

The Intelligibility of the Reversed-Stethoscope Technique in Age-Related Hearing Loss



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ABSTRACT

Background

This study evaluated the effectiveness of the reverse stethoscope technique in improving speech intelligibility. In this technique, a clinician places the earpieces of their stethoscope into the ears of a hearing-impaired patient and speaks into the chest piece.

Methods

The International Speech Test Signal was presented to four Littman[®] stethoscope models and a Pocketalker[®] personal voice amplifier using an Audioscan[®] hearing instrument test box. The acoustic outputs of the stethoscopes and voice amplifier were measured across the frequency spectrum of speech. The Speech Intelligibility Index of the resulting speech was calculated for natural speech and for each device in relation to 10 standardized hearing losses representing the population of older adults.

Results

For each of the 10 hearing losses, the speech signal emitted by the stethoscopes was quieter and yielded lower speech intelligibility scores than regular speech. In contrast, the voice amplifier provided mid- and high-frequency amplification and improved speech intelligibility scores for all but the mildest hearing losses.

Conclusions

The reverse stethoscope technique worsens the clarity of speech and should not be used with older, hearing-impaired patients. Instead, clinicians should use regular speech or, preferably, personal voice amplifiers.

Key words: hearing loss, health-care accessibility, stethoscope

INTRODUCTION

Among adults over 70, nearly two thirds have a hearing impairment.⁽¹⁾ In the geriatric patient population, this proportion is believed to be higher as individuals with hearing

loss experience more chronic health conditions than their age-matched peers,⁽²⁾ and are more frequently hospitalized.⁽³⁾ While receiving care, hearing loss presents challenges. Pope *et al.*⁽⁴⁾ found the speech comprehension of patients with hearing loss declined dramatically in the presence of hospital noise. Hearing aids can mitigate this problem, but almost four out of five octogenarians with significant hearing loss do not wear amplification devices.^(5,6) Moreover, patients frequently lose their hearing aids during hospital admissions.⁽⁷⁾ As a result, 75% of patients with hearing loss report sometimes or often misunderstanding their health-care providers.⁽⁸⁾

Personal voice amplifiers, such as the Pocketalker[®] (Williams AV, LLC., Eden Prairie, MD), are well recognized tools for improving communication. These battery-operated devices contain a microphone, amplifier, and headphones through which users listen. Both the volume and the pitch of the acoustic output can be modified to amplify to the degree and nature of the user's hearing loss.⁽⁹⁾ No research has quantified the speech intelligibility benefits of these devices. However, they have been found to improve quality of life and reduce depressive symptoms in older adults,^(10,11) and to function reliably within care institutions.⁽¹²⁾

Within hospitals, a more readily available alternative to the personal voice amplifier is described in Samuel Shem's 1978 novel 'House of God'. Here, a senior resident, 'The Fat Man', teaches junior residents how to communicate with an elderly patient with a hearing loss:

'With Anna you need the reverse stethoscope technique. Watch.' The Fat Man took off his stethoscope, plugged the earpiece into Anna O.'s ears, and then, using the bell like a megaphone, shouted into it: 'Cochlea come in, cochlea come in, do you read me...'⁽¹³⁾

While *House of God* was a satire, at times physicians use a version of this 'reverse stethoscope' strategy by speaking into the chest piece of an acoustic stethoscope with the earpieces placed in the patient's ears. This method is described in a *Medscape Perspective* article as a strategy for communicating with elderly surgery patients.⁽¹⁴⁾ It was recommended in the

British Medical Journal's Innovations section for a similar purpose.⁽¹⁵⁾ The textbook “Emergency Care in the Streets” includes it as a tip for working with patients with hearing impairment.⁽¹⁶⁾ A *British Medical Journal* practice pointer describing evidence-based strategies for communicating with patients with hearing loss did not include this technique,⁽¹⁷⁾ a fact which three clinicians wrote in to comment on via the article’s “Rapid Responses”. Despite this technique’s popularity, the intelligibility of speech when delivered through acoustic stethoscopes has never been scientifically evaluated.

Stethoscopes are designed to transmit low-frequency cardiac, respiratory, and gastrointestinal sounds⁽¹⁸⁾ Acoustic stethoscopes aid in the auscultation of these sounds in three ways. First, by pressing the chest piece against the human body, the device overcomes tissues’ acoustic impedance (i.e., resistance to sound wave transmission between tissue and air).⁽¹⁹⁾ Second, by funneling sound waves into the tubing of the acoustic stethoscope, a greater proportion of the sound energy is directed towards the ear.^(20,21) Finally, some—but not all—models provide resonance peaks of sufficient amplitude to amplify certain very low-pitched frequencies, below 200 Hz.^(22,23,24) For sound waves with frequencies higher than 200 Hz, the intensity (i.e., loudness) of the delivered sound waves decreases steadily up until 1000 or 1500 Hz, at which point they can no longer be appreciated by human hearing. These outputs may not fully reflect the acoustics characteristics of the reverse stethoscope technique, as the stethoscope diaphragm vibrates in free air rather than pressed against a body surface.^(25,26) Still, as most speech sounds exist between 500 and 8000 Hz,⁽²⁷⁾ this pattern of declining output calls the reverse stethoscope technique into question.

Stethoscopes’ lack of mid- and high-frequency output is particularly problematic for patients with age-related hearing loss, who experience a greater degree of loss in the high frequencies. For older adults, the high frequency sounds, including the /f/, /th/, and /s/ phonemes, are more difficult to discriminate than lower pitched vowel sounds and the sonorant consonants such as the /m/ and /r/ phonemes. This is visually demonstrated through the 10 ‘standard audiograms’ in Figures 1 and 2. These standard audiograms were developed by vector quantization of almost 30,000 audiograms from older adults with hearing loss.⁽²⁸⁾ In each of these standard hearing losses, thresholds worsen as the frequency of the test tone increases.

Given the diversity of hearing losses, the Speech Intelligibility Index is one way to quantify the degree to which a hearing device provides appropriate amplification for a given loss. This index, based on calculations outlined by the American National Standards Institute,⁽²⁹⁾ estimates the percentage of daily speech sounds which a person with a given hearing loss can hear. It can be calculated to reflect the speech intelligibility of standard speech, as well as the intelligibility of amplified speech emitted by an assistive hearing device.

Existing literature suggests that stethoscopes attenuate, rather than amplify, the mid-to-high frequencies in which speech is found. This leads us to doubt the efficacy of the reverse stethoscope technique and ask the following questions:

1. Does the Speech Intelligibility Index for 10 standard audiograms improve when the International Speech Test Signal is presented through four models of Littmann® stethoscopes (3M Littmann Stethoscopes, St. Paul, MN) in a test-box setup mimicking the “reverse stethoscope” technique?
2. How do these scores compare to the Speech Intelligibility Index scores associated with a Pocketalker personal voice amplifier?

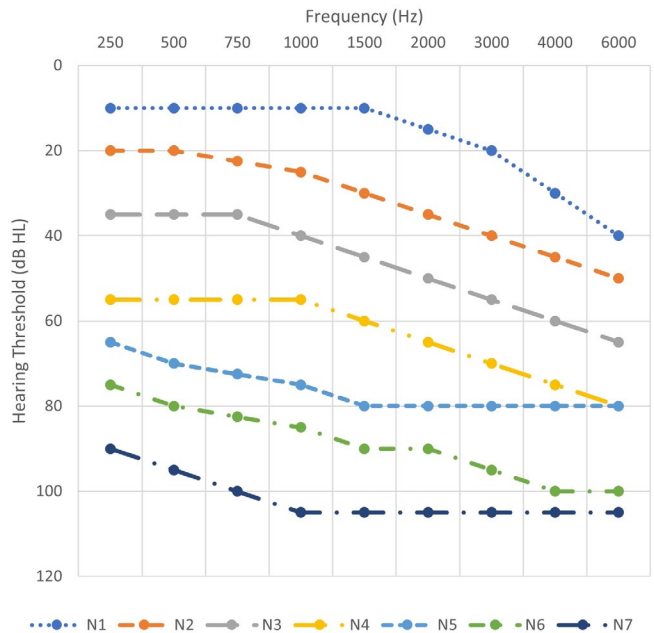


FIGURE 1. Flat and moderately sloping standard audiograms

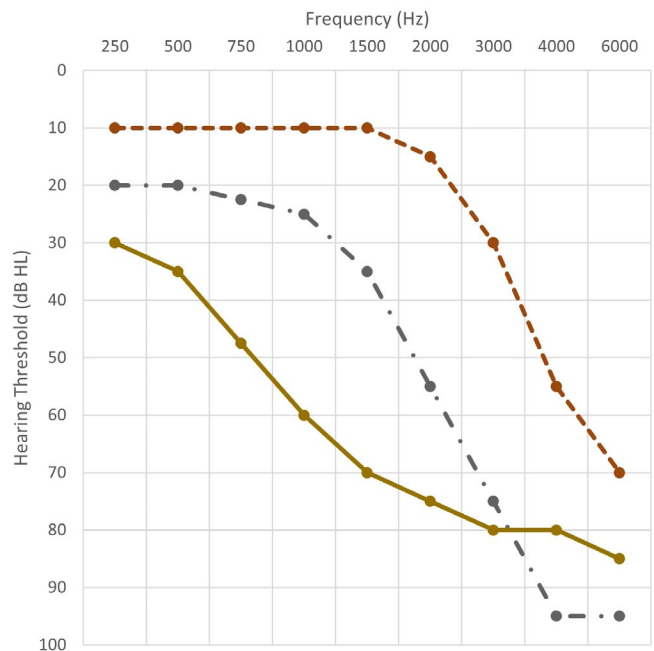


FIGURE 2. Steeply sloping standard audiograms

METHODS

Materials and Set Up

To evaluate the stethoscopes’ acoustic outputs, we used the Audioscan® Verifit2 test box (Audioscan, Dorchester, ON) and software. Best practices within the field of hearing-loss amplification recommend that hearing instruments and other assistive devices be evaluated relative to the user’s specific hearing loss using a test box and associated sound processing software.⁽¹⁸⁾ One widely used test box system is the Audioscan Verifit2. This noise-insulated box contains three core components: a speaker emitting a standardized signal calibrated by a reference microphone, a coupler designed to hold the hearing instrument’s earpieces and mimic the acoustics of an ear, and a microphone positioned within this coupler.

In using the Audioscan Verifit2 to test the reversed stethoscopes, the adult-sided bell of each Littmann stethoscope was positioned within the test box facing the speaker at a distance of 2 cm. Due to their size, each consecutive stethoscope extended out of the test box with the metal component of the stethoscope tubing passing under the foam-sealed, test-box lid. The coupler likewise extended outside the test box via an extender cable. The earpieces of the stethoscope were then putted to the 0.4 cc coupler, following standard practice for in-the-ear hearing aid verification (Audioscan Verifit, 2019). Foam was used to seal the lid, and the reference microphones within the test box were re-calibrated to this arrangement to account for any residual signal leakage.

In this configuration, test signals were presented to a Littmann Classic II SE stethoscope, a Littmann Cardiology IV stethoscope, and a Littmann Cardiology IV stethoscope with short-length tubing (56 cm vs. 69 cm). In addition, test signals were presented to a Littmann 3100 Electronic stethoscope in diaphragm (i.e., high frequency) mode, and with amplification turned up to level nine (i.e., the highest level of amplification provided by the device). This electronic stethoscope was included to reference to the speech intelligibility that amplified stethoscopes might offer. All stethoscopes’ outputs were measured by the microphones within the test box’s 0.4 cc couplers.

The acoustic output of the Pocketalker personal voice amplifier was evaluated using a comparable set-up. The hand-held unit was placed within the box, with the microphone facing the speaker at a distance of 2 cm. The device’s acoustic output was presented to the 0.4 cc coupler microphone via a mono earbud putted to the coupler. The output of the stethoscopes and personal voice amplifier were interpreted by the Audioscan software to 1) provide spectral analyses of each devices’ outputs, and 2) calculate the Speech Intelligibility Index scores associated with each device relative to each of the 10 standard hearing losses.

Spectral Analyses

The output of the stethoscopes in dB HL was measured for frequencies between 125 and 13,000 Hz. We used Pink Noise

as the input to evaluate the stethoscopes’ frequency response, following the methods of Weiss et al.^(18,31) A 65 dB Pink Noise signal was presented via the test box speaker to the devices, captured by the coupler microphone, and presented using the ‘Multicurve’ function of the Audioscan software.

Speech Intelligibility Index Measurement

The Audioscan software was configured to measure the Speech Intelligibility Index for each of 10 standard audiograms reflecting the population of hearing-impaired older adults (see Figures 1 and 2). The Speech Intelligibility Index was calculated both at baseline, to reflect natural speech, and in response to speech presented through the reversed stethoscope. Software settings were chosen to improve accuracy, as outlined in Table 1.

Procedure

The International Speech Test Signal was delivered through the test box speakers at 65 dB HL, reflecting the intensity of average conversational speech (Audioscan Verifit, 2019), and filtered through each of the stethoscopes and the Pocketalker one at a time. The software interpreted the output for each device relative to each of the 10 standard losses outlined in Figures 1 and 2.⁽²⁸⁾ Each standard loss’ baseline “unaided” Speech Intelligibility Index was also calculated by the Audioscan software. This unaided Speech Intelligibility Index reflected the percentage of speech a person with a standard audiogram could hear without any assistive hearing device.

Data Analyses

The resulting spectral analyses and Speech Intelligibility Index scores were compared using descriptive statistics, as is standard in stethoscope acoustics research.^(18,25,30,31)

RESULTS

Spectral Analyses

Spectral analyses of the Pocketalker and four stethoscopes demonstrated that the Pocketalker provided amplification across all frequencies involved in speech, while the acoustic

TABLE 1.
Audioscan speechmap configuration

<i>Configuration Category</i>	<i>Configuration Selected</i>
Targets	NAL-NL2
Age	Adult
HL Transducer	Insert+Foam
Real Ear to Coupler Difference (RECD)	Wideband (wRECD) average
Binaural	Yes
Language	Non-tonal
Type of Instrument to be Verified	RITE

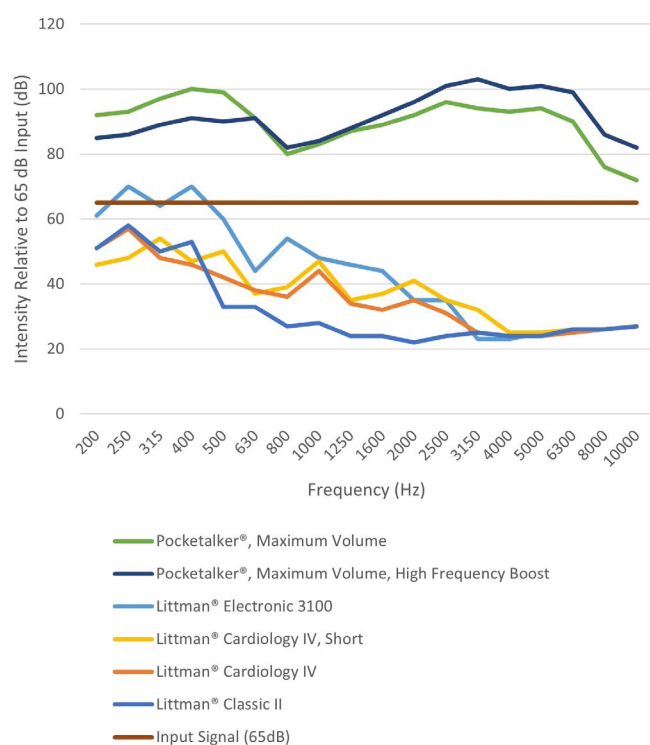


FIGURE 3. Spectral analyses of stethoscopes' and the personal voice amplifier's output in response to 65 dB Pink Noise

stethoscopes only attenuated these signals (see Figure 3). The Pocketalker, at maximum volume, amplified the 65 dB input speech to an output ranging from 72 dB to 100 dB across the frequency spectrum. When the high-frequency setting was activated via the Pocketalker tone dial, the device provided 9 dB of additional amplification in the high frequencies and roughly 10 dB less amplification in the lower frequencies. Conversely, the only stethoscope which provided any amplification of the speech signal was the Littmann 3100 Electronic Stethoscope. At its loudest setting, this device provided an output signal 5 dB louder than the 65 dB input at both 250 and 400 Hz. At other frequencies, the electronic stethoscope's output was attenuated (i.e., quieter) relative to the incoming speech.

Speech Intelligibility

Speech signals delivered through the acoustic stethoscopes yielded poorer Speech Intelligibility Index scores than regular speech (see Figures 4 and 5). The Littmann 3100 Electronic stethoscope similarly degraded the speech intelligibility in all standard hearing losses, apart from hearing losses N4 and N5 in which it provided a near negligible 4% and 1% improvement, respectively. In contrast, the output of standardized speech presented through the Pocketalker yielded improved speech intelligibility relative to unaided standard speech in all but the mildest standardized hearing losses, as demonstrated in Figures 4 and 5. The benefit provided by the Pocketalker ranged from a 5% loss in Speech Intelligibility Index scores

for hearing loss N1, the mildest hearing loss, to a 59% gain in the Speech Intelligibility Index score for N4, a moderately severe hearing loss.

DISCUSSION

This study sought to determine whether the Speech Intelligibility Index for 10 standard audiograms improved when the International Speech Test Signal was presented through Littmann stethoscopes in a test box set-up mimicking the "reverse stethoscope" technique. We also sought to evaluate how a personal voice amplifier would impact speech intelligibility in a comparable environment. We found that the reverse stethoscope reduced, rather than improved, Speech Intelligibility Index scores. In contrast, a Pocketalker personal amplifier yielded improved speech intelligibility relative to standard speech in all but the mildest hearing losses.

These findings are in keeping with our spectral analyses of the stethoscopes. While the Pocketalker personal amplification device provided up to 38 dB of amplification across the spectrum of frequencies, the acoustic stethoscopes attenuated the speech signal in all frequencies, and the electronic stethoscope only provided modest amplification in the lowest frequencies. The spectral output of our devices is consistent with the existing literature, which has identified resonance peaks in stethoscopes below 500 Hz, followed by a progressive attenuation of output, reaching 20 dB of attenuation of all input signals beyond 1,000 Hz.^(22,23,24,32) Together, these findings support the assertion that stethoscopes are designed to transmit the low frequency sound waves which contain internal body sounds, rather than the mid- to high-frequency sound waves which contain speech sounds.

While the reversed stethoscope technique is not supported, this study demonstrates the benefits to speech-intelligibility provided by personal voice amplifiers when communicating with patients with age-induced hearing loss. It clarifies why previous research has found that these personal voice amplifiers improve communication and psychosocial outcomes in older adults.^(10,11,12) Patients only require basic training in the use of the Pocketalker, and Gilligan and Weinstein⁽³³⁾ have published instructions explaining the devices' use at a grade five reading level.

If a personal voice amplifier is not available, other strategies exist which improve communication in the presence of hearing loss. To improve speech comprehension, health-care providers should reduce ambient noise,⁽³⁴⁾ face the patient when speaking,⁽³⁵⁾ articulate consonants carefully,⁽³⁶⁾ and identify patients with hearing loss using signage within charts or at the bedside.⁽³⁷⁾ Transcription and amplification technologies in the form of iPhones or Android apps also have potential.⁽³⁸⁾

This study demonstrates that the reverse stethoscope technique worsens rather than improves Speech Intelligibility Index scores. However, our research was performed in a lab setting using standardized hearing losses, rather than patients in an authentic hospital setting. As a result of this limitation, it is possible that we failed to capture certain aspects of the

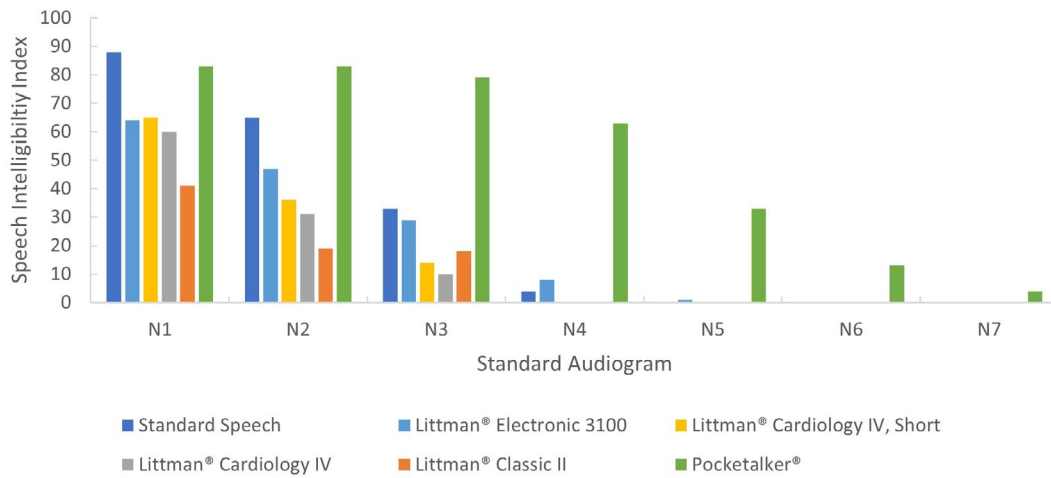


FIGURE 4. Speech Intelligibility Index scores for flat and moderately sloping standard audiograms, ranging from mild loss (N1) to profound loss (N7) in response to 65 dB standard speech input into Littman stethoscopes and Pocketalker personal voice amplifier

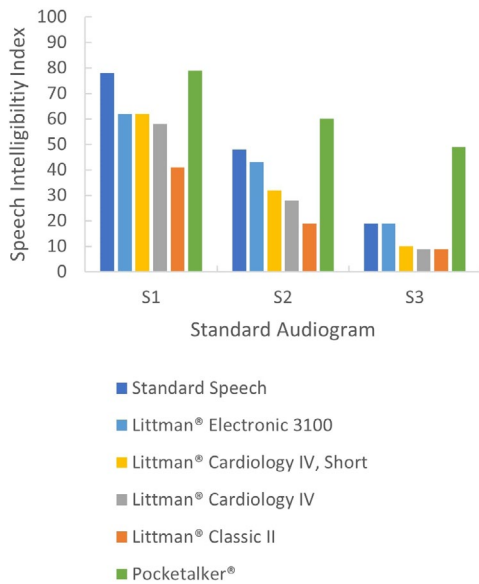


FIGURE 5. Speech Intelligibility Index scores for severely sloping standard audiograms, ranging from mild (S1) to severe (S3), in response to 65 dB standard speech input into Littman stethoscopes and the Pocketalker personal voice amplifier

practice. For example, stethoscope earpieces may block distracting ambient hospital noise. Likewise, while using this technique, clinicians are forced to face the patient, which can facilitate speech reading.⁽³⁵⁾

Alternatively, this “reverse stethoscope” technique may have persisted simply by encouraging patients to ‘nod along’ instead of expressing their concerns to the physician. Patients with hearing loss are known to cope by withdrawing rather than drawing attention to their disability. This stems from a desire both to avoid being associated with the

stigmatized disability, and to avoid inconveniencing conversation partners.^(39,40,41) Future research might explore this and other reasons for which this acoustically ineffective technique continues to be used.

CONCLUSION

In conclusion, three quarters of adults with hearing loss report sometimes or often misunderstanding their health-care providers.⁽⁸⁾ The reverse stethoscope technique has been described as a ‘megaphone’ for amplifying a physician’s voice for older patients.⁽¹³⁾ Unfortunately, our findings confirm that stethoscopes do not amplify or even effectively transmit the frequencies important to speech. Instead, this technique decreases Speech Intelligibility Index scores. Conversely, the Pocketalker personal voice amplifier meaningfully improved Speech Intelligibility Index scores for all but the mildest hearing losses. Older adults with hearing loss have a moral and legal right to accessible health care.^(42,43) Based on this study’s findings, accessible communication for older adults with hearing loss is best pursued through personal voice amplifiers.

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Not applicable.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood the Canadian Geriatrics Journal’s policy on conflicts of interest disclosure and declare that there are no conflicts of interest.

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