed on the mastoid of the "dead" ear. While 30 to 50 dB or more of gain may be required for the output from an AC quasi-transcranial CROS to reach the cochlea of the better ear, minimal gain is required for a signal delivered via BC to reach the cochlea of the better ear. This is, of course, because interaural attenuation via BC is virtually 0 dB.

One way to accomplish this is with an eyeglass fitting, and using this style we recently evaluated seven patients with unilateral hearing loss.[10] Six of the seven patients decided to purchase the hearing instrument (rejection rate of 14.3%). Interestingly, one patient who decided to purchase the BC hearing aid had a long history of experience with CROS amplification. These seven patients reported improvements in communication similar to those described earlier by our patients using a quasi-transcranial CROS. Whereas the acceptance rate at Washington University for conventional CROS fittings for this population is 10%, the acceptance rate was 86% for an eyeglass BC hearing aid.

Although this fitting was very successful with this small group of patients, a BC eyeglass fitting presents numerous obstacles. First, when the eyeglass is removed the patient will be without amplification. Second, not all unilaterally hearing-impaired patients have visual impairments and therefore may not be interested in wearing an eyeglass fitting.

This problem was solved for two patients by having the optician fit clear glass into the eyeglass frame. Third, it is very important for the bone vibrator to fit directly on the mastoid with sufficient static pressure to deliver the amplified signal effectively to the mastoid process.

15 I've never fitted this type of hearing aid. Are bone-conduction hearing aids still available?

Yes, an eyeglass BC aid is available (from Starkey Laboratories) with a series of 10 extension tips to place the bone vibrator directly on the mastoid. It is often necessary to make several visits to an experienced optician before the ideal placement and pressure are achieved. For some patients, the required pressure necessary for maximum benefit from this type of hearing instrument may cause irritation of the skin under the bone vibrator, discomfort, and headaches. These problems led to rejection by one of our patients, although he found the hearing aid fitting beneficial.

In addition, audiologists tend to avoid eyeglass fittings because they assume the patient would not be interested in it. A body BC fit is still available through Oticon and, I'm sure, from other manufacturers that make body aids. BC aids are also available coupled to a body aid with the BC vibrator held in place via a headband.

16 As you say, traditional BC aids have many problems. I know there is now a Bone-Anchored Hearing Aid (BAHA) available. Can you tell me about that?

Yes, in 2002, the Food and Drug Administration approved the BAHA by Cochlear Corporation for patients with UHL.[12-16] Recently, the Divino, a digital version of the BAHA, was introduced. In the Divino, the directional microphone is encased in the unit, whereas in the previous Compact version, the directional microphone was an attached option. Even more recently, Cochlear Corporation has introduced the Intenso, which reportedly provides 13 dB greater output than the Divino. However, in the Intenso, a directional microphone is not encased in the device.

With the BAHA, the patient undergoes outpatient surgery during which a titanium screw and abutment are implanted into the mastoid process of the dead ear. In the adult, it takes about 3 months for the implant to osseointegrate with the mastoid bone before the BAHA device can be snapped into the abutment and fitted.

Currently, the BAHA is available in the Intenso, Divino, and Cordelle II. The Cordelle II provides about 13 dB greater output than the Divino and is typically used for patients who report that the gain provided by the Divino is insufficient. The Cordelle has a built-in telecoil (M/T/MT switch), a tone switch for low- and high-frequency attenuation, and K-Amp™ signal processing that permits adjustment of the compression kneepoint and the loudness boost.

The Divino has two programs (one for quiet and the other for noise) and uses a size 13 battery. It has a volume control/on/off, tone control, and output control (AGCo). The Divino can connect directly to hearing assistive technology (FM, infrared, Walkman devices, etc.) via direct auditory input (DAI). Finally, a telecoil "wand" that plugs into the bottom of the Divino may be ordered as an option.

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

In January 2006 the BAHA became eligible for coverage under Medicare. On the surface, this would appear to be a positive step toward bringing this technology to older patients. Unfortunately, as of this writing, audiologists are not reimbursed for their time and expertise when fitting this device. For this reason, many facilities are rejecting this technology as an option for Medicare patients. And, because BAHA is being denied to our Medicare patients, it must be denied to *all* patients, including both other third-party reimbursed and our self-paying patients. For now, at least at the facility where I work, BAHA is not being offered to anyone.

17 Who is a candidate for the BAHA?

A patient for whom *no better alternative treatment* exists may be considered a candidate for the BAHA if he/she:

(1) has a better-ear BC pure-tone average (BCPTA) at 500, 1000, 2000, and 3000 Hz that is 20 dB HL or better (the closer to 0 dB HL the better);
(2) is free from a generalized disease process that could result in poor wound healing;
(3) is unable to use conventional AC or BC hearing aids;
(4) is strongly motivated to try this surgical procedure;
(5) is able to understand the objectives and expectations of this method of amplification;
(6) is psycho-emotionally stable enough to maintain the hygiene of the percutaneous titanium abutment;
(7) is at least 5 years old.

18 Earlier, you said there are three true BC options. You've mentioned two. What's the third?

A fitting option that recently became available for UHL patients is the TransEar from Ear Technology Corporation (for a photo, go to www.transear.com). With this device, acoustical signals are transferred to a small BC vibrator encased in an earmold placed in the ear canal of the poorer ear. The BC signal in the poor ear is then transferred to the cochlea of the better ear via BC. The signal processing is digital and can be programmed through NOAH to shape the frequency response. This device is available with two programs with different frequency responses. The first program is for quiet listening conditions, while the second program is designed for listening in noise.

I tried this product with three patients at our clinic. Two were current users of the BAHA, while the third had no prior experience with amplification. Unfortunately, due to problems related to feedback, the patients were unable to achieve a sufficient amount of gain. Based on these observations, the manufacturer redesigned the wire connecting the BTE to the BC encased in the ear canal and produced a bone vibrator is significantly smaller than the initial product. I've tried this newer version on three subjects and thus far it has resulted in significant improvement over the first version in the amount of achievable gain,

as well as providing greater comfort.

19 Based on your experience with these quasi and true BC devices, how critical is the bone-conduction threshold of the better ear?

This is a very important question. Based on my experience, the closer BC thresholds at 250-4000 Hz in the better ear are to 0 dB HL, the higher the probability of success. Some manufacturers suggest BC thresholds in the better ear can be as great as 20-30 dB HL, but I have not found that to be true.

You also have to think about the possibility of the BC thresholds in the better ear growing worse over time and creating a situation in which a device that was effective at the time of the fit becomes ineffective. When the BC threshold is closer to 0 dB, there is a better chance of success at the initial fit and also of the fitting remaining effective for a longer time.

20 Our time is nearly up. Is there anything you'd like to add?

Yes, my primary goal in this conversation was to reinforce the idea that several fitting options are available for the UHL patient. Hopefully, the fitting options I've mentioned will instill the concept that patients with UHL experience significant communication problems. Simply advising them "Direct your head toward the desired signal" or recommending CROS amplification to the better ear should not be seen as the only rehabilitative options for these patients.

Over the years, I've gained considerable experience with the fitting options we've discussed, and I urge everyone to consider wireless CROS, TransEar, BAHA, quasi-transcranial CROS, or bone-conduction options for patients with UHL. I am convinced that one or more of these choices will be more beneficial in many cases than the "traditional" options.

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