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Original Research Article

Effect of Low Frequency Gain Attenuation on Subjective Rating Scale in Individual with SSD

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ABSTRACT

Objective: The object of the study was to evaluate the effect of low frequency gain attenuation on scale in single sided deafness.

Methods: In present study total of twenty SSD post-lingual subjects with age range of 15 to 40 years. BAHA was programmed with four different settings i.e. without attenuation (WA), low frequency attenuation of 250,750 and 1500Hz. Subjective rating scale were used to determine the quality of sound in different condition on brightness, softness, clarity, reverberation, fullness, loudness. Total Time period of 2 hour were given to the subject before rate on the scale so that subject gets habituated to the sounds in which 30 minutes were given to each setting i.e.

Statistical analysis and Results: Non parametric test (Friedman Test) was carried results reveal that there was a significant difference in loudness across all experimental conditions tested, indicating loudness decreases as the attenuation frequency increased from 250 Hz to 1500 Hz. Without low frequency attenuation the loudness was higher. This can be attributed to importance of low frequency in perception of loudness.

Conclusion: The results from subjective rating scale indicate that there is no deleterious effect on acoustic output quality with low frequency attenuation. But there was significant difference noted in loudness without on with low frequency attenuation, indicating that low frequency gain in the BAHA only adds loudness which is not required for the speech intelligibility.

Key word: SSD – single sided deafness, WA – without attenuation, BAHA – bone anchored hearing aid.

INTRODUCTION

Single sided deafness (SSD) or unilateral hearing loss is condition where an individual has non-functional hearing in one ear and having normal hearing thresholds in the other ear. The non-functional ear can also have profound hearing loss but not necessarily. It is assessed that single sided deafness (SSD) afflicts almost nine million people in the United States alone (Wazen, Spitzer, Ghossaini, Fayad, Niparko, & Cox, 2003).

There are several aetiological factors that were well known to cause SSD. The most common causative factor for acquired SSD is sudden hearing loss. Byl(1978), Berg and Sudden hearing loss is usually unilateral but Rambur (1989) reported incidence of sudden bilateral hearing loss in United States up to 17% of the cases. The other aetiological factor for SSD is acoustic neuroma or a space-occupying lesion in brainstem (Goodhill, Harris, & Brockman, 1973).

The most recent amplification approach for subject with SSD is BAHA. BAHA typically uses surgically implanted titanium screw is placed in the parietal/temporal region of the skull on poorer ear. The working principle of BAHA is mainly based on bone conduction (BC) pathway and there are certain frequency dependent variations among BC sound transmission revealed through head related transfer functions.

When a speech signal is presented on poorer ear side of the subjects with SSD the vowel portions are generally transmitted and perceived in better ear. This is due to the fact that vowels comprise of lower frequency information and bends around the head more easily, efficiently because of its higher wavelength. Whereas, consonant speech segments comprised of high frequencies are reflected off the same side of the head because of its shorter wavelength and therefore the opposite ear/ better ear does not receive the information in individuals with SSD.

Acoustically attenuation at the ear contralateral to the sound source is larger at higher frequencies starting from approximately 1.5 kHz and less pronounced at lower frequencies below approximately 1 kHz. According to Shaw (1974), Kompis and Dillier (1993) typical attenuation values are 3 to 7 dB at lower frequencies (200 to 1000 Hz) and 9 to 21 dB for higher frequencies (2000 to 8000 Hz).

Nolan and Lyon (1981) studied the transcranial attenuation using bone conduction audiometry from250Hz to 4 KHz in 15 unilateral hearing loss individuals and 35 normal hearing individuals. The outcome of the study indicated that mean transcranial attenuation was 13dB for both group at 2 KHz but inter-subject variability was extremely high. The inter-subject variability was attributed to the variation in thickness of skull among individuals studied.

Table 1.1Mean transcranial attenuation values based on Nolan and Lyon (1981).

	Frequency in Hz							
	250	500	750	1000	1500	2000	3000	4000
Transcranial attenuation(dB)	8.3	9.3	10.3	10.6	10.3	13	10.3	16

The variability of interaural attenuation across frequency can be attributed to due to spring-effect causes the ossicle to vibrate in-phase with the skull at low frequencies. At higher frequencies the ossicles become vibrationally decoupled from the surrounding bone resulting out of phase with stapes footplate and the otic capsule (Stenfelt, Hato,& Goode 2002).

The above two factors signifies that amplification strategies such as BAHA must emphasize on high frequency amplification a lot more than low frequencies. Also that low-frequency sound is more difficult to transmit with less distortion compared with high-frequency sound. Indeed distortion of BAHA devices is most prominent in the low-frequency range.

This indicates the importance of amplifying the high frequency signals alone rather than low frequencies. Thus low frequency attenuation with commercially available BAHA systems would certainly reflect performance changes in speech understanding. Merely only few researchers studied this factor.

One such study by Pfiffner, Kompis, Flynn, Asnes, Arnold and Stieger (2011) revealed benefit from low-frequency attenuation of Bone-Anchored Hearing Aids (BAHA) in users with SSD. Results reveal that high cut-off levels of up to 1500 Hz for low-frequency sound didn't compromise the benefit of BAHA in SSD when noise presented from the front and speech was presented on the side of the BAHA. Detrimental effect on speech understanding can be reduced when noise is presented from the side of the BAHA by higher cut-off frequencies.

Further exploration in this direction using BAHA system is much required to note the effects of low frequency attenuation in BAHA systems would be useful. The aim of the present study was to evaluate the effect of the low frequency attenuation in pre-implantable BAHA on subjective rating scale.

MATERIALS AND METHODS

All the experimental conditions were performed on participants with single sided deafness (evaluated at department of Audiology, All India Institute of Speech and Hearing) and participated in the study on their own willingness.

Participants

A total of twenty individuals with SSD were participated in the current study ten participants had post-lingual acquired profound hearing loss in left ear and ten were having post lingual profound hearing loss in the right ear. Onset of hearing loss was post-lingual for all participants, thus having adequate speech and language. Age range of the participants selected was from 15 to 40 years. All the participants were oriented about the study and written consent was taken regarding their willingness to participate in the study. The participants were selected if they had

- Unilateral hearing loss in one ear (> 90 dB HL) and other ear should be hearing within normal limit (<20 dB HL) with the average of 4 frequency in audiogram.
- First language/ Native language being Kannada language (Language that has been spoken majorly in one of the province in southern part of INDIA).
- Correlation of Speech Recognition Threshold with Pure Tone Average threshold being within ±12 dB.
- Speech identification score using phonetically balanced words should be above 90% in better ear.
- No indication of middle ear pathology in both ears on immittance evaluation at the time of evaluation and study.
- No illness on the day of testing.
- No history of neurologic/ cognitive/psychological problems.
- All the participants were nave to use BAHA and were not had any previous experience with BAHA.

Test material

Testing Environment

All tests were carried out in a sound treated two room situation. Ambient noise levels in the test rooms were as per the standards of ANSI S3.1 (1999) with adequate illumination.

Calibration of the instrumentation

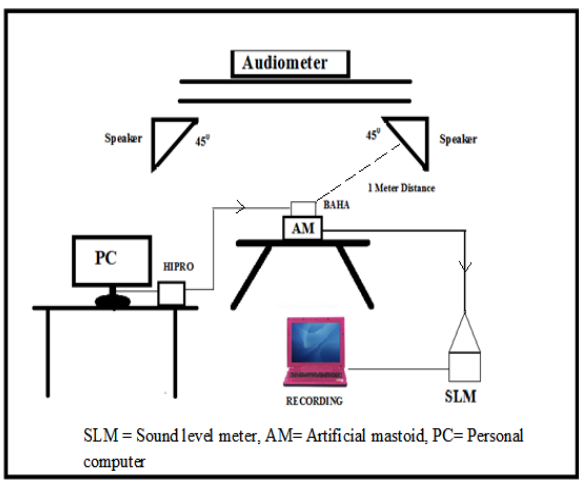
All the equipment and instrument in used the study were calibrated accordingly of described below-

Determining the cut off frequency gain values BP100

Prior to the testing with BAHA minimum gain values at three different cut-off frequencies (250Hz, 750Hz & 1500Hz) in the programming software were determined. The minimum gain values were the gain settings in the programming software at which the output sound pressures levels measured through artificial mastoid (Type 4191, Bruel & Kjaer) were same as the sound pressure levels presented in the sound field.

A calibrated MEDSON ITERA dual channel sound field audiometer having with one calibrated ITERA loudspeakers were used. Loudspeaker was placed at $+45^0$ on side of the BAHA device. Distance between loudspeaker and BAHA was maintained at one meter.

The BAHA was connected to a personal computer through HI-PRO interface with specific BAHA cable. Cochlear BAHA fitting software 2.0 versions was used to program and to manipulate the gain setting in BAHA device under all circumstances. Test band was used to couple BAHA with artificial mastoid and tightness of test band was adjusted such that instrument movements and squalling sound was minimised. The instrumentation used to determine the gain values is depicted in figure 1.1.



SLM = Sound level meter, AM= Artificial mastoid, PC= Personal computer

Figure 1.1 Illustration of instrumentation of output verification of BAHA.

Artificial mastoid (Type 4191, Bruel & Kjær) was connected to the SLM (Larson-Davis system 824, model no. 2540) device to monitor the response from BAHA. The output from SLM was connected to a laptop installed with PRAT software to record the response. Additional feature such as directionality as omnidirectional microphone, noise reduction algorithm was deactivated and feedback cancellation and position compensation were on.

BAHA along with headband was fixed on the artificial mastoid for all conditions. Warble tone with frequencies of 250, 750 and 1500 Hz, respectively, was presented through a loudspeaker at 60dBHL. SLM recordings were measured and compared to input sound level such that there is no gain at 60dBHL.

Procedure:

Participants were selected based on the participant selection criteria and on willingness to participate. Cases were taken from the Department of Audiology who were diagnosed as having unilateral profound hearing loss in the one ear and normal hearing sensitivity in other ear.

Programming and / or optimizing the digitally programmable BAHA.

The BAHA was fitted to subject during programming through test band. The digitally programmable BAHA was connected to the HI-PRO, using specific BAHA cable. The HI-PRO was in turn connected to the personal computer having the BAHA specific fitting software. Initially BAHA was programmed based on the audiometric thresholds and cochlear BAHA prescriptive fitting formula. BAHA was programmed for overall gain condition in which the gain values were increased or decreased to the point where the feedback was not reported.

For three different low frequency cut-off condition the attenuation or reduction in gain was tuned up to the point which was obtained through objective verification but the gain values above cut-off were maintained to the target gain curve where no feedback was reported by participant but in case of acoustic feedback problem gain was reduced at high frequency to such an extent that no acoustic feedback.

Audiological measures

Subjective rating scale: Subjective rating scale were used to determine the quality of sound in different condition and it was adopted from Pfiffner et al. (2011), in which each subject was asked to rate output using 11 point (that was vary from +5 to -5) where the -5 is the lowest score and +5 is highest score. Parameters of scale were:-

1. Brightness
2. Softness
3. Clarity
4. Reverberation
5. Fullness
6. Loudness

The subjective rating scale was administered with BAHA with overall gain setting and with two extreme cut-off frequencies i.e. 250 and 1500Hz. Total Time period of 2 hour were given to the subject before rate on the scale so that subject gets habituated to the sounds in which 30 minutes were given to each setting i.e. without attenuation (WA),low frequent attenuation of 250,750 and 1500Hz.

RESULTS AND DISCUSSION

Subjective rating scale: The participants were asked to rate the sound quality of BAHA on six parameters using eleven point rating scale. The parameters included were Brightness, Softness, Clarity, Reverberation, Fullness and Loudness. Subjective rating scale was obtained in only three experimental conditions i.e. BAHA without low frequency attenuation, BAHA with low frequency attenuation below 250Hz and BAHA with low frequency attenuation below 1500Hz. Simple statistics of the subjective ratings across three experimental conditions and parameters were given in table 1.2.

Table 1.2: Mean and Standard deviation (SD) of subjective rating scale for the quality of sound across three different conditions.

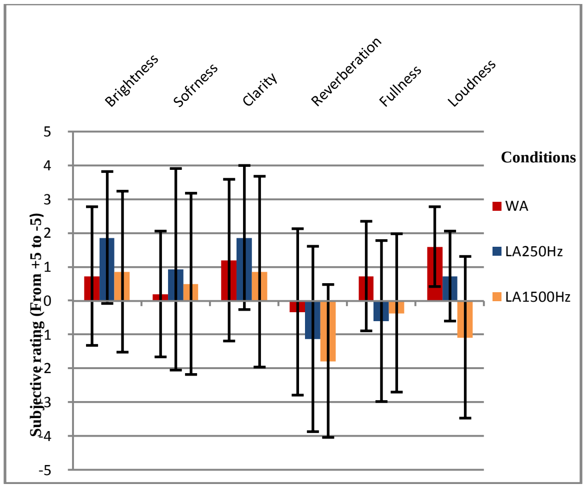
Conditions	Statistical parameter	Subjective parameters					
		Brig	Soft	Clar	Reverb	Fulln	Loud
WA	Mean	0.75	0.29	1.3	-0.22	0.80	1.2
	Std. Deviation	2.2	1.9	2.25	2.46	1.55	1.2
	Median	1	0	1	1	0	1
LA250Hz	Mean	1.87	0.93	1.87	-1.13	-0.6	0.73
	Std. Deviation	1.95	2.98	2.13	2.74	2.38	1.33
	Median	2	2	3	-1	0.0	.00
LA1500Hz	Mean	0.82	0.5	0.88	-1.72	-0.35	-1.02
	Std. Deviation	2.38	2.68	2.82	2.26	2.34	2.38
	Median	2	0.5	1.5	-0.5	0.0	-2

Note:*Brig: Brightness, Soft: Softness, Clar: Clarity, Reverb: reverberation, Fulln: Fullness, Loud: Loudness.*

Non parametric test (Friedman Test) was carried out to find out if there is a significant difference across experimental conditions.

The result of Friedman Tests indicated that there was a significant difference in loudness across conditions [χ^2 (2) = 8.652, p= .130]. There was no significant differences observed in parameters across conditions brightness; [χ^2 (2) = 2.711, p =0.258], softness;[χ^2 (2) = 1.574, p = 0.455], clarity;[χ^2 (2) = .360, p = 0.835], reverberation;[χ^2 (2) = 4.383, p = 0.111], fullness;[χ^2 (2) = 3.931, p 0.140]. These results suggest that there is no effect of low frequency attenuation in BAHA on subjective perception of sound quality except loudness is decreased.

Since there was significant difference between the across conditions in loudness Wilcoxon Signed Ranks Test was done to see which group has significant difference.



Graph 1.1: Mean and standard deviation values across quality of sound in three different conditions.

Table 1.3: Shows levels of significance for loudness in each pair.

Statistical values	Loud 250 – loud WA	loud1500 – loud WA	loud1500 – loud 250
Z-values	-2.04	-2.84	-2.13
P- values	.040	.004	.033

Results from Wilcoxon Signed Ranks Test (table 1.3) reveal that there was a significant difference in loudness across all experimental conditions tested, indicating loudness decreases as the attenuation frequency increased from 250 Hz to 1500 Hz. Without low frequency attenuation the loudness was higher. This can be attributed to importance of low frequency in perception of loudness.

Overall results suggest that low frequency information only contributing to loudness of the sound not affecting to other quality of sound. This result is in agreement with that of reported by Pfiffner et al. (2011) where they reported that no significant difference between the ratings of the two BAHA settings that 270Hz and 1500Hz cut-off setting. However, reverberation and loudness are rated higher for the cut-off frequency of 270 Hz than for 1500 Hz. Thus attenuating low frequency information up to 1500Hz doesn't change the sound quality to great extent except loudness.

SUMMARY AND CONCLUSION

BAHA provides promising results in rehabilitation of individuals with unilateral hearing loss/SSD mainly to improve speech recognition abilities (Niparko, Cox, & Lustig 2003; Snik et al., 2005; Hol, Kunst, Snik, & Cremers, 2010). But the device works on principle of bone conduction for transmitting information from implanted ear to better cochlea. Through BAHA amplification at low frequencies would lead to produce distortion due to lesser transcranial attenuation. Thus lower frequency attenuation could provide better speech understanding in the noisy background and also provide better sound quality. Hence the present study was conducted with the aim of examining the effect of the low frequency attenuation in pre-implantable BAHA on speech perception ability in the presence of noise, horizontal plane localization and subjective rating.

The results from subjective rating scale indicate that there is no deleterious effect on acoustic output quality with low frequency attenuation. But there was significant difference noted in loudness without on with low frequency attenuation, indicating that low frequency gain in the BAHA only adds loudness which is not required for the speech intelligibility.

Further after subjective rating scale each participant was asked for their preference across BAHA conditions (without and with low frequency attenuation at two high pass cut off frequencies 250Hz & 1500Hz). Fourteen participants of 20 preferred low frequency attenuation with 250Hz condition followed by 1500Hz conditions than without low frequency attenuation. Four participants preferred without low frequency attenuation setting and two participant preferred low frequency attenuation with cut-off 1500Hz conditions. As most of participants preferred low frequency attenuation of 250Hz it can be said that loudness is not changed significantly preserved while preserving the speech perception cues. Hence low frequency attenuation below and at 250Hz would be most appropriate option while programming BAHA.

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