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Prescriptive Amplification Recommendations for Hearing Losses with a Conductive Component and Their Impact on the Required Maximum Power Output: An Update with Accompanying Clinical Explanation

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Abstract

Background: Hearing aid prescriptive recommendations for hearing losses having a conductive component have received less clinical and research interest than for losses of a sensorineural nature; as a result, much variation remains among current prescriptive methods in their recommendations for conductive and mixed hearing losses (Johnson and Dillon, 2011).

Purpose: The primary intent of this brief clinical note is to demonstrate differences between two algebraically equivalent expressions of hearing loss, which have been approaches used historically to generate a prescription for hearing losses with a conductive component. When air and bone conduction thresholds are entered into hearing aid prescriptions designed for nonlinear hearing aids, it was hypothesized that that two expressions would not yield equivalent amounts of prescribed insertion gain and output. These differences are examined for their impact on the maximum power output (MPO) requirements of the hearing aid. Subsequently, the MPO capabilities of two common behind-the-ear (BTE) receiver placement alternatives, receiver-in-aid (RIA) and receiver-in-canal (RIC), are examined.

Study Samples: The two expressions of hearing losses examined were the 25% ABG + AC approach and the 75% ABG + BC approach, where ABG refers to air-bone gap, AC refers to air-conduction threshold, and BC refers to bone-conduction threshold. Example hearing loss cases with a conductive component are sampled for calculations. The MPO capabilities of the BTE receiver placements in commercially-available products were obtained from hearing aids on the U.S. federal purchasing contract.

Results: Prescribed gain and the required MPO differs markedly between the two approaches. The 75% ABG + BC approach prescribes a compression ratio that is reflective of the amount of sensorineural hearing loss. Not all hearing aids will have the MPO capabilities to support the output requirements for fitting hearing losses with a large conductive component particularly when combined with significant sensorineural hearing loss. Generally, current RIA BTE products have greater output capabilities than RIC BTE products.

Conclusions: The 75% ABG + BC approach is more appropriate than the 25% ABG + AC approach because the latter approach inappropriately uses AC thresholds as the basis for determining the compression ratio. That is, for hearing losses with a conductive component, the AC thresholds are not a

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measure of sensorineural hearing loss and cannot serve as the basis for determining the amount of desired compression. The Australian National Acoustic Laboratories has been using the 75% ABG + BC approach in lieu of the 25% ABG + AC approach since its release of the National Acoustic Laboratories—Non-linear 1 (NAL-NL1) prescriptive method in 1999. Future research may examine whether individuals with conductive hearing loss benefit or prefer more than 75% restoration of the conductive component provided adequate MPO capabilities to support such restoration.

Key Words: Assistive listening devices, hearing aids

Abbreviations: ABG air-bone gap; AC air conduction; BC bone conduction; BTE behind-the-ear hearing aid; CAM2 Cambridge Method for Loudness Equalization 2—High-Frequency; DSL m[i/o] desired sensation level multi-stage input/output algorithm; HFA high-frequency average; OSPL90 output sound pressure level for a 90 dB input level; MPO maximum power output; NAL National Acoustic Laboratories; NAL-NL2 National Acoustic Laboratories—Non-linear 2; NAL-R NAL—Revised; RIA receiver-in-aid; RIC receiver-in-canal

The earlier National Acoustic Laboratories (NAL) formulas for linear hearing aids (NAL, Byrne and Tonisson, 1976; NAL—Revised [NAL-R], Byrne and Dillon, 1986) prescribed gain approximately equal to half the sensorineural hearing loss (i.e., 0.46) at the three-frequency average of .5, 1, and 2 kHz, which is similar to the half-gain rule of Lybarger (1963). Pertinent to the topic discussed herein, for hearing losses with a conductive component, Lybarger (1963) proposed that gain should equal half the air-conduction (AC) threshold plus one-quarter the air-bone gap (ABG) in a frequency-specific manner. ABG is the difference between an AC threshold and a bone-conduction (BC) threshold. Lybarger's proposal became the "rule-of-thumb" approach for establishing the gain requirements for hearing losses with a conductive component. Hence, the past rule of thumb was reintroduced within the NAL-R formula (Byrne and Dillon, 1986) because the original NAL formula of Byrne and Tonisson (1976) had been designed around the requirements of persons having mild to moderately severe sensorineural hearing losses only. The past rule-of-thumb amount has been disputed (Byrne, 1983), but increasing the prescribed gain for each ear by approximately 20–25% of the ABG remained the recommended approach for several years (Byrne and Dillon, 1986; Berger et al, 1989; American Speech-Language-Hearing Association, 1998)

The past rule of thumb for conductive hearing loss gain requirements can be expressed algebraically as

$$1/2\mathrm{AC} + 1/4\mathrm{ABG}.$$

In turn, the formula also can be expressed as

$$1/2(\mathrm{BC} + \mathrm{ABG}) + 1/4(\mathrm{ABG}),$$

which simplifies to

$$1/2\mathrm{BC} + 3/4\mathrm{ABG}.$$

The primary intent of this brief clinical note is to demonstrate that while the expressions are algebraically equivalent, when air- and bone-conduction thresholds are entered into hearing aid prescriptions designed for nonlinear hearing aids, these two expressions do not yield equivalent amounts of prescribed insertion gain and output. From this data, this article demonstrates why the NAL chose to use 1/2BC + 3/4ABG since the 1999 release of NAL—Non-linear 1 (NAL-NL1) and the current release of NAL—Non-linear 2 (NAL-NL2) in lieu of the previous rule of thumb, 1/2AC + 1/4ABG, used in other prescriptive predecessors by addressing the following question: What is the difference in prescribed insertion gain, output, and resulting compression ratios between prescriptive approaches for conductive hearing loss components applying gain based on a

1. 25% of the ABG plus an AC threshold-based prescription (25% ABG + AC)
2. 75% of the ABG plus a BC threshold-based prescription (75% ABG + BC)?

This study is of expected interest to dispensers of hearing aids because of clinic practice that persists with regard to

1. adding 20–25% of the ABG to generated prescriptive targets from AC thresholds, the preceding first approach
2. the static correction of adding 10 dB to generated targets from AC thresholds alone without regard to size of the actual ABG.

The latter of these two clinical practices has no supporting evidence base and by its static nature of applying an additional 10 dB is incapable of variation based on the size of the conductive component but, hearsay indicates, appears to be used with some frequency among dispensers of hearing aids. Having a clinical approach for prescribing amplification that considers the size of the ABG seems intuitive and is scientifically defensible within the context of selective amplification for individual patients. Hence, the static correction of adding to 10 dB will not be considered or discussed any further herein. As testimonial evidence to the lack of confidence, and perhaps information, in some clinical practice sites regarding the prescriptive recommendation of gain and compression parameters for conductive components of hearing impairment based on measured thresholds of the air-bone conduction gap, Martin (2012) offers the advice of ignoring the air-bone gap and alludes to the vague notion of simply doing what is best for the patient.

Of relevant historical interest to hearing aid prescriptions is to recount why 1/4 (25%) of the ABG above the prescription based on AC thresholds was used in the first place. One possible explanation is that early hearing aid prescriptions were designed with a focus on individuals having sensorineural hearing loss, where AC thresholds were within 10 dB of BC thresholds; in the case of diagnosed sensorineural loss, only AC thresholds were needed for calculation (e.g., the original NAL method of Byrne and Tonisson [1976]; the 1/3 and 2/3 methods of Libby [1986], the POGO method of McCandless and Lyregarrd [1983]; the Berger [1976] method). When a hearing aid prescriptive fitting considered the ABG, in those years adding the additional 25% of the ABG onto the AC threshold-based prescription was a straightforward calculation even if done by "hand." Today generic hearing aid prescriptions (e.g., NAL-NL2; Cambridge Method for Loudness Equalization 2—High-Frequency, CAM2; and desired sensation level multi-stage input/output algorithm, DSL m[i/o]) are able to handle both AC and BC threshold assessment data simultaneously for the calculation of recommended targets.

The NAL-NL2 procedure (Keidser et al, 2011), like its predecessor NAL-NL1 (Dillon, 1999; Byrne et al, 2001), has the principle of applying its prescriptive rule to the BC thresholds and then applying three-quarters of the ABG to determine insertion gain (1/2BC + 3/4ABG). The decision to compensate for less than the full amount of the conductive component has been supported by the research of Walker (1997a, 1997b) at NAL. The tendency for patients to prefer less than full restoration of the conductive component was, at least in part, owing to the maximum output of the hearing aid being too low in comparison to the gain required for full restoration (Walker, 1997b). In other words, patients did not like the sound quality because the hearing aid was saturated, and presumably distortion was high. Accordingly, using enough gain to restore fully (100%) the conductive component ABG caused the hearing aid to frequently saturate, resulting in distortion. Shortly afterward Walker (1999) indicated with a sample population of only six subjects that 100% ABG restoration can be preferred in easy listening environments for intelligibility and pleasantness when maximum power output (MPO) exceeded the amplified frequency response of the input signal. Therefore, the amount of ABG restoration preferred could well depend upon the MPO capabilities of the hearing aid as well as the listening environment and attribute of desired sound quality.

A sampling study of other prominent generic prescriptive techniques (i.e., Johnson and Dillon, 2011) indicated that DSL m[i/o] provided much less insertion gain than CAM2 or NAL-NL2 for hearing losses containing a conductive component. One possible reason may be continued usage of an AC threshold plus 25% of the ABG approach based on the following statements from Scollie et al (2005):

> With the DSL m[i/o] general aim of maximizing comfortable audibility, for conductive hearing losses in particular the predicted upper limits of comfort (ULC) are increased that in turn makes the input/output function more linear applying more gain. Limits to this approach include not exceeding 140 dB SPL in the ear canal with the ULC increased by 25% of the audiometric ABG, averaged across 500–4000 Hz to a maximum 60 dB ABG. (p. 190)

The CAM2 prescriptive method appeared to use near 100% restoration of the ABG for hearing loss having a conductive component (Johnson and Dillon, 2011). Again, 100% restoration of the ABG may be suitable when MPO of the hearing aid can support the prescribed insertion gain for moderate to high input levels without causing the real ear aided response to saturate and degrading sound quality (Walker, 1999; Dillon, 2001; Mueller and Hornsby, 2002).

With regard to MPO limitations, the fitting audiologist is cautioned when prescribed insertion gain approximates 70 dB for average speech level inputs of 65 dB SPL or 55 dB for high speech level inputs of 80 dB SPL. In both cases, the output would approximate 135 dB. This number is near the customary upper dB limit of MPO (mid-to-high 130s and occasionally low 140s) in "power" BTEs with receivers built into the hearing aid casing; the MPO, however, is said to be significantly lower in hearing aids of smaller styles and in BTEs placing the receiver in the canal due to receiver size reductions (Kuk et al, 2008). Hence, smaller style hearing aids and RIC BTEs may be inappropriate when larger ABGs are present in combination with an underlying sensorineural component (i.e., a substantial mixed loss) because the MPO would not support the required output. Another fact to consider is that variable output compression limiting thresholds can make obtained MPO even lower depending upon the hearing loss and/or manufacturer default settings (Mueller et al, 2008). As a result, audiologists have been encouraged to examine not only the maximum high-frequency average (HFA) gain but also the MPO limitation of the hearing aid when fitting hearing losses with a conductive component (Mueller and Hornsby, 2002).

Accordingly, an additional purpose of this brief clinical note was to report the required MPO when fitting a few example hearing losses with a conductive component. Because many individuals with a conductive component are fit with hearing aids of a BTE style due to outer and middle ear pathologies, it is reasonable to consider the MPO capabilities of BTE-style hearing aids. Hence, also compared in this clinical note is the MPO, both peak and HFA, of BTE instruments grouped based on either RIA or RIC placement. This comparison was completed to examine the statement of Kuk et al

(2008) that an RIC placement has less MPO than an RIA placement because of receiver size reduction across a range of hearing aid manufacturers. A difference, if found, may be of importance because of the previously reported findings that indicate inadequate MPO capabilities can negatively impact the sound quality of hearing aid amplified speech. Audiologists may, as a result, want to choose the receiver placement affording the greater MPO capability, particularly if concerns exist that meeting prescriptive recommendations while ensuring good sound quality will be an expected challenge.

METHODS

Recommended Gain and Required MPO for the Audiograms

An analysis of multiple audiograms with conductive components of various sizes indicated an interaction of differences in prescribed insertion gain between the two approaches (i.e., 25% ABG + AC and 75% ABG + BC) based on the magnitude of AC and BC hearing loss as well as size of the conductive component. Therefore, to bring focus on observed differences a few select audiograms are chosen for demonstration. These three audiograms represent:

1. a maximum conductive hearing loss with BC thresholds of 0 dB HL and 60 dB HL AC thresholds,
2. a severe mixed hearing loss with BC thresholds of 55 dB HL and AC thresholds of 85 dB HL, and
3. a moderately severe sloping to profound mixed loss with BC thresholds from borderline normal sloping to moderately severe.

These three audiograms are shown in Figure 1.

Prescribed insertion gain values were taken from NAL-NL2 version 2.0 (dll v2.15) stand-alone software, the same version that was licensed to many hearing aid manufacturers. Specific client variables within the software were an adult-aged client of unknown gender, experienced hearing aid use, and communication in a nontonal language. Audiological input variables within the software were dB HL thresholds with an insert earphone plus foam tip transducer type. Of the hearing aid selection input variables within the software, the one affecting insertion gain value recommendations, that is, number of hearing aids, was set to bilateral instead of unilateral. Insertion gain values were obtained for the 25% ABG + AC approach by inserting AC thresholds only and generating a prescription of insertion gain to which 25% of the ABG was manually added; hence, the software had no reference to BC thresholds. Insertion gain values were obtained for the 75% ABG + BC approach by inserting BC thresholds only and generating a prescription of insertion gain to which 75% of the ABG was manually added; hence, the software had no reference to AC thresholds.[1]

Compression ratios (i.e., the change in gain as a function of input level) were calculated as the change in input divided by the change in output based on calculated real ear aided response curves with input levels of 50 and 80 dB SPL. The soft and high input levels of 50 and 80 dB SPL were based on spectral shape provided in Scollie et al (2005), a long-term average speech spectrum, corrected for overall level. MPO requirements for each audiogram were calculated in 1/3-octave bands as the average speech input level of 80 dB SPL plus the audiogram-respective NAL-NL2 real-ear insertion gain plus the average adult diffuse sound field to eardrum transfer function of Moore et al (2008). As an estimate of the required HFA (1000, 1600, and 2500 Hz) MPO needed to fit the targets of each approach for an 80 dB SPL speech input signal, an average of those frequencies were taken. This average could then be compared to the MPO capabilities in commercially available BTE-style instruments.

A Comparison of MPO Limitations in BTE-Style Instruments

The technical specifications of BTE-style hearing aids available for purchase on the U.S. federal purchasing contract through the U.S. Department of Veterans Affairs in February 2012 were reviewed. Included specifically from the available information were the peak and HFA MPO data made available by completion of the ANSI S3.22 (2003) electroacoustic analysis standard. The BTE style was subdivided into the common groups of RIA and RIC. To reduce the number of available models and because of interest in the highest MPO possible only the "power" versions of the products were examined, which effectively excluded micro-BTEs in the RIA grouping. A RIC could still be of a mini-BTE style as long as it had a "power" receiver attachment. Across the nine brands on contract this review yielded 24 RIA products and 14 RIC products.

RESULTS

Required Gains, Outputs, and Compression Ratios for the Three Audiograms

Beginning with the first audiogram of a maximum conductive hearing loss, the difference in prescribed insertion gain is demonstrated in Figure 2. Made evident by the figure is the fact that the 25% ABG + AC approach assigns less gain than the 75% ABG + BC approach for input levels greater than 50 dB SPL, while the overall gain for soft speech of 50 dB SPL is similar. Notice also that the 75% ABG + BC approach does not prescribe decreasing gain with increasing input level (i.e., no compression). That

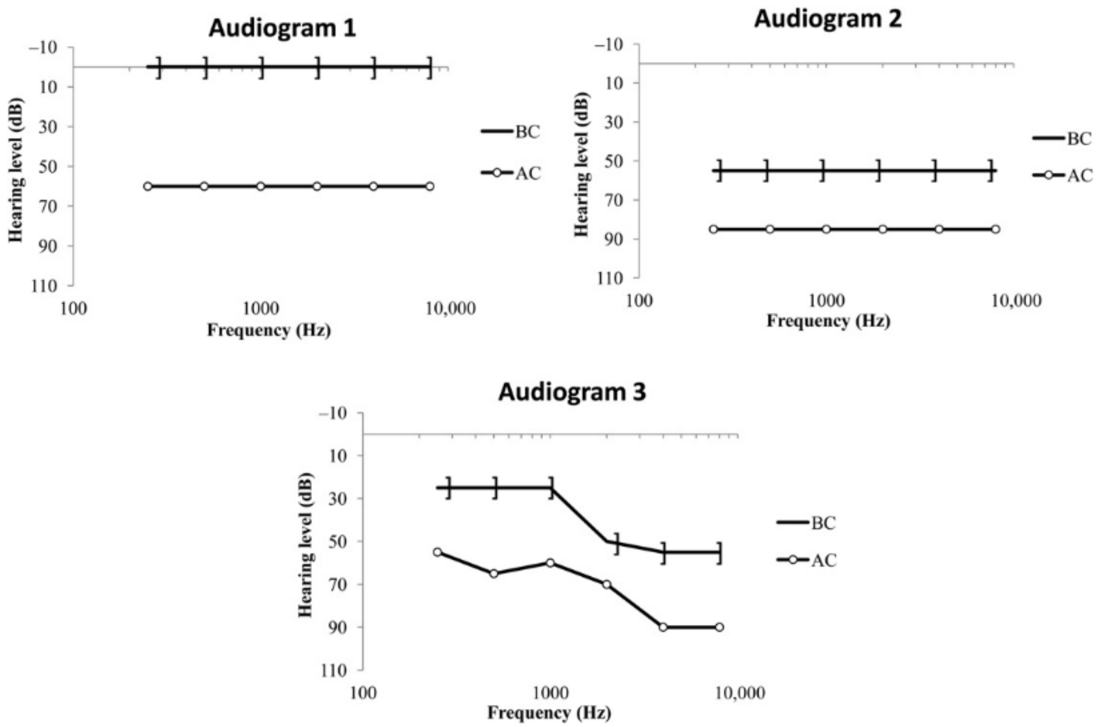

Figure 1. Three example audiograms representing patients with a conductive component to their hearing losses. BC = bone-conduction thresholds. AC = air-conduction thresholds.

is, the 75% ABG + BC hearing aid prescription is linear because there is no sensorineural hearing loss. Hence, there was no need for compression because all outer and inner hair cell function presumably remains as suggested by the 0 dB HL BC thresholds. The prescribed compression ratios for this audiogram and the remaining audiograms by both approaches are listed in Table 1.

In Figure 3, the 25% ABG + AC approach is shown to prescribe more insertion gain across all input levels than the 75% ABG + BC approach for Audiogram 2. Table 1 demonstrates that the 25% ABG + AC approach chooses a more linear amplification strategy because of the flat 85 dB HL AC thresholds that inaccurately portray the amount of sensorineural loss. Patients with severe-to-profound magnitude of sensorineural hearing loss have generally preferred less compression (Keidser et al, 2007); hence, these patients are prescribed less compression than might be expected with respect to the accompanying reduced dynamic range of hearing. Concurrently, the 75% ABG + BC approach chooses more compression due to flat 55 dB HL BC thresholds and presumption for need to replace the nonlinearity of damaged outer hair cells in the cochlea because 55 dB HL represents the true amount of sensorineural hearing loss.

Figure 4 demonstrates the differences in prescribed insertion gain for Audiogram 3. The 75% ABG + BC approach prescribes less gain and less compression in the lower frequencies through 1 kHz than the 25% ABG + AC approach, where better BC thresholds were present. Meanwhile, the 75% ABG + BC approach prescribed more gain and more compression at 4 kHz than the 25% ABG + AC approach.

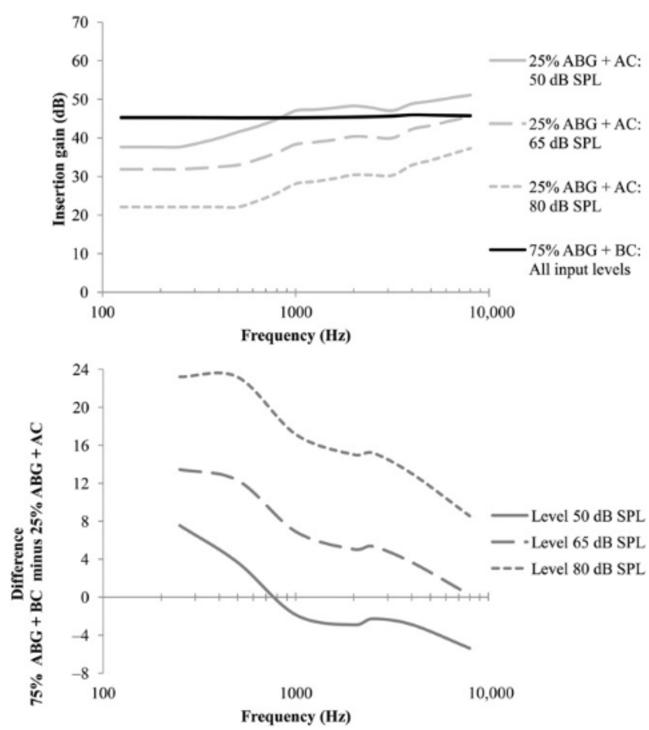

Figure 2. Prescribed insertion gain for Audiogram 1 from the two approaches (top). The plotted difference in prescribed gain as a function of input and frequency between the two approaches (bottom).

Table 1. Compression Ratio from Each of the Two Prescriptive Approaches

	500 Hz	1000 Hz	2000 Hz	4000 Hz
25% ABG + AC				
Audiogram 1	3.6	1.9	2.0	1.8
Audiogram 2	1.8	1.6	1.6	1.7
Audiogram 3	2.7	1.8	1.7	1.6
75% ABG + BC				
Audiogram 1	1.0	1.0	1.0	1.0
Audiogram 2	3.7	2.0	2.1	2.0
Audiogram 3	1.1	1.2	1.8	2.1
Compression Ratio Difference*: (25% ABG + AC) − (75% ABG + BC)				
Audiogram 1	2.6	0.9	1.0	0.8
Audiogram 2	−1.9	−0.5	−0.5	−0.3
Audiogram 3	1.6	0.6	−0.1	−0.5

*A positive difference indicates more compression than necessary with the 25% ABG + AC approach while a negative difference indicates less compression than necessary with the 25% ABG + AC approach for the amount of audiometric-diagnosed sensorineural hearing loss.

MPO Requirements for the Three Audiograms

For a hearing aid to meet the prescribed targets for an 80 dB SPL speech input level, the hearing aid would need at least the following HFA MPO limits for each of the two prescriptive approaches. The total overall SPL capability required by the summation of output (converted to intensity before summation) across frequencies from 160 to 8000 Hz are also shown.

Audiogram 1
25% ABG + AC approach requires a 108 dB SPL HFA MPO for a total overall SPL of 117 dB
75% ABG + BC approach requires a 124 dB SPL HFA MPO for a total overall SPL of 133 dB
Audiogram 2
25% ABG + AC approach requires a 120 dB SPL HFA MPO for a total overall SPL of 129 dB
75% ABG + BC approach requires a 115 dB SPL HFA MPO for a total overall SPL of 124 dB
Audiogram 3
25% ABG + AC approach requires a 114 dB SPL HFA MPO for a total overall SPL of 124 dB
75% ABG + BC approach requires a 109 dB SPL HFA MPO for a total overall SPL of 121 dB

When consideration is given to input levels higher than 80 dB SPL—for example, a 90 dB SPL, the swept pure tone signal typically used for an output sound pressure level for a 90 dB input (OSPL90) curve—the MPO requirements need to be increased by the change in dB afforded by the prescribed compression ratio for each hearing loss (e.g., in the case of Audiogram 1 for the 75% ABG + BC approach, another 10 dB because of the 1:1 compression ratio).

MPO Limitations in BTE-Style Instruments

The review of technical specifications on hearing aids available for purchase on the U.S. federal purchasing contract indicated the average peak MPO of RIA instruments was 135 dB SPL and for RIC instruments was 124 dB SPL; an independent samples t-test confirmed the difference was statistically significant, $t(36) = 5.452$, $p < 0.001$ (Fig. 5). The average HFA MPO of RIA was 128 dB SPL and for RIC instruments was 118 dB SPL; an independent samples t-test also confirmed this difference was statistically significant, $t(36) = 5.930$, $p < 0.001$ (Fig. 5). A multivariate analysis of variance including brand labeling as an independent variable yielded a nonsignificant difference in the dependent variables of either peak or HFA MPO capabilities, $F(2,20) = 2.357$, $p = 0.057$, which also did not interact with the RIC or RIA category, $F(8,20) = 1.043$, $p = 0.438$.

DISCUSSION

Clear from these three example audiograms is that two prescriptive approaches of 25% ABG + AC and 75% ABG + BC do not prescribe equivalent insertion gain amplification values across a range of input levels. Far more logical and scientifically defensible is the approach of prescribing gain based on magnitude of the BC thresholds and adding some portion of the conductive component on top (e.g., 75%). Also more restoration of the conductive component may be reasonable pending MPO limitations of the hearing aid and the listening environment of the patient (Walker, 1997b, 1999). National Acoustic Laboratories—Saturation

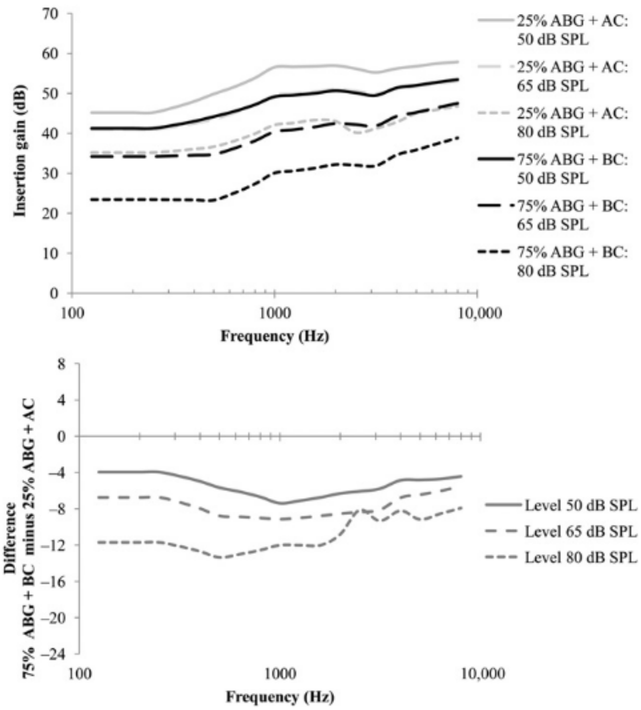

Figure 3. Prescribed insertion gain for Audiogram 2 from the two approaches (top). The plotted difference in prescribed gain as function of input and frequency between the two approaches (bottom).

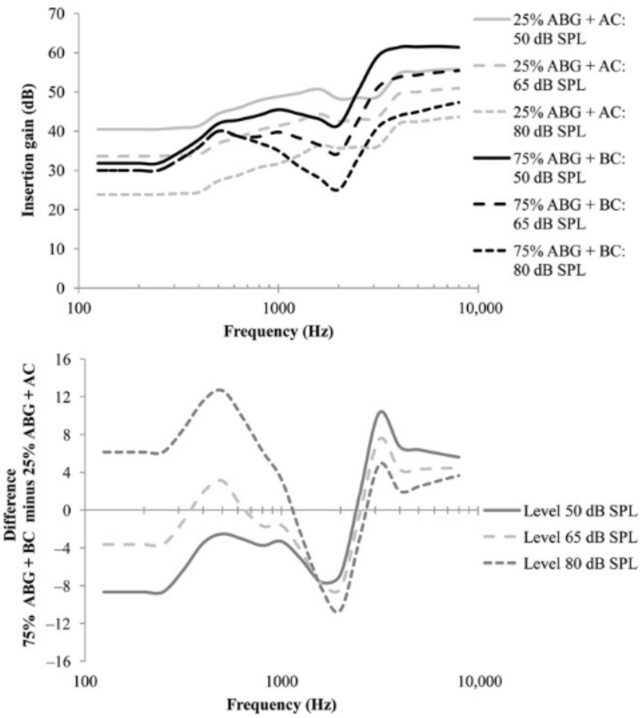

Figure 4. Prescribed insertion gain for Audiogram 3 from the two approaches (top). The plotted difference in prescribed gain as function of input and frequency between the two approaches (bottom).

Sound Pressure Level (NAL-SSPL), an OSPL90 prescription in the early to mid-1990s, called for 87.5% of the conductive loss (Dillon, 2001) but was not implemented in either NAL-NL1 or NAL-NL2 probably based on the Walker (1997b, 1999) data collected at NAL.

Other noticeable differences between the two approaches occur for the prescribed compression ratio as well as for the required MPO. The 75% ABG + BC approach prescribes compression ratio based on the magnitude of sensorineural hearing loss where the 25% ABG + AC approach does not. The explanation for a compression ratio difference is that the 25% ABG + AC approach references the AC thresholds, but not the BC thresholds directly, when prescribing compression whereas the 75% ABG + BC approach does directly use the amount of assessed sensorineural loss. Hence, the 25% ABG + AC approach has an inaccurate compression ratio for the magnitude of sensorineural hearing loss. As a result, the gain for 50, 65, and 80 dB input levels can be quite different between the two approaches.

Generally speaking the MPO requirements for the three audiograms each containing a conductive overlay to the hearing loss were considerable for both the 25% ABG + AC and the 75% ABG + BC approaches. This fact has clinical relevance to the hearing aid fitting in that the MPO of the hearing aid must allow for such sound pressure levels to be obtained. MPO requirements for the 75% ABG + BC approach will be greatest when a larger conductive component is present alongside a moderately severe sensorineural hearing loss.

The current (as of February 2012) MPO limitations of RIC BTEs are less than that of RIA BTEs consistent with the statement of Kuk et al (2008). This fact has the potential to create limitations in the output that would be needed when fitting with a 75% ABG +BC approach to some hearing losses with a conductive component. Given an 80 dB SPL speech input, Audiogram 1 required an HFA MPO of 124 dB SPL, which was in excess of the 118 dB SPL average of all RIC products reviewed. A select few RIC products, however, did have HFA MPOs of 124 dB SPL exactly (29%), but none exceeded 124 dB SPL. Even the RIC BTEs that could just support the HFA MPO requirements would likely have some sound quality degradation due to saturation of high input level peaks of speech and would not be able to handle higher level inputs than 80 dB SPL of either a speech or nonspeech type.

In contrast, 22 of the 24 RIA BTEs had an HFA MPO of at least 124 dB SPL or greater with the average RIA BTE having a 128 dB SPL HFA MPO. These numbers suggest that the vast majority of the RIA BTEs without a “micro” or “mini” label could support the output requirements of fitting hearing losses with large conductive components. Whether the RIC or RIA BTE is the preferred dispensing choice, the performance measure that should be checked for adequacy is the MPO capability. With a high MPO capability, a high gain

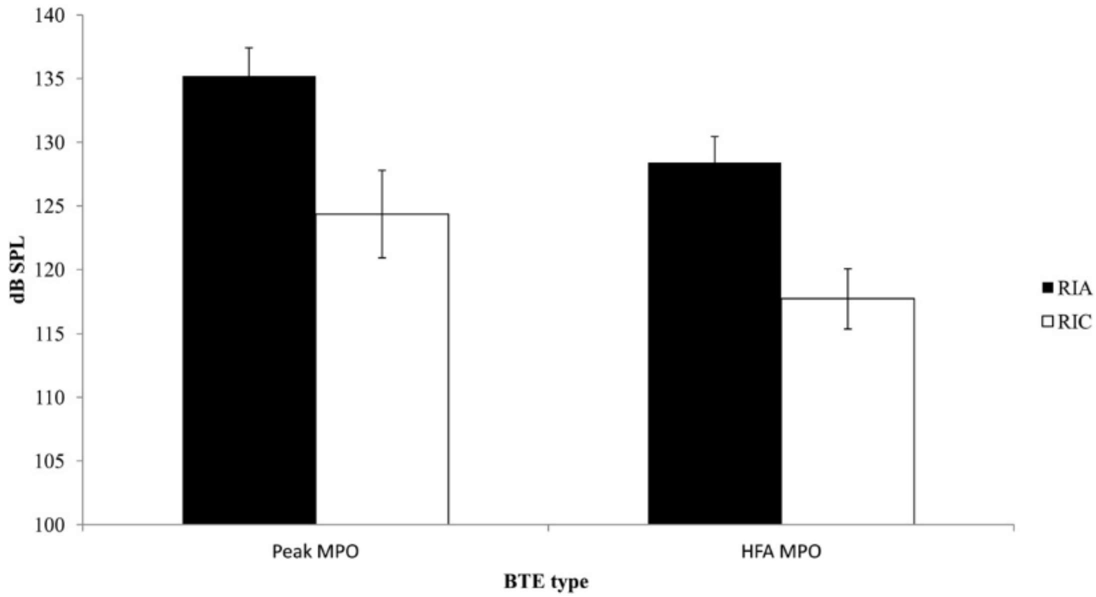

Figure 5. Peak and HFA MPO of sampled "power" BTE hearing aids on the U.S. federal purchasing contract in early 2012.

is generally a concomitant actuality in modern commercial hearing aids.

In order for the audiologist to use the 75% ABG + BC prescriptive implementation in the clinical environment, the audiologist need not be more cognizant of its implementation than simply entering both the AC and BC thresholds on standard verification equipment (e.g., the Audioscan Verifit, the Frye Fonix 7000 or 8000, etc.). The prescriptive approaches of NAL-NL1 and NAL-NL2 will add 75% of the ABG (as linear gain) to the BC threshold-based prescriptive recommendations. In other words, there is no need to further modify the generated prescribed targets when the hearing assessment reveals a conductive hearing loss component. Other prescriptive methods (i.e., DSL, CAM, or manufacturer-specific proprietary methods) may not be implementing the 75% ABG + BC approach. Audiologists may wish to seek clarification from the developers of each method or defer to generated real ear aided response targets of the individual prescriptions relative to unaided thresholds (as conventionally plotted in the SPL mode of hearing aid verification equipment) for real-time information when making decisions about the most appropriate input-level-dependent amplitude-frequency responses of a hearing aid when a patient has a hearing loss with a conductive component.

The 75% ABG + BC threshold approach will prescribe amplification, specifically a compression ratio, that is more in line with the amount of sensorineural hearing loss than does a 25% ABG + AC threshold approach. The study of prescriptive recommendations for conductive hearing loss should receive further study and clinical attention, given the following considerations:

1. Advancements in hearing aid receiver technology that now offers MPO limitations of 140+ dB
2. The expected audibility improvements for soft speech by increasing gain for individuals with more conductive hearing loss than sensorineural loss
3. The modest population of hearing impaired patients who receive hearing aids each year with a diagnosis of either conductive or mixed hearing loss (z 5% in the U.S. Department of Veterans Affairs health-care system)
4. The lack of consensus between current peer-reviewed and validated generic prescriptions for hearing losses with a conductive component (Johnson and Dillon, 2011)

Of particular interest is whether 75% restoration of the ABG or a larger percentage is most appropriate for patients as a function of MPO limitations in hearing aids.

NOTE

1. This addition does not need to be manually done when actually using the NAL-NL2 prescriptive method when both AC and BC thresholds are entered as audiometric input variables (i.e., the standard way); the manual addition for the purposes of this article allowed for the most straightforward comparison of the 25% ABG + AC and 75% ABG + BC approaches.

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