ORIGINAL ARTICLE

Hearing Loss Screening Tests for Adults

Perla B. Becerril-Ramírez,* Dina F. González-Sánchez, Angélica Gómez-García, Rafael Figueroa-Moreno, Gerardo A. Bravo-Escobar, Miguel A. García de la Cruz

División de Otorrinolaringología y cirugía de cabeza y Cuello, Secretaría de Salud, Hospital General Dr. Manuel Gea González, Ciudad de México, Distrito Federal Mexico, Mexico

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KEYWORDS
Hearing loss;
Adults;
Ageing;
Screening

Abstract
Introduction: The early detection of hearing loss has been studied widely in newborns due to the emerging technologies for diagnosis and treatment. There are detailed protocols for this goal. Nonetheless, hearing loss screening in adults has become more important lately with the increase of the life expectancy, an expected change in the Mexican population pyramid towards a rectangular shape in the next 50 years (with increased hearing loss prevalence) and the creation of public policies for social security such as the ''Seguro Popular''. There are no Mexican studies about hearing loss screening in adults.

The aim of this work was to assess a tone emission and a questionnaire as screening tools for hearing loss in adults.

Methods: A sample size of 500 individuals without otology pathology from the outpatient clinics at a general hospital. An otoscopy, 2 screening tests (tone emission and questionnaire) and tonal audiometry were performed on all subjects.

Results: The questionnaire turned out to be a sensitive test but with low specificity, whilst the tone emission was less sensitive but more specific with a higher rate of precision. In this study, the best result was achieved by a combined strategy using the two tests above, with a precision of 90%.

Conclusions: The best screening strategy proposed by this study for hearing loss in adults is a questionnaire and tone emission test, which guarantees complete hearing assessment in objective and subjective manners, performed quickly and without special training.

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PALABRAS CLAVE
Hipoacusia;
Adultos;

Pruebas de despistaje auditivo en adultos

Resumen

Introducción: La detección temprana de hipoacusia ha sido ampliamente estudiada en recién nacidos gracias a las nuevas tecnologías en pruebas diagnósticas y tratamiento; existen


* Corresponding author.

E-mail address: perlita.b@gmail.com (P.B. Becerril-Ramírez).

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Introduction

The decrease in hearing sensitivity or hypoacusis (hearing loss) is defined by a hearing threshold (pure tone average at 0.5, 1, 2 and 4 kHz) of 25 dB or more. The World Health Organisation (WHO) defined disabling hearing weakness as a permanent hearing threshold of 41 dB or more in the better ear. Age-related hearing loss is known as presbycusis and is the most common sensory deficit in older adults. It has become a severe social and health problem. It is estimated that 1 in 5 adults suffers a bilateral hearing problem that affects their hearing and communication.

In the United States, it is estimated that over 28 million people are affected, but a large number of cases go undetected and therefore remain untreated, thus affecting productivity, functioning and quality of life for those individuals. People who develop hearing impairments as adults face different problems from those who grew up deaf, since they must adjust to many new circumstances. From the social and emotional standpoint, the onset of hearing impairment in the life of a person with normal hearing represents a need for re-adaptation at the social, and in some cases work, level. Nevertheless, it has been reported that treatment can reverse depressive symptoms and social isolation and improve quality of life. The subtle and gradual onset of hypoacusis, as well as the lack of visible symptoms contribute to its underdiagnosis.

Audiometry is the standard for evaluating hearing loss. It is a behavioural study used to assess hearing sensitivity. This measurement includes the central and peripheral auditory systems. The pure tone threshold is defined as the softest sound which a person can hear on 50% of the times it is presented. Hearing sensitivity is defined through a graph, called an audiogram, which displays the intensity of the sound, the decibels on the vertical axis (y), as a function of frequency, measured in Hertz, on the horizontal axis (x). This study has a sensitivity of 96% and a specificity of 92%, and is inexpensive and useful. Unfortunately, it cannot be considered as a screening test because it requires about 1 h to be performed by a trained audiologist in a soundproofed cabin and with specialised equipment.

Screening tests for hearing loss should be precise and practical. According to the WHO, screening procedures should include: a short questionnaire, otoscopy and a hearing test whose characteristics are known and proven. Subjects in whom a hearing problem is detected should be referred for a full otological and auditory evaluation.

Two tests have shown accurate detection and have been recommended as useful tools; one is hearing evaluation with an otoscope that emits tones, and the other is a self-assessment questionnaire for hearing impairment. Both studies can be performed quickly and without special training.

A positive test result for hearing loss is considered when patients do not hear a tone of 40 dB at a frequency of 2000 Hz in either ear. Screening through the questionnaire is performed with the validated Spanish version of the “Hearing impairment inventory for the elderly”, which consists of 10 questions measuring the degree of social and emotional disability caused by hearing loss. Its scores range from 0 (no disability) to 20 (maximum disability). The questionnaire can be completed within 5 min. Patients with scores over 10 are considered positive for hearing loss. These tools can be complementary, since each identifies different aspects of hypoacusis.

In several developed countries, such as the United Kingdom, United States and Canada, healthcare prevention organisations have recommended routine screening for hearing loss in adults. The WHO has published guidelines for the implementation of diagnostic strategies and hearing aid provision in developing countries, pointing to the importance of programmes with a wide coverage, optimising resources for diagnosis and treatment.

The availability of precise and practical auditory screening methods enables an early diagnosis of hearing impairment which facilitates the referral of identified individuals for further evaluation or adequate intervention, as appropriate.
In addition to accuracy and practicality, there are other criteria which justify the implementation of screening programmes. These include the fact that the impact of the disease is significant enough to justify the screening effort. In addition, there are treatments available for detected cases and the natural history usually allows time for intervention.1

In Mexico there are no studies assessing auditory screening tests, which are becoming increasingly important due to the creation of social healthcare protection programmes, such as the Seguro Popular ("general insurance"), which will require strategies that benefit the greatest number of people, whilst optimising available resources.

General Objective

- To determine the sensitivity and specificity of 3 auditory screening tools (questionnaire, tone emission and both tests together).

Specific Objectives

- To determine the number of subjects with hearing loss identified through each of the tests.
- To determine differences between female and male gender in the outcome of the tests.
- To describe the results of the 3 tests in subjects with comorbidities.
- To establish mean audiometric curves according to age groups, for healthy subjects and for those with comorbidities.

Methods

Design

The current study was analytical observational, open, prospective and transversal.

Sample Size

The sample size was calculated using the following formula:

\[ n = \frac{z^2pq}{B^2} \]

where \( z = 1.96 \) for a 95% confidence interval; \( p = \text{expected frequency} \); \( q = 1 - p \); \( B = \text{admitted error or precision} \).

The expected prevalence was 20%, with a 5% margin of error and a 95% confidence level. The required sample size was 246 subjects.

Selection Criteria

Inclusion Criteria

Patients or carers, aged between 40 and 75 years, who consulted at the outpatient clinic of a general hospital, with no history of otological disease or any other disease interfering with the sense of hearing, who agreed to participate in the study by signing the informed consent form and who completed all the required tests.

Exclusion Criteria

We excluded those patients with ages outside the accepted range or with a known history of otological pathology.

Elimination Criteria

We eliminated those subjects who did not complete the 3 evaluation tests (tone emission, questionnaire and audiometry).

Definition of Variables

- Hearing threshold: mean pure tone threshold at frequencies of 0.5, 1 and 2 kHz.
- Hearing loss by audiometry: hearing threshold greater than 25 dB.
- Positive tone emission test for hearing loss: a tone of 40 dB at 2 kHz is not perceived by one or both ears.
- Positive questionnaire for hearing loss: the sum of the response scores is equal to or greater than 10.
- Comorbidities considered: systemic arterial hypertension, diabetes mellitus (DM), dyslipidemia and rheumatoid arthritis.
- Speech audiometry: a test that aims to assess the ability of a subject to understand language. It was considered abnormal when 100% comprehension of words at 40 dB was not reached.

Description of Procedures

1. At the outpatient consultation of the General Hospital, we identified patients or caretakers who met the inclusion criteria and asked them to sign the informed consent form.
2. We asked about the presence of previously diagnosed comorbidities, of which we considered the following for the study: arterial hypertension, type 2 DM, dyslipidemia and rheumatoid arthritis.
3. We performed otoscopy to rule out the presence of earwax blockages (which were removed, if present) or otological pathology which, if detected, eliminated the subject from the study.
4. We conducted a questionnaire on auditory weakness. The tool used was the validated Spanish version of the “Hearing impairment inventory for the elderly”,9 which consists of 10 questions measuring the degree of social and emotional disability caused by hearing loss. “Yes” responses were scored with 2 points, “Sometimes” responses with 1 point and “No” responses with 0 points. Scores ranged from 0 (no disability) to 20 (maximum disability). Patients with scores greater than 10 were considered positive for hearing impairment (Annex 1).
5. We conducted a tone emission test. Subjects were given headphones through which a 40 dB tone at a frequency of 2 kHz was emitted independently for each ear. It was considered a positive test for auditory weakness when patients did not hear the tone.
6. Patients were referred to the Audiology Service to undergo an audiometry, which is the gold standard for
the assessment of hearing sensitivity. It consists of a pure tone threshold test (audiometry) and a speech discrimination test (speech audiometry). It takes place in a soundproofed cabin and is conducted by an audiologist.

7. Subjects with hearing impairment confirmed by audiometry were referred for a complete ENT evaluation which determined the best treatment according to each case.

Statistical Analysis

We used the software package SPSS 10.0 to conduct the statistical analysis. We calculated the basic measurements (mean, standard deviation, and frequency) and odds ratio.

Results

The study was completed over a period of 4 months (July to October 2011) with 400 subjects who met the inclusion criteria. They underwent otoscopy, answered the questionnaire and underwent the tone emission test and tone audiometry.

A total of 239 subjects were female and 161 were male. Their mean age was 58.57 years (SD=9.68). Table 1 shows the distribution by age groups.

The sensitivity, specificity and predictive values of the tests are shown in Table 2. The combination of the questionnaire and the tone emission test as a single screening strategy took into account a positive result for both tests.

The audiometry showed that 45% of subjects suffered unilateral hearing loss (n=360), whilst 36.7% suffered bilateral hearing loss (n=147). In total, 40.5% of females and 51.5% of males suffered unilateral hearing loss by audiometry. In the speech audiometry test, 25.4% of subjects had an abnormal unilateral result (n=203). In the questionnaire, 65.8% (n=526) of subjects were positive for hypoacusis. The tone emission test identified 27.9% positive cases (n=223).

Table 3 shows the characteristics studied in subjects divided by gender. Males were more affected in all tests.

In total, 29% of subjects (n=116) presented some of the comorbidities studied. In this group, 55% of subjects presented hearing loss according to their hearing threshold and 34.9% presented a unilateral, abnormal speech audiometry. In addition, 69.8% of subjects presented positive questionnaires for hearing loss, and 25.4% presented positive tone emission tests. Table 4 shows the results of tests comparing those subjects who reported any of the comorbidities studied against those who did not have this variable. In all tests, except for the tone emission test, subjects with comorbidities had a higher percentage of positive cases for hypoacusis and presented worse hearing thresholds.

Graph 1 shows the mean audiometric graphs for each age group in subjects without comorbidities. Graph 2 shows subjects with comorbidities.

### Table 1 Number of Subjects per Age Group.

<table>
<thead>
<tr>
<th>Age group, Years</th>
<th>Number of Subjects, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–49</td>
<td>150 (18.8)</td>
</tr>
<tr>
<td>50–59</td>
<td>292 (36.5)</td>
</tr>
<tr>
<td>60–69</td>
<td>234 (29.3)</td>
</tr>
<tr>
<td>70–75</td>
<td>124 (15.5)</td>
</tr>
</tbody>
</table>

### Table 3 Result of Tests Conducted According to Gender.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
<td>58 years</td>
<td>56.5 years</td>
</tr>
<tr>
<td>Mean threshold right ear, dB</td>
<td>25.4</td>
<td>29.3</td>
</tr>
<tr>
<td>Mean threshold left ear, dB</td>
<td>24.3</td>
<td>31</td>
</tr>
<tr>
<td>Bilateral hypoacusis by audiometry</td>
<td>30%</td>
<td>45%</td>
</tr>
<tr>
<td>Abnormal speech audiometry</td>
<td>20.2%</td>
<td>32.9%</td>
</tr>
<tr>
<td>Positive questionnaire for hypoacusis</td>
<td>63.1%</td>
<td>69.5%</td>
</tr>
<tr>
<td>Mean score of the questionnaire</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Positive tone test for hypoacusis</td>
<td>21.3%</td>
<td>37.5%</td>
</tr>
</tbody>
</table>

### Table 4 Result of Tests Conducted on Subjects With and Without the Studied Comorbidities.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Without comorbidities</th>
<th>With comorbidities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
<td>57.3 years</td>
<td>61.4 years</td>
</tr>
<tr>
<td>Mean threshold right ear, dB</td>
<td>26.2</td>
<td>29</td>
</tr>
<tr>
<td>Mean threshold left ear, dB</td>
<td>24.3</td>
<td>30.3</td>
</tr>
<tr>
<td>Bilateral hypoacusis by audiometry</td>
<td>32%</td>
<td>48.2%</td>
</tr>
<tr>
<td>Abnormal speech audiometry</td>
<td>21%</td>
<td>34.9%</td>
</tr>
<tr>
<td>Positive questionnaire for hypoacusis</td>
<td>64%</td>
<td>69.8%</td>
</tr>
<tr>
<td>Mean score of the questionnaire</td>
<td>11</td>
<td>12.36</td>
</tr>
<tr>
<td>Positive tone test for hypoacusis</td>
<td>28.8%</td>
<td>25.4%</td>
</tr>
</tbody>
</table>

NPV, negative predictive value; PPV, positive predictive value.
sensitivity and specificity of screening tests

There have been several studies evaluating various hearing screening tests. Gates et al. compared the full hearing disability questionnaire vs performing a single overall question and the combination of both as a screening test. They found that the full questionnaire had a sensitivity of 35% and a specificity of 94%. The overall question had a sensitivity of 71% and specificity of 71%. Combining both tests failed to improve the sensitivity of the questionnaire and the specificity of the overall question. In their conclusions they recommend the use of the overall question as part of the initial clinical history of elderly patients.\textsuperscript{13}

In a screening study conducted with veterans, Yueh et al. mentioned a sensitivity of 63%–80% and a specificity of 67%–77% for the questionnaire, and a sensitivity of 94% and a specificity of 69%–80% for the tone emission test. They also mentioned that there are no data available on the use of both tests in combination.\textsuperscript{12}

Conducting a screening for any disorder attempts to increase the likelihood of identifying those affected (sensitivity) and exclude those who are not (specificity). The more sensitive a screening method is, the more it increases the likelihood of false positives. Therefore, there is an inherent and inevitable equilibrium between sensitivity and specificity. The objective of a screening programme is an approach that allows this exchange to be managed. In our study, the questionnaire showed good sensitivity but low specificity, whereas the tone emission test showed low sensitivity but good specificity. However, by combining the positive results of both tests we obtained the best result, with a sensitivity of 88% and a specificity of 75%, as well as an accuracy of 82%. This strategy enables a comprehensive assessment of the objective and subjective hearing condition of individuals in a quick manner which does not require special training. It also makes it possible to identify individuals who could benefit from treatment to reverse the impact of hearing loss in communication, quality of life and in the workplace.

prevalence of hypoacusis among adults

The prevalence of hearing loss among adults is considerable. According to the WHO, an estimated 413 million people globally suffer a slight hearing loss, 187 million suffer a moderate loss and 46 million suffer a severe to profound loss.\textsuperscript{14}

Studies conducted in the United Kingdom reported that approximately 20% of adults suffered a hearing problem which affected their communication.\textsuperscript{15} The incidence in our sample was higher, with 45% of subjects presenting unilateral hypoacusis and 36.7% bilateral hypoacusis. These figures alert us about the need to implement diagnostic tools that can identify a significant, potentially affected fraction of the population which would otherwise remain undiagnosed and suffer a delay of approximately 10–15 years in the establishment of a treatment, which could, in turn, become increasingly complex and less effective.\textsuperscript{12}

differences between females and males

In a study using screening tests and audiometry to detect hypoacusis, Gates et al. reported that males met the criteria for hearing loss in 35% of cases, whereas females did so in 22%.\textsuperscript{13} In our study, males presented hearing loss by threshold in 51.5% of cases, compared to females in 40.5%.

After conducting a study with 224 subjects, Sha-rashenidize et al. reported that males presented age-related hypoacusis at earlier ages than females, and that their loss progressed more quickly than that of females. They also mentioned that, for all decades studied, females presented better hearing than males and that these differences may reflect different dynamics in the onset of age-related hearing loss.\textsuperscript{16}

This trend towards a more severe involvement among males was also observed in our study. Males presented a higher prevalence of hearing loss in all our tests.

comorbidities

Agrawal et al. conducted a study on the association between cardiovascular risk and hearing level at specific frequencies
and found a difference with worse hearing levels among subjects with DM and hypertension. Diabetes doubled the risk of suffering hypoacusis.¹⁷

Uchida et al. found an adverse effect of DM on hearing. This effect varied according to age at high frequencies.¹⁸

Huang and Tang reported that several medical conditions, some related to age, could be determining factors for hearing loss (cardiovascular risk, metabolic diseases, DM). Nevertheless, they also stated that more research focused on this field was needed.¹⁹

In our study, subjects with comorbidities showed a higher prevalence of hearing loss in all tests, except for the tone emission test, as well as a worse hearing threshold at different frequencies. It is probable that, in this group, audiometric curves are affected at younger ages and are influenced by the duration and effectiveness of the treatment for the underlying disease.

In the light of these results, we consider that suffering any of the studied comorbidities (DM, systemic arterial hypertension, dyslipidemia and rheumatoid arthritis) places subjects at an increased risk of hearing loss. In this group it is especially relevant to consider a screening test which identifies hearing impairment from the time of diagnosis and which is part of a comprehensive monitoring.

The mean audiometric charts represent a reference of the threshold expected for each age group. Schuknecht proposed 4 types of presbycusis after studying the audiograms and histopathology of elderly patients. In his classification, type 1 referred to a sensory hypoacusis with a loss of external ciliated cells which is reflected by an audiometry with a sharp drop at high frequencies, below the frequencies of speech (0.5, 1, and 2 kHz).²⁰ The audiometric pattern was the same as that observed in our sample in all age groups and in subjects with and without comorbidities.

Conclusions

- Based on the results of this study, we recommend a combination of the questionnaire and the tone emission test as the best screening strategy.
- Our population suffered a higher prevalence of hearing loss than that reported in the literature.
- Males presented a higher frequency of hearing loss in all tests conducted.
- Subjects with presence of any of the studied comorbidities presented a higher frequency of hearing loss in all tests (except tone emission) compared with those who did not have this factor. Therefore, in this group it is especially important to consider a hearing screening test as a routine test at the time of initial diagnosis.
- Early identification of hearing loss is important to minimise the impact on the daily lives of subjects, both of working age and older adults.
- Social healthcare protection programmes can benefit from this study, as it proposes a strategy for a simple, fast, reliable and inexpensive method to identify subjects suffering hypoacusis.

Conflict of Interests

The authors have no conflict of interests to declare.

Annex 1. Questionnaire on Hearing Impairment

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>Sometimes</th>
<th>No</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you noticed that you need people to repeat things because you do not manage to hear them properly? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For that reason, have you at some point answered something different from what you were being asked? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Further, have you felt uncomfortable because you had to ask to have things repeated to you several times? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you noticed that you have trouble hearing a conversation when you are in a restaurant or in other noisy places? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you experience difficulty understanding words when several people speak to you at the same time? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you find it difficult to understand words when people whisper? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you find it difficult to understand the radio or television at the intensity which other people normally set? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you noticed that you do not manage to hear everything you are told when you are in the theatre, in a conference or in church? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you have trouble hearing when you speak on the telephone? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have you noticed that loud noises make you more uncomfortable than before? Yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

References