Auditory and Corporal Laterality, Logoaudiometry, and Monaural Hearing Aid Gain

Mariela Benavides,[a] Yolanda R. Peñaloza-López,[b] Sabino de la Sancha-Jiménez,[b] Felipe García Pedroza,[a] and Paula K. Gudiño[a]
[a]Investigación en Medicina Familiar, Facultad de Medicina, Universidad Nacional Autónoma de México, México
[b]Neurofisiología-Investigación, Instituto Nacional de Rehabilitación, Col. Arenal de Guadalupe, Tlalpan, México

Introduction and objective: To identify the auditory or clinical test that has the best correlation with the ear in which we apply the monaural hearing aid in symmetric bilateral hearing loss.
Material and method: A total of 37 adult patients with symmetric bilateral hearing loss were examined regarding the correlation between the best score in speech discrimination test, corporal laterality, auditory laterality with dichotic digits in Spanish, and score for filtered words with monaural hearing aid.
Results: The best correlation was obtained between auditory laterality and gain with hearing aid (0.940).
Conclusions: The dichotic test for auditory laterality is a good tool for identifying the best ear in which to apply a monaural hearing aid. The results of this paper suggest the necessity to apply this test in patients before a hearing aid is indicated.

Key words: Monaural hearing aid. Symmetric bilateral hearing loss. Auditory laterality. Corporal laterality. Hearing aid gain. Dichotic digit test in Spanish.

Lateralidad auditiva y corporal, logoaudiometría y ganancia del audífono monoaural. Aplicación en hipoacusia bilateral simétrica
Introducción y objetivo: Identificar la correlación de las pruebas audiológicas o clínicas respecto al lado en que se obtiene la mejor ganancia del auxiliar auditivo monoaural en hipoacusia bilateral simétrica.
Material y método: Se examinó a 37 pacientes adultos con hipoacusia bilateral simétrica, respecto a la correlación entre la máxima captación fonémica de la logoaudiometría, la lateralidad corporal, la lateralidad auditiva con la prueba de dígitos dióticos en español, la utilidad social de la audición y la ganancia de auxiliares auditivos.
Resultados: La correlación más alta se obtuvo para lateralidad auditiva respecto a la ganancia del audífono (0,940).
Conclusiones: La prueba de dígitos dióticos para la lateralidad auditiva es útil para identificar el mejor oído para la aplicación monoaural de auxiliar auditivo en casos de hipoacusia bilateral simétrica. Este resultado es importante, ya que indica la necesidad de aplicar la prueba de lateralidad auditiva antes de indicar el uso de auxiliar auditivo.

Palabras clave: Auxiliar auditivo monoaural. Hipoacusia bilateral simétrica. Lateralidad auditiva. Lateralidad corporal. Ganancia del auxiliar auditivo. Prueba de dígitos dióticos en español.

INTRODUCTION

Auditory laterality is studied as a part of the central hearing processes.[1,2] In this paper, we consider the influence of this mechanism on the peripheral levels of hearing, hence its importance for the adaptation and use of a monaural hearing aid in cases of symmetric bilateral hypoacusia.

Auditory Laterality

The preference of the right ear for verbal dichotic stimuli is found in more than two-thirds of right-handed people and is generally assumed as a function of the dominance of language in the left hemisphere (Jäncke et al,[3] 1993). This preference is variable among the different reports on this subject, as Nakagawa et al[4] (2002) observed, in a study designed to identify auditory laterality in the human brain by cerebral cartography, that only 6 of the 10 subjects showed left cerebral dominance for vocal emission /a/.

Correspondence: Y.R. Peñaloza López.
Planta 1 Torre de Investigación. Instituto Nacional de Rehabilitación. Avda. México Xochimilco, 289. Col. Arenal de Guadalupe. Tlalpan. 14389 México DF. México.
E-mail: yploza@yahoo.com.mx

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Auditory laterality is a process of high complexity, as it involves cognitive and perceptual components (Khalfa et al,[5] 1998). In addition, anatomically, the relationships among ipsilateral and contralateral tracts, ascendant and descendant tracts, multiple connections with subcortical nuclei, and functional delimitation of the primary and secondary hearing cortex hinder the following of the central representation of hearing signals (Firszt et al,[6] 2006).

Neuroimaging studies such as functional magnetic resonance offer objective elements on the function and organization of the auditory cortex of the human being and its relationship with language.[6] In addition electrophysiological methods such as electroencephalography and evoked potentials allow the evaluation of the response originated by diverse populations of neurons. Magneto encephalography (MEG), which measures the activity of the magnetic field associated with the flow of intracellular ions in the brain, has the advantage, by means of an imaging study of the central hearing processes, of excellent temporal resolution down to tenths of a millisecond, even though it also has disadvantages, such as the fact that it is not sensitive to currents in a radial direction.[6]

Evidence has been obtained from positron emission tomography studies that the brain has a clear laterality in linguistic aspects that refer to speech and are processed mainly by the left hemisphere, while the prosodic aspects that are included in non-verbal stimulation, such as musical notes, are processed in the right hemisphere.[7] Some reports have however noted that laterality depends on the hearing strategies of the subjects, an analytic strategy that is predominantly associated with greater activity in the left hemisphere.[7,8]

Dichotic Tests

The simultaneous presentation of different signals in the ears (dichotic presentation) has been used extensively for the study of auditory laterality since it was reported by Broadbent in 1956. In this model, in the study subjects, the spoken signals received by the right ear are identified more exactly than those received simultaneously by the left ear.[9,10] Experimentally, an advantage of the right ear has been found in more than 80% of right-handed subjects.[11]

The experiments initiated by Kimura[12] in the 1970's in the Neurological Institute of Canada, on dichotic listening using digits as stimuli, have deepened our knowledge of asymmetries existing in the hearing system. This procedure has been applied to the study of auditory function laterality in different child development disorders and also in older adults.[13-15]

It is interesting to observe that there are manifestations of the cochlear receptor that are expressing auditory laterality in functional peripheral levels of hearing. McFadden[16] has indicated that interaural asymmetry in the amplitude of otoacoustic emissions, in which greater sensitivity is identified in the right ear, may be attributed to sensitivity inhibition of the left ear. From the above a proposal is derived whereby asymmetry in peripheral hearing might be due to that very central asymmetry, assuming that this condition is exercised in the peripheral hearing receptor through efferent nerve activity.

The filtered word tests have also been widely used for the study of central hearing processes since the initial publication by Bocca et al.[17]

Recently, the importance of cognitive functions in these tests, in which attention, memory, and speed influence mental processing, has been discussed. This does not eliminate the need for functional and anatomical integrity of the hearing canal, which is of fundamental importance for appropriate performance in evaluation tests of the central hearing processes.[18,19]

Hearing Aid Treatment

In the lifestyles currently displayed by humans, providing amplification for subjects with hypoacusia involves a series of adjustments, depending on the subject's attention and the stimulus amplified, in order to achieve sound perception that is useful for communication, especially the reception of verbal information. The WHO defines hearing disability in adults as permanent hearing damage with auditory thresholds of 41 dB or more in the better ear. For this proposal hearing thresholds are considered in the better ear according to the average thresholds for the frequencies of 0.5, 1, 2, and 4 kHz.[20]

Within the reference framework supporting the adaptation of hearing aids, it has been confirmed that 2 ears are better than 1 in detecting weak signals. Whether in a background of noise or in silence, sounds are heard more intensely with 2 ears. The most important contribution of binaural hearing through the use of a hearing aid is allowing the hearing of sounds from sources that come from different directions.[21-24]

There is currently the alternative of amplification through hearing aids implantable directly in the temporal bone, in the ossicular chain, in the tympanic membrane, and in the otic capsule, or even in the brainstem.[25]

For the prescription of hearing aids, the doctor considers the individual necessities for improving the patient's hearing, supported by the result of tonal audiometry and logoaudiometry (determination of the percentage of meaningless monosyllables recognized between 20 and 100 dB HL) and also by the behaviour of the monaural or binaural test in front of the horn in the soundproof room for speech discrimination with bisyllabic or trisyllabic words. This test is designated the social utility of hearing and consists in determining the average correct repetition score for verbal stimuli at 55, 70, and 80 dB HL. A speaker emits stimuli in front of the patient in a soundproof room. A score <80% indicates the need to use hearing aids.[21]

In cases with symmetric hypoacusia, such as those considered in this paper, the rationale for prescribing just a single hearing aid is financial. Usually the ear selected for monaural amplification will be that with better word discrimination, as measured in logoaudiometry and later with the use of the hearing aid. Physicians must also consider the manual preferences of patients for better handling of the aid controls.[26,27]

Among older adults, the adaptation of hearing aids creates word discrimination difficulties in some cases, especially in environments where the signal to noise ratio is unfavourable for hearing discrimination.[24,28,29] Chmiel et al[30] explain this difficulty by a peripheral deficit in the left ear that leads to an imbalance or asynchrony in binaural signal or by a cognitive or hearing processing deficit for interhemispheric transference. The predilection for the use of the hearing aid in the right ear is reflected in the performance of dichotic digits tests (DT) in free as well as directed choice, according to the model that we are using in this paper[31] applied in Spanish,[32] that can be noted for English in the 4 cases that Strouse et al[33] published.

Because of the high cost of hearing aids, it is usual in our practice for adult patients to be prescribed just 1 (monaural adaptation). In current clinical practice, we consider that the ear to be amplified in cases of superficial, medium, and severe bilateral and symmetric hypoacusia is designated without any tangible elements to form the basis of this decision, except that the clinician nearly always opts to prescribe for the right side. The theoretical proposal is to determine what the hearing predominance is in patients requiring hearing aids; the prescription of these resources will improve hearing discrimination and, thus, the benefit users can obtain with their acquisition.

The objective of this work is to identify, in adult subjects with bilateral symmetric hypoacusia, the audiological test or clinical procedure that obtains the greatest correlation with the greatest benefit through the gain from the hearing aid for the FWT with a low-pass filter.

The hypothesis proposes the greatest correlation between the dominant ear, obtained by DDT, and the ear with greater benefit from the hearing aid through FWT.

MATERIAL AND METHOD

The study subjects are patients who attended an audiological clinic at the Human Communication Institute in May and June, 2004, and met the following inclusion criteria: patients with hearing loss who attended the Human Communication Institute in the speciality of audiology; between 18 and 65 years of age; potential candidates for the use of hearing aids; with superficial, medium, or severe bilateral and symmetric hypoacusia (10) dB; either gender; with conductive, mixed, or sensorial hypoacusia; cases with controlled metabolic or vascular diseases; who voluntarily agreed to participate in the study and gave their informed consent.

The exclusion criteria were: patients with profound hypoacusia, with neurological diseases, or whose audiological study would not be reliable.

Resources

Amplaid 460 Audiometer. Compact disc player. HP computer. Central hearing processes laboratory. The tonal audiometry, logoaudiometry,[34] and case history results were taken from the clinical files of the Human Communication Institute. Dichotic digits test in Spanish (DDT). Gain tests for FWT with a UNAM-INCH low-pass filter.[35] Subirana[36] laterality tests. Soundproof room for the determination of social utility. Bravo Widex and Oticon Digital Atlas behind-the-ear (BTE) type digital hearing aids. LPB programmer for hearing aid programming.

Methods

The method applied in this clinical investigation is transversal, prospective, descriptive, and correlative.

The tonal audiometry thresholds and logoaudiometric results were recorded from the clinical file.

The Subirana laterality test was performed, comprising the evaluation of one-handed daily life activities, following questioning of the subject on the hand normally used for executing these tasks. This test consists of 21 orders for manual execution, 5 for testing feet, and 4 for eye and head movement. A count of successes was performed for each side, expressed as a percentage, to define the subject's corporal laterality. The subject is right-handed if more than 60% of the orders were performed with the right hand, or vice-versa to determine left-handed subjects.

The DDT and FWT tests in Spanish with a low-pass filter were designed and recorded at the acoustic installations of the Centre for Applied Sciences and Technological Development (UNAM). The DDT test has its precursor in Strouse et al.[37] Its efficacy has previously been demonstrated for the study of auditory laterality, according to the results obtained by Kimura (1961), and in a case-control study of dyslexic children by Olivares et al (2004).

Auditory laterality was defined through the application of DDT. The patient had to verbally repeat the digit they heard best from each pair of stimuli.

The hearing aid was programmed according to hearing loss, using 500 and 3000 Hz frequencies as a reference, and adjusted through the Senso SPS programmer. With verbal stimuli, the FWT was applied with a low-pass filter (UNAM) in a soundproof room in front of a speaker at 55, 70, and 80 dB, without the hearing aid, and finally with the hearing aid on either side. A percentage value of the responses was obtained for each condition examined.

A correlation was established between the maximum phonemic reception from logoaudiometry and auditory laterality (DDT), and between maximum phonemic reception and corporal laterality; in addition, the correlation between auditory laterality and gain with the hearing aids, in terms of individual percentage values by right/left side and if applicable equal conditions in logoaudiometry or mixed laterality in the tests corresponding to hearing or corporal laterality.

The information was analyzed through a statistical database using the SPSS 11 programme. The Pearson correlation test was applied with this same programme.

Ethics

There is no conflict of interest. Informed consent was obtained from each patient.

RESULTS

In the period from May to June 2004, 37 patients attending the out-patient clinic at the CNR were reviewed; they presented mild, moderate, or severe bilateral symmetric hypoacusia, determined by the mean of the audible tones for the frequencies 0.5, 1, 2, 3, and 4 kHz. Nine men (24.3%) and 28 women (75.7%) were included, between 24 and 65 years of age, with a mean of 44.5 years; 2 (5.4%) patients, were declared left-handed and the rest (94.6%) right-handed (Table 1).

The thresholds obtained in tonal audiometry were expressed through the mean of the audible tones (PTA 4). It was found that 2 (5.4%) patients had mild right hypoacusia and as many again in the left ear; 25 (67.5%) had moderate hearing loss in the right ear and 24 (64.8), in the left; 10 (27%) had severe loss in the right ear and 11 (29%), in the left ear (Table 2).

In terms of the topography of hearing damage, 14 patients had conductive type hypoacusia; 19 sensorial type hypoacusia, and 2 had mixed hypoacusia (both conductive and sensorial).

In logoaudiometry, with regard to the maximum percentage of meaningless monosyllable recognition, 100% was obtained in the right ear in 26 (70.3%) patients and in the left ear in 23 (62.2%); impaired discrimination was found in a minimum proportion in the right ear as well as in the left, ie, 50% and 40%, in only 2 patients (Table 3). The figures cited corroborate the fulfilment of the principal inclusion criteria of the studied cases, symmetric bilateral hypoacusia, in pure tone hypoacusia levels as well as for maximum phonemic reception in logoaudiometry (Tables 2 and 3).

In the Subirana corporal laterality test, we observed that 35 patients (94.6%) were completely right-handed and only 2 (5.4%) were left-handed. None were mixed (Table 4). This corroborated the opinion the patients had with respect to their corporal laterality. However, for the auditory laterality obtained with DDT, a difference was noted with respect to corporal laterality, as in this test 31 patients (83.9%) were right-dominant and 6 (16.2%) left-dominant. None were mixed (Table 4).

The type of hearing aids with which the 37 cases were evaluated varied: 4 cases were evaluated with the 100% digital Atlas BTE type hearing aid from Oticon on each side, programmed in accordance with IGO, and the rest of the patients (33) were evaluated with the BTE type Senso Bravo Widex hearing aid, programmed with the Senso SPS portable programmer.

In the gain test with the use of the hearing aid, it was observed that, of the 37 patients, 31 (83.8%) obtained a greater gain on the right side, while 3 (8.1%) had a greater gain on the left side and 3 (8.1%) did not favour either ear (Table 4).

In free field FWT without the use of hearing aids, the greatest concentration of patients were found in the range of 0% to 20%, where 23 patients (62.2%) had more precarious discrimination. The lowest concentration was found between 41% and 60% discrimination, a category comprising only 3 patients (8.1%).

Table 1. Distribution of the Groups Studied by Gender

Age, Years	*Females, No.*	*Males, No.*	*Total*
24-30	4	1	5
31-40	5	1	6
41-50	5	2	7
51-60	7	3	10
61-65	7	2	9
Total	28 (75.7%)	9 (24.3%)	37 (100%)

Table 2. Magnitude of the Hearing Loss (Mild, Moderate, or Severe), According to the WHO Criterion, 2001 (n=74)

Degree of Hypoacusia	*PTA Right Ear*		*PTA Left Ear*	
	Frequency	*%*	*Frequency*	*%*
Mild	2	5.4	2	5.4
Moderate	25	67.5	24	64.8
Severe	10	27	11	29.7
Total	37	100	37	100

Table 3. Distribution of the Maximum Capture Obtained by Each Ear in the 37 Cases Examined. Notable Symmetry of the Hearing Between Left and Right Ears (n=74)

Maximum Capture, %	*Right Ear*		*Left Ear*	
	Frequency	*%*	*Frequency*	*%*
100	26	70.3	23	62.2
90	6	16.2	7	18.9
80	3	8.1	5	13.5
50	1	2.7	1	2.7
40	1	2.7	1	2.7

In the gain evaluation, also applying free field FWT with the use of a hearing aid in the right side, the greatest frequency was found between 21% and 40% discrimination in 17 patients (45.9%) and the least, in the range of 61% and 80% discrimination in 1 (2.7%). With the use of a hearing aid in the left ear, the greatest concentration was visible between 0% and 20%, with 25 patients (67.6%), and 1 (2.7%) discriminated between 61% and 80%.

In the statistical analysis, the Pearson test correlations obtained (SPSS 11) gave the following results.

The maximum Pearson correlation, r=0.940 for 2 tails and P=.01, were obtained between auditory laterality with respect to hearing aid gain by ear (Table 5).

The other correlations indicate there is no linear relationship (Table 5).

Table 4. Frequency and Percentage Behaviour of the Right, Left, Mixed, or Identical Conditions for Corporal Laterality, Maximum Capture in Logoaudiometry, Auditory Laterality According to the Dichotic Digit Test in Spanish, and the Dominance of Hearing Aid Gain for Filtered Words Using a Low-Pass Filter, Versus a Loudspeaker in a Soundproof Room

	Corporal Laterality		*Maximum Capture in Logoaudiometry*		*Auditory Laterality in Dichotic Test*		*Dominance of Gain With Hearing Aid*	
	Frequency	*%*	*Frequency*	*%*	*Frequency*	*%*	*Frequency*	*%*
Right	35	94.6			31	83.8	31	83.8
Left	2	5.4	6	16.2	6	16.2	3	8.1
Mixed							3	8.1
Identical			31	83.8				
Total	37	100	37	100	37	100	37	100

Table 5. Pearson's Correlation for Clinical Variables and Audiological Tests

	Word Laterality	*Corporal Laterality*	*Diotic Auditory Laterality*	*Gain Laterality*
Word laterality	1	–0.271	–0.043	0.031
Corporal laterality	–0.265	1	0.219	0.104
Auditory laterality	–0.043	0.219	1	0.940[a]
Gain laterality	0.031	0.104	0.940[a]	1

[a]Maximum correlation between the gain with hearing aid and auditory laterality according to the dichotic digit test in Spanish.

DISCUSSION

Considering the high cost of hearing aids and that people with economic limitations for acquiring them dominate our practice, the proportion of medical prescriptions for a single hearing aid is notable. In this case, it is desirable that the monaurally adapted hearing aid prescribed for symmetric bilateral hypoacusia provides the user the greatest advantage.

In this study, the levels of hearing loss make it clear that the majority of cases had medium hypoacusia and also high proportions of maximum word reception in the word intelligibility curve or logoaudiometry.

On the other hand, maximum word reception, that is usually a good resource for the identification of the ideal ear for unilateral amplification, is of little assistance for the prescription of the monaural hearing aid when the hypoacusia is symmetrical between both ears. On the basis of these results, it is evident that the criterion for selecting the ear to amplify according to the greatest percentage of correct repetition in logoaudiometry is not much help.

In the results of the DDT application to identify auditory laterality, the majority of the cases with symmetrical performance in the word intelligibility curve effectively gave a preference towards the right ear. Thus the dominance of right laterality is found, as expected, in over 80%, just as numerous references have identified for the corporal laterality effect, while 16.2% showed left auditory laterality.

However, when the gain from the hearing aid is verified for verbal material distorted by the application of a low-pass filter, applied separately to the right ear and the left ear with the use of a monaural hearing aid, the percentages of reception corroborate the better performance of the right side in 83.3%, the left side in 8.1%, and no ear is favoured in 8.1% of the cases.

From the above it is concluded that 8.1% of the cases had a preference for using the left ear for amplification. This means that it is appropriate for the audiologist to rely on the DDT to discern the best amplification option in those cases where, for whatever reason, only one hearing aid is prescribed.

The evaluation of corporal laterality according to the Subirana scheme shows that it is a process that can certainly define the right or left option for amplification, with a Pearson correlation of 0.249 with respect to auditory laterality and 0.104 with respect to gain from the hearing aid.

The vast majority of right-handed subjects had language representation in the left hemisphere, as well as two-thirds of the population of left-handed people while one third of the latter use the right hemisphere. However a large proportion of left-handed and ambidextrous people have bilateral representation, by which they are more heterogeneous than right-handed people in the direction and degree of cerebral dominance. These findings could be explained by information storage duplication in ambidextrous (left-handed) people, parallel to the bilateral representation of language in the cerebral hemispheres.[38]

From the Pearson correlation test, there is a noteworthy strengthening of the hypothesis posed in this study as the maximum correlation (r=0.940; P<.01) occurs between auditory laterality obtained with DDT and gain from the hearing aid.

The use of FWT with a low-pass filter to evaluate gains from hearing aids was necessary because very high percentage values were obtained on both sides with the conventional unfiltered phonetic material for performance as a gain of the

monaural hearing aid, preventing the definition of a predominant ear. Thus, the use of FWT with a low-pass filter explains the percentage values expressed in low figures for hearing aid adaptations that could be definitive. It must be stressed that the application of filtered words as hearing gain evaluation material with the use of hearing aids was not intended to study central auditory processes.

When a unilateral hearing aid is adapted, the possibilities of locating the sound source are found to be reduced. From the design of the research commented here, it is not possible to ascertain this. It may be appropriate to specify in future whether hearing location has any relationship with auditory laterality and also if this location skill with a single hearing aid has a favourable evaluation in the course of time, based on cerebral plasticity factors enhanced by the use of hearing amplification.

The results of this work strengthen the proposed hypothesis, and it is concluded that, to determine the ear that offers better results in verbal discrimination with the use of a monaural hearing aid in symmetric bilateral hypoacusia, the method of choice is to identify auditory laterality through DDT.

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