What is severe hearing loss?
Historically, severe loss refers to auditory thresholds between 70 and 90 dB HL. The obvious problem caused by severe loss is difficulty hearing soft sounds, and most individuals with severe loss can make out little if any conversation unless the speech is amplified. The problem is even worse if there is background noise, or if visual cues are not available. For example, many patients with unaided severe loss do not use the telephone, attend movies or enjoy meeting friends in restaurants. Unfortunately, amplifying speech offers only a partial solution to this problem. Patients with severe hearing loss complain that amplified speech is louder, but unclear. Recent studies of auditory physiology and perception suggest that these individuals have significant damage to both outer and inner auditory hair cells which results in broadened auditory filters. Simply put, the patient’s auditory system cannot detect a difference between two sounds that differ in frequency (pitch). The ability to make that distinction is necessary for almost every aspect of hearing. Without good frequency selectivity, we cannot hear the difference between ‘me’ and ‘knee’, distinguish speech from unwanted background noise, ignore interfering environmental sounds, or listen to music without distortion.

Severe hearing loss affects all aspects of everyday life. A patient with binaural severe loss recently commented to me that although he had worn hearing aids for 20 years, they had all failed to provide for adequate speech understanding, and he continued to feel isolated during any social gatherings. As a group, individuals with severe hearing loss report communication problems and feelings of isolation leading to decreased involvement in daily activities. Until human auditory hair cells can be regenerated or we develop a novel and completely successful treatment for sensorineural hearing loss, clinicians need to use the tools at their disposal to maximum advantage. For most patients with severe loss, the primary tool will be well-fitted hearing aids.

Improving audibility and loudness comfort, hopefully with minimal distortion
From decades of study, we know that improving audibility is the necessary foundation for improving speech understanding. Multichannel wide-dynamic range compression (WDRC) amplification offers us an excellent opportunity to improve audibility across a range of speech input levels. With this processing strategy, we can provide greater gain for low-level inputs than for high-level inputs and variable gain can be set within each compression channel to reflect the limitations of the listener's audiogram. Consider a simple example, a hypothetical listener with 60 dB HL thresholds below 1 kHz, 80 dB HL thresholds above 1 kHz, and loudness discomfort levels of 100 dB HL at all frequencies. Gain is applied to bring lower intensity speech above threshold, while maintaining higher-level speech below the discomfort level. Above 1 kHz, there is less energy in the conversational speech spectrum and the listener has a smaller dynamic range. In the high frequencies then, we need to further increase the gain for low-intensity speech. The end result will be a hearing aid fitted with compression at all frequencies, but with more compression applied to sounds above 1 kHz.

In most digital aids, the amount of compression is controlled by adjusting compression ratio and compression threshold in combination with time constants. In theory, to achieve the best audibility for a severely-impaired listener with a small dynamic range we would use a low compression threshold, high compression ratio, and short attack and release times. Carried to an extreme this would provide perfect audibility of all speech cues. Such an effect is undesirable however when we remember that clear speech depends on spectrotemporal contrasts, as the unique frequency spectrum of each phoneme varies rapidly over time. More compression channels coupled with higher compression ratios

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will reduce spectral contrast, and short release times coupled with higher compression ratios will reduce temporal contrast. Our work shows that increasing compression beyond a certain point results in rapidly degraded intelligibility for vowels, and consonants, leading to poor perception of meaningful sentences. This is not usually a problem for listeners with mild to moderate loss, where standard prescriptive methods rarely prescribe compression ratios greater than 2:1. However, target compression ratios for severely impaired listeners can be much higher. Achieving those compression ratios improves audibility, but at the expense of speech clarity. How then do we resolve this and pick the appropriate hearing aid settings for each individual with severe loss?

A complicating factor is the wide range of hearing aid benefit seen in this population, even with appropriately fitted hearing aids. Figures 1 and 2 illustrate the benefit of multichannel WDRC hearing aids (expressed as improvement in conversational speech recognition, compared to a linear hearing aid for the same listener) for 23 listeners with severe loss. Negative benefit scores indicate that listeners did worse with WDRC than with linear amplification. In Figure 1, listeners are grouped according to their pure-tone average thresholds, in Figure 2, according to their quiet speech recognition score (measured under headphones at 40dB above pure-tone average). On average, all listeners benefited from the multichannel WDRC processing except those individuals with the poorest thresholds and the worst speech recognition. Note also that these results are for conversational speech; benefit for low-intensity speech where multichannel WDRC drastically improved audibility was considerably greater. It would be helpful if we could use such data to make decisions about hearing aid choices for individuals. However, for clinical predictions, the variability is too large. An individual with a severe loss who has a pure-tone average of 75dB HL and unaided speech recognition scores of 55% might show speech recognition improvements as high as 10%, or decrements as low as 20%, when comparing WDRC processing to linear processing. Understanding the factors which determine individual benefit will aid clinical decision making.

One specific concern is that with broad auditory filters and poor frequency selectivity, a severely-impaired listener depends more on the temporal than on the spectral aspects of the signal thus we should avoid unnecessary distortion of temporal cues. Some hearing aid manufacturers have begun to take this position as well. The documentation for using slow-acting compression in one commonly fitted digital aid states that 'The big advantage of this [program] is that the time structure of speech signals is not changed... The time structure contains valuable information... to distinguish different phonemes'. In one recent study, we reasoned that if listeners with severe loss depend heavily on temporal cues to speech recognition, they ought to perform more poorly with fast-acting WDRC that alters temporal cues. Listeners with less hearing loss, who have better access to spectral cues, ought to be unaffected by differing time constants. We fitted two groups of study volunteers: one with binaural mild-to-moderate loss and the other with binaural severe loss. All listeners received a hearing aid set as it would be in the clinic, with one exception: we created two different programs, a 'fast' WDRC program (short attack/release times) and a 'slow' WDRC program (long attack/release times). The listeners with severe loss had consonant recognition scores that were about 5% worse, on average, with the fast WDRC; the listeners with mild loss performed the same with both WDRC conditions. The data suggest that listeners with severe loss should be fitted with slow WDRC. However, it was
of great interest to us that a minority of patients with severe loss did better with fast-acting than with slow-acting compression. They tended to be the listeners with the poorest thresholds, suggesting that their need for improved consonant audibility outweighed the distortion effects of the fast compressor. Alternatively, those individuals might have had better spectral discrimination than their peers, or used a listening strategy which placed less ‘weight’ on temporal cues. For now, it seems reasonable to use multichannel WDRC with the lowest possible distortion (that is, lowest compression ratio and longest time constants) that will achieve acceptable audibility. Audibility can be assessed using multilevel probe microphone measurements, aided speech recognition, and/or benefit questionnaires.

In the quest for improved speech audibility, acoustic feedback is the enemy. No patient will wear a squelching aid (or, at least, there may be strenuous objections from family members!). Once an innovation and now a standard feature, digital feedback suppression allows up to 35 dB more gain than aids without digital feedback management. This is a clear advantage over the ‘old’ method of using tighter fitting earmoulds and/or smaller vents to control feedback. Accordingly, some means of digital feedback suppression is a necessity in any hearing aid ordered for an individual with severe loss.

Severe high-frequency hearing loss

Some patients have relatively good (or, at least, relatively better) low-frequency performance at that frequency range. On one hand, it may seem inconceivable that patients with severe high-frequency loss present unique challenges, but also ultimately determine hearing aid benefit for patients. It seems likely that individual auditory processing abilities, combined with cognitive ability to direct auditory attention and integrate contextual and visual cues, will ultimately determine hearing aid benefit for an individual. Patients with severe hearing loss present unique challenges, but also unique rewards when they receive a hearing aid that allows them to hear conversation, participate in family events and enjoy daily activities.

References