The Journal of International Advanced Otology

J Int Adv Otol 2019; 15(1): 62-9 • DOI: 10.5152/iao.2019.6224

Original Article

Hearing Impairment and Quality of Life in Adults with Asymmetric Hearing Loss: Benefits of Bimodal Stimulation

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Cite this article as: Sanhueza I, Manrique-Huarte R, Calavia D, Huarte A, Manrique M. Hearing Impairment and Quality of Life in Adults with Asymmetric Hearing Loss: Benefits of Bimodal Stimulation. J Int Adv Otol 2019; 15(1): 62-9.

OBJECTIVES: Bimodal stimulation for asymmetric hearing loss is an emerging treatment with proven audiometric outcomes. Our objectives are to assess the changes of the hearing impairment and the quality of life of patients treated with this type of stimulation, when compared to a unilateral Cochlear Implant (CI) stimulated condition.

MATERIALS and METHODS: 31 patients with asymmetric hearing loss (Group 1) were recruited for the study. They were divided into three groups, based on their hearing loss in the ear treated with the hearing aid: Group 1A (Pure Tone Audiometry (PTA) between 41 and 70 decibels (dB)); Group 1B, (PTA between 71 and 80 dB) and Group 1C (PTA between 81 and 90 dB). 30 patients had profound, bilateral hearing loss. Then, users of a unilateral cochlear implant were recruited for the control group. Their hearing impairment and quality of life were analyzed with questionnaires Abbreviated Profile of Hearing Aid Benefit (APHAB), Speech, Spatial and Qualities of Hearing Scale (SSQ) and the Health Utilities Index (HUI). They were followed up for at least 2 years.

RESULTS: The group with the asymmetric hearing loss obtains a statistically significant clinical improvement in the APHAB under category "with hearing aid" compared to "without hearing aid". The group with the asymmetric hearing loss benefits more across basically all variables compared with the control group in the SSQ. Group 1A obtains the best outcome of the sample in the HUI.

CONCLUSION: Bimodal stimulation and better hearing in the ear treated with the hearing aid reduce hearing impairment and improve the quality of life.

KEYWORDS: Asymmetric hearing loss, quality of life, bimodal stimulation

INTRODUCTION

Asymmetric hearing loss (AHL) may be defined as an interaural difference >10 dB, using the average value of air conduction thresholds in the pure tone audiometry (PTA) for 500, 1000, 2000, and 4000 Hz frequencies [1]. AHL can occur between two sick ears or one sick ear and another healthy ear. Hearing loss may span from mild to profound and vary from sensorineural to mixed or conductive. Therefore, the greater the difference between both ears, the greater the asymmetry is.

There are multiple choices of treatment, one of which is combining a hearing aid (HA) and a cochlear implant (CI). This type of stimulation is called bimodal stimulation. This choice of treatment is successful in restoring the patient's binaural hearing [2-5]. These authors and others have used audiometric tests to prove such benefits. However, there are very few published studies about the changes to the quality of life (QOL) that these patients with AHL experience with bimodal stimulation.

In 1997, Newman et al. [6] used the Hearing Handicap Inventory for Adults in 63 patients with AHL. He concluded that although these patients are hearing impaired, there is no clear correlation between the asymmetry and the degree of impairment. In 2001,

This study was presented as a part of a Doctoral Thesis, defended at Universidad de Navarra in October of 2017.

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Submitted: 31.10.2018 • **Accepted:** 26.12.2018
Available online at www.advancedotology.org

Parving et al. [7] used the Gothemburg Profile and the Short Form 36 in 634 patients. He concluded that the group with AHL suffers greater impairment than the average normal hearing population. Finally, in 2015, Vannson et al. [8] used the Speech, Spatial and Qualities of Hearing Scale (SSQ) and the Glasgow Scale Handicap Index in 46 patients with AHL and compared them with 11 normal hearing people. He found differences between the groups to the advantage of the normal hearing population.

Given the diverse questionnaires and type of patients included to date, the aim of the present study was to show the benefit obtained with regard to the QOL for a group of patients treated with bimodal stimulation (CI in the ear with profound hearing loss and HA in the contralateral ear), with different degrees of hearing loss in the better ear, and compare them with a group of patients with profound, bilateral hearing loss who used a unilateral CI.

MATERIALS AND METHODS

Subjects

This was a retrospective study conducted in a population treated between January 2009 and January 2015 in a Cochlear Implant Center of Reference. A total of 61 out of 900 patients implanted were selected. Inclusion criteria in the ear treated with a CI include profound, postlocutive hearing loss. They had been wearing the CI for at least 2 years, and their age at implantation was similar. There were no anatomical alterations in the implanted ear. Two groups are established depending on the degree of hearing loss in the contralateral ear. Group 1 (AHL group) is made up of 31 subjects with moderate to severe hearing loss in that ear. Group 2 (unilateral CI group) is made up of 30 subjects with profound, sensorineural hearing loss. Three subgroups are set within Group 1 depending on the degree of hearing loss in the contralateral ear. Based on the classification of the International Bureau for Audiophonology: Group 1A is made up of 13 patients with moderate sensorineural hearing loss (PTA between 41 and 70 dB HL), Group 1B is made up of eight patients with type 1 severe sensorineural hearing loss (SSHL) (PTA between 71 and 80 dB HL), and Group 1C is made up of 10 patients with type 2 SSHL (PTA between 81 and 90 dB HL). The ears in Group 1 were being treated with an HA, so it might be said that patients with AHL were all receiving bimodal stimulation.

Assessment

A previous study [4] analyzes these population groups with the PTA and speech audiometry tests. The outcome of this research shows that bimodal adaptation is superior to monaurality, and that patients with the best residual hearing obtain the best results.

In the present study, each patient is assessed through three questionnaires, which will be filled out at the time of their routine yearly checkups at the implant center.

Abbreviated Profile of Hearing Aid Benefit (APHAB)

The APHAB [9] questionnaire is the short version (“Abbreviated”) of the “Profile of Hearing Aid Benefit,” which was originally designed to measure the benefit gained by the patient who uses an HA. The APHAB is made up of 24 questions, and there are seven possible answers to each. The authors of the questionnaire have previously given a percentage value to each answer. The patient is required to choose one single answer in each question, and each question is answered with and without using the HA. The questions are internally divided into four subscales, which are ease of communication (EC), background noise (BN), reverberation (RB), and aversiveness to noise (AV).

Speech, Spatial and Qualities of Hearing Scale

The SSQ [10, 11] questionnaire is designed to self-report hearing impairment in connection to several domains of hearing. It reflects the daily hearing of the patient, the speech in context, directional, and spatial hearing, and hearing moving objects at a distance. It also assesses sound segregation and splitting attention among several speakers, the ease of hearing, the ability to identify sound, and the ease of hearing several speakers, music pieces, and common sounds. The SSQ has 49 questions divided into three sections or domains: 14 questions related to hearing speech, 17 questions related to spatial hearing, and 18 questions related to the quality of hearing. Each question is answered by making reference to a visual analog scale from 0 to 10, and you can choose any point in the visual analog scale, decimals included. Each domain is divided into subscales as follows:

- Speech Hearing domain: Speech in Quiet, Speech in Noise, Speech in Speech Context (SiSCont), and Multiple Speech Stream Processing and Switching;
- Spatial Hearing domain: Localization (Loc) and Distance and Movement (DisMov);
- Quality of Hearing domain: Segregation of Sounds (SegSnds), Identification of Sound and Objects, Sound Quality and Naturalness, and Listening Effort (Eff).

Health Utility Index

The Health Utility Index (HUI) [12] questionnaire is part of a family of questionnaires designed to measure the *standard* of health and QOL and produces useful values for the population. Out of all the QOL questionnaires to which we had access, the HUI has been selected because it includes a specific section on hearing impairment. The questionnaire covers eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain, and each attribute has five or six levels of ability or disability. The HUI would in practice create 972,000 unique standards of health according to the result. The patient must choose the situation or level of ability or disability that best describes him/her in each of the attributes mentioned above. Each standard of ability or disability, in each attribute, has a percentage value, previously set by the authors of the questionnaire. The final result is the global utility of the patient vis-à-vis his/her QOL as a patient with a chronic pathology. The HUI calculates the same responses in two different ways, thereby delivering two similar values: Mark II or Mark III. We will express results both ways for their subsequent analysis.

Statistical Processing

Analysis of Group 1 (AHL)

APHAB Questionnaire

A mixed factorial ANOVA was used to compare the difference between subgroups and the “without HA” and “with HA” status. This test will yield the significance for the differences within and between groups. Sphericity will be controlled by Mauchly's Test. If it is not met, the ANOVA will be corrected by the Greenhouse-Geisser method. If there are statistically significant differences between "without HA" and "with HA," as they are two metrics, the significance would be maintained. When there are statistically significant differences across the groups, as there are three comparisons, the post-hoc Least Significant Difference (LSD) would be used to make the adjustments. If the interaction between both factors was significant or there was a suggestion of interaction, the main effects would not be checked, and the following checks would be made to measure simple effects: the intragroup differences in each group (Student's T test of related samples for each group, adjusting the average standard deviation with the corresponding error term in the general model) and intergroup differences for each condition (ANOVA of independent metrics for each condition, adjusting the error term with their corresponding counterpart in the general model). If there were statistically significant differences, it would be checked by the post-hoc LSD, taking into account homoscedasticity. In case of heteroscedasticity, the ANOVA would be replaced by Welch's test, and if there were statistically significant differences, they would be checked by Tamhane's post-hoc T2.

SSQ and HUI Questionnaires

A one-factor ANOVA or an independent factor ANOVA would be performed to analyze these two questionnaires, as they cannot be analyzed internally. Owing to this, the same methodology previously described in the intergroup analysis would be used.

Group 1 (AHL) versus Group 2 (Unilateral CI) Analysis

The Student's T test for independent variables would be used to analyze quantitative variables, as it is a comparison between the two groups. In case of an abnormal distribution, Mann-Whitney U test for independent samples would be used, with the exact significance when the size of the sample is <20. The Pearson's X^2 would be used to analyze qualitative variables with a contingency table [13]. Homoscedasticity will be checked by the Levene test. The Shapiro-Wilk test and Box-plot will be used to check normality.

Statistical Analysis

Statistical Package for the Social Sciences v20.0 (IBM SPSS Corp., Armonk, NY, USA) was used as statistics software. The level of significance was set at 0.05 for all analyses.

RESULTS

APHAB

The hearing impairment was lower "with the hearing aid" in all the variables in the study than "without the hearing aid," and it was statistically significant, except in AV, where we only found such difference in Group 1C. We have not found an interaction between hearing conditions and type of asymmetry.

Then, the differences across the three AHL groups in the category "with hearing aid" were analyzed. Group 1A yielded a better outcome, statistically significant, than 1B and 1C for variables Global, EC, and RB (Figure 1 a-e).

SSQ Group 1

We have observed that Group 1A has a better outcome in subdivision EA, within the Quality of Hearing domain, than 1B and 1C. We have not observed differences in any of the other variables analyzed by questionnaire SSQ (Figure 2 a-d).

SSQ Group 1 versus Group 2

We have observed that the outcome of Group 1 is better than that of Group 2, with significant differences across all domains of the questionnaire and in the global result. When each domain is observed separately, there are significant differences in Speech Hearing in all subdivisions except SiSCont. In the Spatial Hearing domain, there is a statistical significance in two subdivisions, Loc and DisMov, and in Quality of Hearing, there are statistically significant differences in all subdivisions except SegSnds (Figure 3 a-d).

HUI Group 1

In the HUI Mark II, we have observed that Group 1A's better outcome tends to be statistically significant than Group 1B (p=0.07) and Group 1C (p=0.072). In the HUI Mark III, we have observed that Group 1A's better outcome tends to be statistically significant than Group 1C (p=0.055). No differences were observed in the rest of the metrics (Figure 4a).

HUI Group 1 versus Group 2

We have not found significant differences across the groups in either HUI Mark II or HUI Mark III (Figure 4b).

DISCUSSION

There are limited bibliographic references regarding the use of APHAB to research AHL treated with CI, as it is a questionnaire originally designed to assess the improvement in patients using HA [14, 15]. However, for a few years now, the use has been extended to assess the population groups treated with bone conduction implants, active middle ear implants, and CIs and also residual hearing to be treated with electroacoustic stimulation.

According to our results, bimodal stimulation (CI+HA) was significantly superior to monaural hearing (CI without HA) in the global APHAB. Our data show that when the HA is correctly fitted and bilateral stimulation is restored, this is perceived as clearly beneficial by the patient, even in type 2 SSHL, where basal hearing might be compromised. This is of the utmost importance, since it allows to state that even with little residual hearing in the ear with the HA, the patient can benefit from bimodal stimulation in daily activities. When comparing the differences across the groups, we observe statistically significant differences between Group 1A compared with 1B and 1C (p=0.009 and p=0.011, respectively). These differences are mainly drawn from differences in subscales EC and RB.

The better outcome obtained by bimodal stimulation might be due to how electrical stimulation combines and complements one ear with the acoustic stimulation in the other, or simply to having restored the bilateral stimulation of the hearing system. In the latter case, it can be clearly observed when applying this questionnaire that bilateral stimulation yields a better outcome.

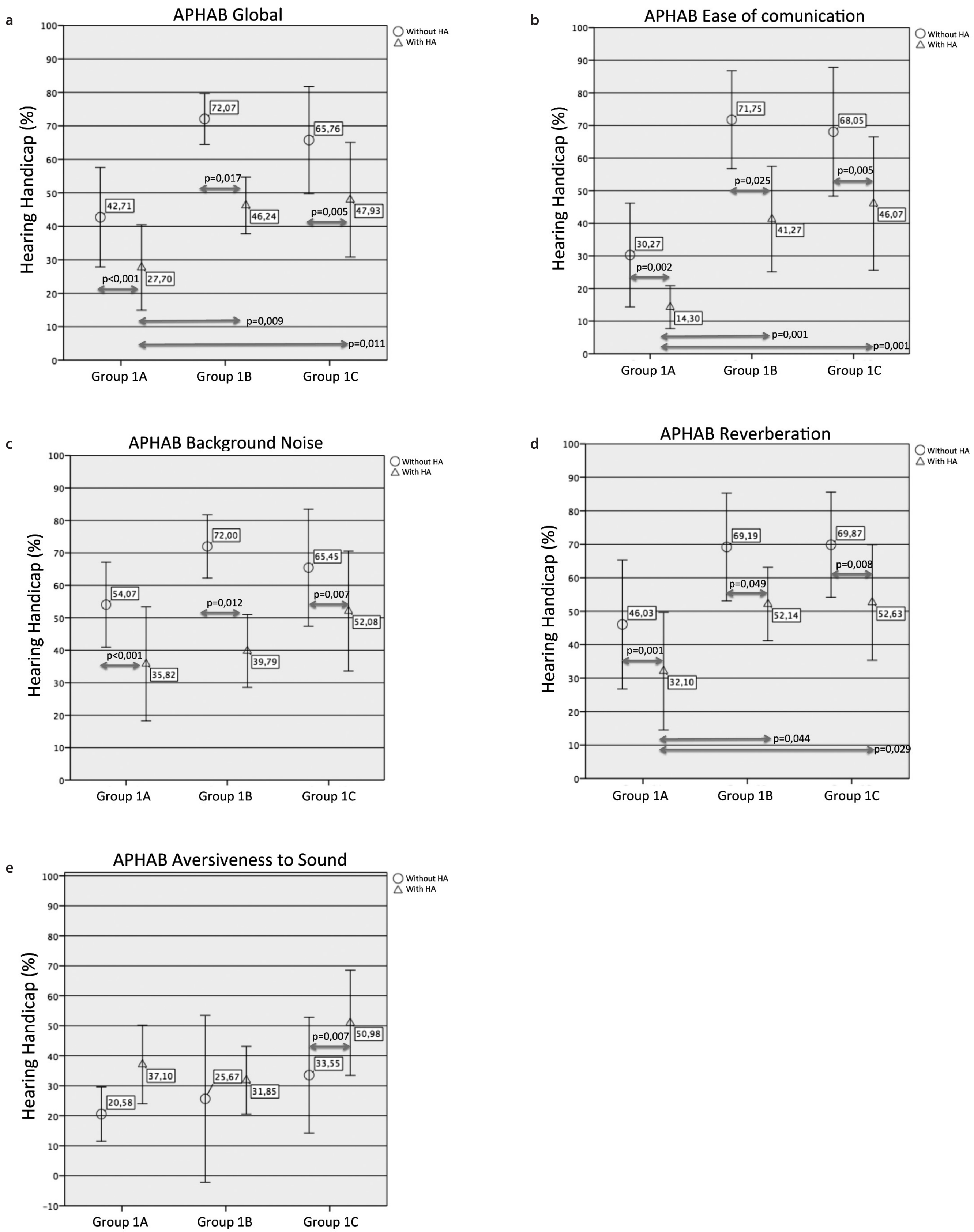

Figure 1. a-e. AHL group comparison of the results obtained in the APHAB questionnaire global score (a), ease of communication (b), background noise (c), reverberation (d), and aversiveness to noise (e). The groups are defined on the basis of the level of hearing with the ear contralateral to the implanted ear: Group 1A (PTA 41-70 dB SPL), Group 1B (PTA 71-80 dB SPL), and Group 1C (PTA 81-90 dB SPL).
HA: Hearing Aid.

In addition to a balanced programming of the CI and the HA, the stimulation strategy implemented in the CI had impact on the benefits drawn from bimodality. In the present study, the Advance Combinational Enconder or ACE strategy was used for the majority, and the results obtained agree with those published in the literature [16].

The results obtained in this questionnaire show the benefits of a bimodal strategy, which by definition facilitates the stimulation of both ears. Other research with CI+a Contralateral Routing of Signal or CROS HA [17] describes a decrease in the discrimination with BN. This was finally expressed in poorer results in the questionnaire, globally and in subscale EC, compared with monaural hearing. These data support the transcendence of having truly bilateral stimulation to enhance hearing in noise, as it is systematically shown in the present study by using bimodal stimulation.

Speech, Spatial and Qualities of Hearing Scale

We have not observed statistically significant differences in any of the comparisons made across domains in Group 1. Upon analysis of each domain subscales, the only significant differences are in Eff, within the domain Quality of Hearing, between Group 1A compared with Groups 1B and 1C (Figure 2c). This outcome indicates that patients with AHL with bimodal stimulation have a relatively transversal hearing impairment across the groups, and the only significant difference is driven by the lesser Eff made by the group with better residual hearing in the non-implanted ear.

However, when comparing results of Group 2 to the results of the AHL group or Group 1, one can observe that Group 1 obtains better results systematically across all the domains of the SSQ, as well as in the global score (Figure 3 a-d). When each domain subscale is analyzed, there are significant differences in all except two: speech in different settings and sound segregation. These results are especially

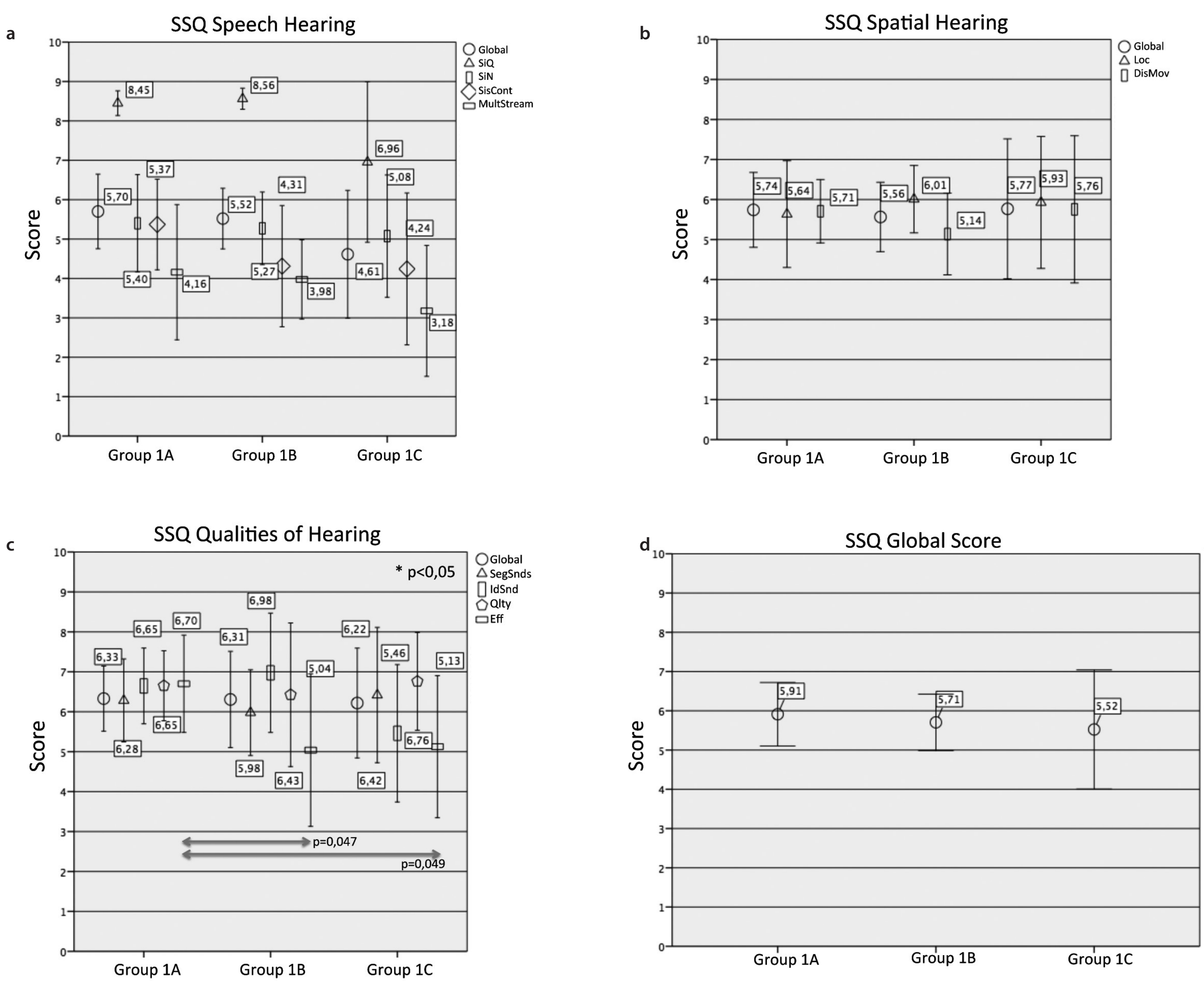

Figure 2. a-d. AHL group comparison of the results obtained in the SSQ questionnaire for the Speech Hearing domain (a), Spatial Hearing domain (b), Qualities of Hearing domain (c), and Global Score (d). The groups are defined on the basis of the level of hearing with the ear contralateral to the implanted ear: Group 1A (PTA 41-70 dB SPL), Group 1B (PTA 71-80 dB SPL), and Group 1C (PTA 81-90 dB SPL).

SiQ: Speech in Quiet; SiN: Speech in Noise; SiSCont: Speech in Speech Context; MultStream: Multiple Speech Stream Processing and Switching; Loc: Localization; DisMov: Distance and Movement; SegSnds: Segregation of Sounds; IdSnd: Identification of Sound and Objects; Qlty: Sound Quality and Naturalness; Eff: Listening Effort.

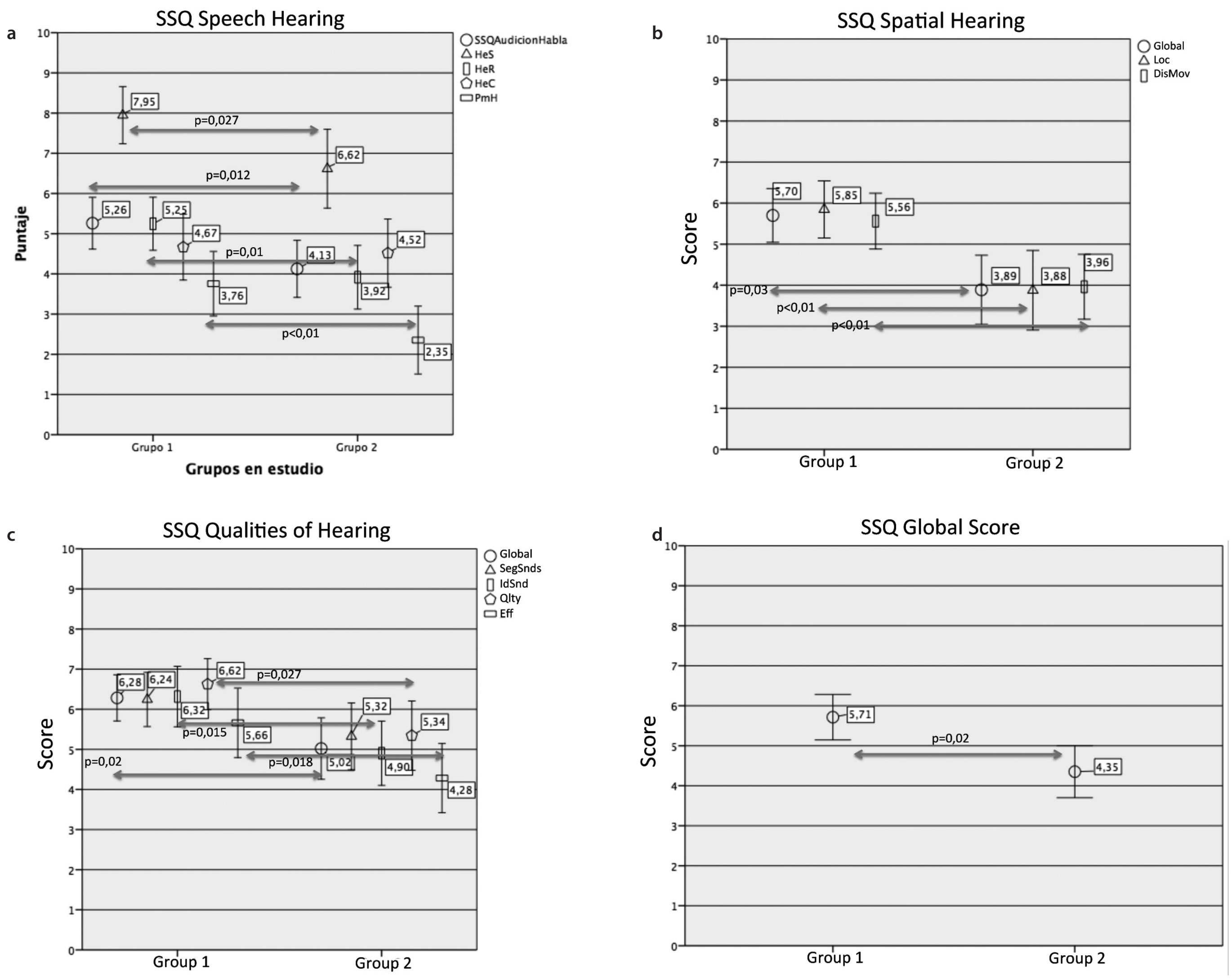

Figure 3. a-d. Between-group comparison of the results obtained in the SSQ questionnaire for the Speech Hearing domain (a), Spatial Hearing domain (b), Qualities of Hearing domain (c), and Global Score (d). The groups are defined regarding bimodal stimulation (Group 1) or unilateral cochlear adaptation (Group 2).

SiQ: Speech in Quiet; SiN: Speech in Noise; SiSCont: Speech in Speech Context; MultStream: Multiple Speech Stream Processing and Switching; Loc: Localization; DisMov: Distance and Movement; SegSnds: Segregation of Sounds; IdSnd: Identification of Sound and Objects; Qlty: Sound Quality and Naturalness; Eff: Listening Effort.

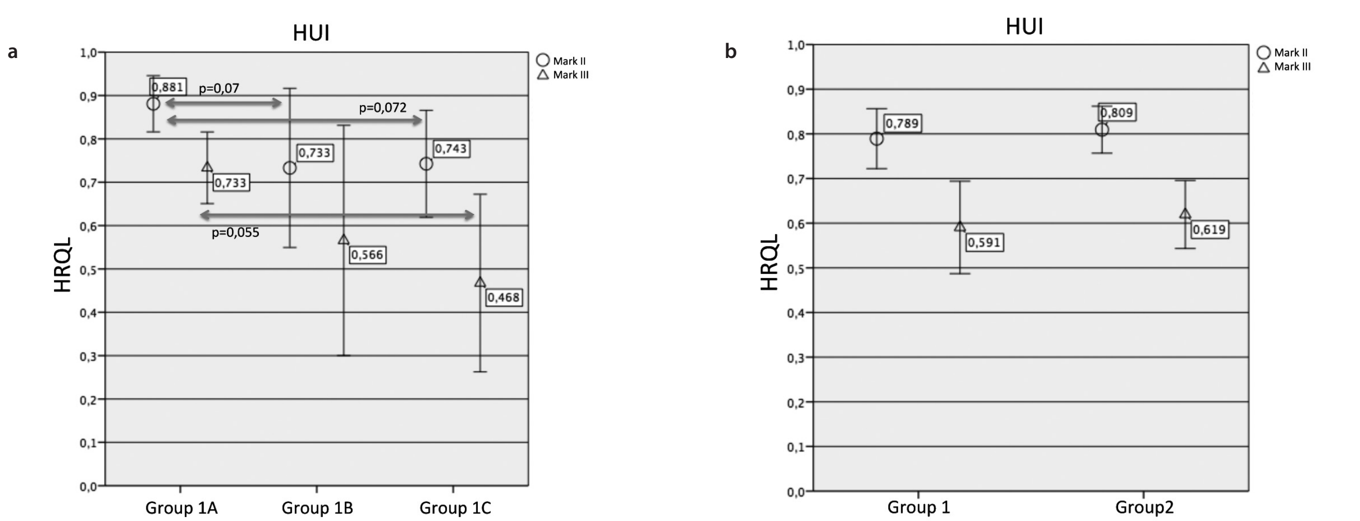

Figure 4. a, b. Results obtained in the HUI questionnaire for the AHL group comparison (a) and the between-group comparison (b). For the AHL, the groups are defined on the basis of the level of hearing with the ear contralateral to the implanted ear: Group 1A (PTA 41-70 dB SPL), Group 1B (PTA 71-80 dB SPL), and Group 1C (PTA 81-90 dB SPL). For the between-group comparison, the groups are defined regarding bimodal stimulation (Group 1) or unilateral cochlear adaptation (Group 2).

important, as they reconfirm the relevance of restoring binaurality, and its contribution to communication [18-20]. This has direct impact on the outcome of the Speech Hearing domain, as the statistical difference obtained in this section hinges on leveraging binaural hearing [21].

The outcome obtained in the Loc domain and its subscales were expectable, as spatial hearing depends on the bilateral input of sound to correctly process it centrally.

In the Quality of Hearing domain, the unilateral implantation group endures a clear disadvantage. This subscale includes questions directly geared toward listening music, intonation, pitch, and ease of sound. Although the CI is an excellent prosthesis for hearing, it lacks the tools to detect the full complexity of the musical spectrum or prosodic cues. This is supplemented with an HA that offers important acoustic cues to perceive such nuances. Although the final outcome is not optimal, bimodal stimulation is significantly better than unilateral implant.

Health Utility Index

This QOL questionnaire has been broadly used in the literature and validated in several languages [22-26]. It also includes a specific section on hearing loss, which is extremely important for the purpose of this research. However, its use by the hearing loss population is limited [27, 28], and there is only one study to date [29] that measures the QOL in AHL using the HUI, but with a lower "n" than ours.

The literature that measures QOL in AHL is rare, and the methodology varies widely in most of them [6-8]. However, they all agree on the fact that the hard of hearing patient enjoys lower QOL than a normal hearing population.

In the present study, we have found differences across the AHL groups in both the HUI Mark II (1A compared with 1B and 1C) and HUI Mark III (1A compared with 1C). Based on our understanding, Group 1A benefits more from binaurality and, therefore, scores better on this item, which could explain the difference observed vis-à-vis Groups 1B and 1C. This does not detract from the fact that each patient is different, and therefore, they can score higher or lower than their peers on the remaining categories (Figure 4a).

Finally, we have not observed significant differences between Group 1 and Group 2 (Figure 4b). We have already discussed how the groups are homogeneous in everything except in hearing asymmetry, and therefore, it is very likely that the QOL obtained in both groups will be that of a hearing loss population in that age range, regardless of hearing symmetry. Unfortunately, we do not have a standardized value to compare these values with a normal hearing population in this age range, but if we refer to the research abovementioned, the normal hearing population obtained basically perfect results in the QOL questionnaires. Therefore, we could infer that both the AHL group and the unilateral CI group see their QOL to be lower than a normal hearing population.

CONCLUSION

Patients with AHL treated with bimodal stimulation reduce their hearing impairment compared with the benefit of monaural stimulation, and they enjoy better QOL.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – I.S., R.M., D.C., A.H., M.M.; Design - I.S., R.M., D.C., A.H., M.M.; Supervision - I.S., R.M., D.C., A.H., M.M.; Resource - I.S., R.M., D.C., A.H., M.M.; Materials - I.S., R.M., D.C., A.H., M.M.; Data Collection and/or Processing - I.S., R.M., D.C., A.H., M.M.; Analysis and/or Interpretation - I.S., R.M., D.C., A.H., M.M.; Literature Search - I.S., R.M., D.C., A.H., M.M.; Writing - I.S., R.M., D.C., A.H., M.M.; Critical Reviews - I.S., R.M., D.C., A.H., M.M.

Acknowledgements: The authors thank to Salome San Bruno and Rosario Lezaún, for their effort in data collection.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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