fitting severe and profound

hearing losses with advanced technologies

BY DONALD J. SCHUM, PhD

JEFFREY LEESER

As a field, we try to use as many standardized or commonly agreed upon approaches to fitting amplification as possible. We all recognize that each fitting is unique. However, for the sake of clinical efficiency, we try to apply consistent techniques when fitting new hearing aids. We also recognize that different hearing losses such as mild, ski-slope, unilateral, or conductive require modifications of standard approaches. This reality is particularly true when considering those patients with the greatest amount of threshold changes: severe and profound losses.

Fitting patients with severe and profound hearing loss has always challenged hearing care professionals. Compared to patients with less hearing loss, the fitting process for patients with severe and profound losses is complicated by the nature of the damage to the auditory system and the patient's long history of hearing aid use. The overall goal of the fitting is no different than with any other patient: to allow the patient to get the best possible use out of the remaining hearing. The tactics to achieve this goal with patients with severe and profound losses are different in several important aspects.

What do we know about patients with severe and profound hearing loss?

■ **Although all of the patients have audiometric thresholds 75 to 80 dB HL or worse, the variation in auditory abilities varies greatly from patient to patient.** For patients with hearing loss in the mild and moderate ranges, the nature of the physiological changes is reasonably consistent such that standardized fitting rationales are good initial approximations of required gain and compression. However, as the threshold loss becomes greater, the nature of the physiological damage will become more complicated. Patients with lesser degrees of hearing loss usually have some combination of outer hair cell loss with (perhaps) some inner hair cell loss. For patients with thresholds in the severe or profound range, there is also the likelihood of more significant inner hair cell disruptions, metabolic changes in cochlear chemistry, membrane disruptions, large scale neural cell death, or ossification. The pattern of damage will vary from patient to patient such that the audiometric configuration may tell little about the underlying integrity of the sound processing system.

■ **These patients present with a limited dynamic range.** It is well known that, despite changes in thresholds on the order of 80, 90 or 100 dB or more, the change in the uncomfortable loudness level from normal may only be 10 to 30 dB. The typical patient with severe hearing loss may have a dynamic range of only 30 dB, and a patient with a profound loss may offer even less room to work with. In contrast, for some patients, again depending on the nature of the hearing loss, it may not be possible to establish an upper limit of useable hearing due to output limits on audiometers. Some patients may simply have so much damage that it is not possible to provide enough auditory stimulation to create a perception of sound being too loud.

■ **Within the patient's dynamic range, the usability of the remaining hearing will vary from patient to patient.** Simply being able to establish a threshold at a given frequency does not ensure that the hearing in that frequency region is intact enough to process a complex signal such as speech. Given the variability in the physiological changes from ear to ear as discussed above, the patient's resolution ability[1] will be difficult to predict from the thresholds alone. One basic metric of auditory resolution is speech understanding without visual cues, which has been shown to vary dramatically from patient to patient with severe hearing loss. In **Figure 1**, the range of maximum speech understanding in quiet (without visual cues) is shown for a large group of patients with sensorineural hearing loss.[2] Notice the large range of performance once the average hearing loss is greater than 70 dB HL.

■ **Unlike patients with lesser degrees of hearing loss, patients with severe or profound loss may be focused on obtaining sufficient auditory stimulation.** They have a limited amount of hearing and they may want to make sure that hearing is being used. Patients with mild or moderate hearing loss typically feel like they receive plenty of stimulation; they are looking for help in isolating speech from other competing

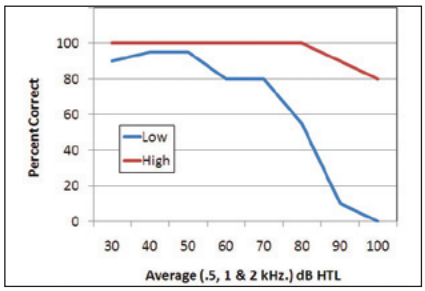

Figure 1: The maximum (red) and minimum (blue) word recognition scores for a large group of patients as a function of average hearing loss, based on the data presented by Lamore et al. (1990).

sounds. Although this desire is certainly at play for those with severe and profound loss, there is a further need to simply hear things. Simple sound awareness and a connection to the environment may be limited.

■ **The patient's hearing loss and hearing aid history become important factors in a new fitting.** These patients will be quite attuned to the sound of their current hearing aids and are quick to compare any new technology to what they are used to hearing. Quite simply, they may have firm opinions as to how sound should "sound."

For patients with longstanding severe or profound hearing loss who otherwise do not receive cochlear implantation, advanced technology can offer new possibilities they may not have experienced in the past. If these patients were fit originally with hearing aids 5, 10, 20 or more years ago, they may have only experienced power, linear amplification. Early attempts to use non-linear amplification with severe hearing loss met with limited success.[3,4] However, with a better understanding of how to create non-linear solutions along with adjustments to environmentally adaptive circuits such as noise reduction and automatic directionality, the hearing aid industry has created effective advanced solutions for these patients.[5]

The strategy that guides the fitting of modern advanced technology amplification to a patient with this much hearing loss is to *challenge the auditory system with more information than has been available in the past*. As noted above, these patients may have firm ideas as to what they expect from the sound of hearing aids. They typically have a long history of amplification and are highly dependent on their hearing aids. Changes in the sound processing may not be immediately appreciated. However, as more new information is provided and as the patient experiences improved communication functioning, the value of the new amplification approach will become evident.

There are several keys to fitting amplification to patients with severe and profound losses.

Improve Audibility

Compared to traditional linear fittings, modern power hearing aids should provide access to sounds that the patient simply may not have been hearing for quite some time. The improved audibility is driven by two factors: improved gain for soft and moderate sounds, and extended bandwidth. Early attempts to provide wide dynamic range compression (WDRC) in power fittings failed probably because too much compression was applied, especially compression using fast attack and release times.

As a field, we have learned how to apply compression in a more selective manner in order to maintain an acceptable sound quality for the patient. Additionally, improved feedback cancellation

approaches and improved receiver technology allow us to provide significant gain and output out in the regions above 2 kHz (which has traditionally been about the upper limit of usable gain in power fittings). Of course not all patients with severe and (especially) profound hearing loss can benefit from an extended bandwidth, but many more than we thought seem to be able to glean something useful from the upper frequencies.

Assertive Patient Management

As noted above, patients with severe or profound loss may be resistive to a change in the sound quality of their hearing aids. The sound of a powerful linear hearing aid with a large response peak in the 1 kHz. region (a typical past power fitting) is different than a non-linear, broader band response. The professional may need to work hard to get the patient to give the new fitting a chance and some time. There is every reason to believe that an advanced technology non-linear fitting should provide the patient with information that has not been available in the previous fittings. The benefit of the new signal processing approach may not be immediately apparent to the patient and quick rejection is often looming.

Power Adjustments

Although there is a strong possibility that a patient with severe or profound loss will benefit from the improved audibility provided by WDRC amplification, the application of gain and compression must reflect the specific needs of those with this much hearing loss. These patients tend to focus on a full sound quality, again reflecting a desire for auditory stimulation. One strategy to achieve this effect is to focus on the "mids & mids," or mid frequencies and mid-level (conversational speech) inputs. With a power linear response, the patient will tend to use lower frequency and louder inputs as a guide to setting the device. With the application of WDRC, the mids & mids can become the focus of the sound of the devices.

Figure 2 provides the NAL-NL1 response (as applied in a commercial instrument) for two different hearing losses with the same modest slope but different degrees of loss. Notice that for the moderate hearing loss in the right ear, the prescribed insertion gain response is relatively flat from 1 kHz through 7 kHz. In contrast, for the severe loss, the response peaks in the 1 to 2 kHz region and then rolls off slightly in the higher frequencies. The patient will still have access to sound above 2 kHz, but the focus of the response is more mid-frequency. Also notice that the prescribed gain for a 65 dB input is closer to the gain prescribed for a 45 dB input than for an 80 dB input. The combination of the mid-frequency response peak and the mid-level gain will have the effect of providing a full sound quality for conversational level speech.

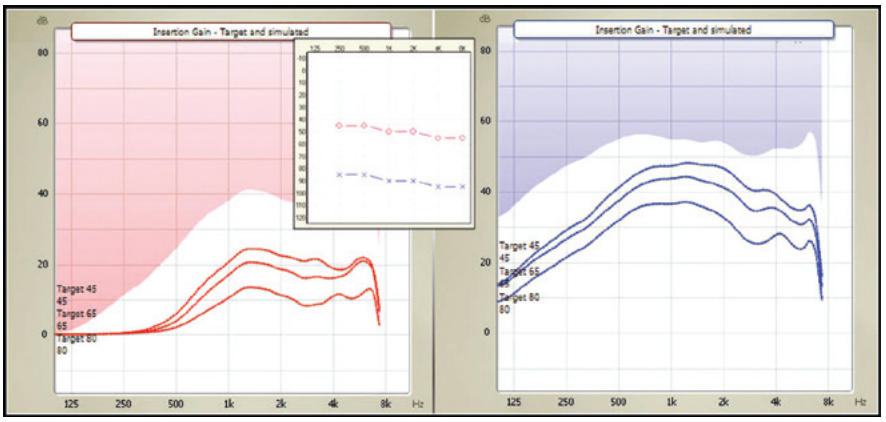

Figure 2: The NAL-NL1 prescribed insertion gain for inputs of 45, 65 and 80 dB SPL for the audiograms shown in the inset, as applied in a commercially available hearing aid.

In addition, patients with this much hearing loss may need longer time constants than are typically used in syllabic (fast acing) compression. The damage to the sound processing mechanisms may be such that a densely compressed speech signal may be difficult to decode. The patient may not receive the full benefit of the improved audibility provided by WDRC. Slower attack and release times (for example, attack times of 10 to 20 ms and release times on the order of 500 ms or more) will preserve more of the short term linearity of the amplified speech signal. That linearity on a phoneme-to-phoneme basis may be essential to extract information.

Explore the Hearing

As indicated above, the professional should expect greater sound processing variability from patient to patient than may be present in the population of more typical hearing aid users. Prescribed responses such as the NAL-NL1 response in Figure 2 should be viewed only as a starting place. The audiogram does not provide a complete picture of how the ears are working. Some of these patients will be able to make use of the extended bandwidth offered by the most recent additions to the power hearing aids market, but some will not. Even with the recommendations about compression stated above, some of these patients will simply not be able to extract meaningful information from a compressed signal and may need a linear response. Others will have enough remaining auditory resolution to handle a highly compressed signal and may even be able to handle faster time constants.

Even after an appropriate adjustment period, some patients still may prefer a low frequency dominated signal. Since the UCL will vary from patient to patient, individual assessment of the highest acceptable output setting is important for these patients. Since fitting software will tend to predict a limited dynamic range and since these patients are sensitive to signals becoming overly compressed, individual assessment of the UCL may allow for the operating output range of the device to be increased so that the amount of compression needed to map sounds into the dynamic range can be decreased. All of these possibilities are difficult to predict but easily can be evaluated through adjustments to flexible amplification.

Apply Automatics Carefully

Patients with severe or profound loss, like all other hearing aid patients, look for help in background noise environments. However, they may respond negatively to the effects on loudness and sound quality that come along with noise reduction and automatic directionality. The nature of noise reduction is to reduce gain in frequency regions that are dominated by noise. Often, this will include low frequencies, and those low frequencies carry a significant portion of the loudness perception of a hearing aid response. When these low frequencies are reduced, the patient with severe or profound hearing loss may dislike the loss of signal. Again, the reaction will vary from patient to patient, but it should not be assumed that all patients will appreciate the noise reduction effect.

The same is true of the reaction to directionality. When a hearing aid shifts from omni to directional, there will be a drop in loudness as a portion of the signal is reduced. Even if the signal-to-noise ratio is improved, the patient may still not prefer the directional response because of the changes in loudness. One guard against this effect is directional circuits that keep the low frequencies in omni and allow only the high frequencies to shift from omni to directional. This will minimize the perception of a loss in loudness while still offering a directional improvement in the frequency regions where the majority of speech information is transmitted.

Final Thoughts

The digital revolution was late to come to power and super power hearing aids. However, the market is now providing an ever increasing number of product options. Important improvements such as feedback cancellation, smaller BTEs, connectivity to external devices, and receiver-in-the-ear (RITE) design are now a reality for those with the greatest amount of hearing loss. The professional serves as the guide to this new technology. The approach to fitting amplification to these patients is different in several important ways; however the goal remains the same as with all hearing aid fittings: to allow the patient to achieve the highest possible levels of auditory performance. $

References

1. Boothroyd, A. (1993). Profound Deafness. In *Cochlear Implants*, R. Tyler (Ed.) pp. 1-34. San Diego, CA: Singular Publishing.
2. Lamore, PJ, Verweij, C, & Brocaar, MP. (1990). Residual hearing capacity of severely hearing-impaired subjects. *Acta Otolaryngologica Supplement*, 469, 7-15.
3. Boothroyd, A, Springer, N, Smith, L, & Schulman, J. (1988). *Journal of Speech & Hearing Research*, 31, 362-376.
4. DeGennaro, S, Braida, LD, & Durlach, NI. (1986). Multichannel syllabic compression for severely impaired listeners. *Journal of Rehabilitation Research and Development*, 23, 17-24.
5. Souza, P, & Bishop, R. (1999). Improving speech audibility with wide dynamic range compression in listeners with severe sensorineural loss. *Ear and Hearing*, 20:6, 461-470.

Donald J. Schum, PhD, is Vice President, Audiology & Professional Relations, at Oticon Inc. Contact him at djs@oticonusa.com.