ORIGINAL ARTICLE

Diagnostic Utility of the Acoustic Reflex in Predicting Hearing in Paediatric Populations

Yolanda E. Pérez-Villa, María E. Mena-Ramírez, Laura E. Chamlati Aguirre, Ignacio Mora-Magaña, Ileana S. Gutiérrez-Farfán

Servicio de Audiología, Instituto Nacional de Rehabilitación, Distrito Federal, Mexico
Instituto Nacional de Perinatología, Instituto Nacional de Pediatría, Distrito Federal, Mexico

Received 19 August 2013; accepted 26 February 2014

KEYWORDS
Acoustic reflex; Broadband noise

Abstract
Introduction and objectives: The sensitivity of prediction of acoustic reflex, in determining the level of hearing loss, is especially useful in paediatric populations. It is based on the difference between the pure tone stapedius reflex threshold and contralateral white noise. The white noise threshold was 60 dB and that of pure tone was 80 dB.

Our objective was to determine the diagnostic sensitivity of the prediction of the acoustic reflex.

Methods: We studied children aged <10 years, from October 2011 to May 2012, by measuring the acoustic reflex with white noise and pure tone. We used contrast tests, with \( t \) and Student's \( t \)-test. Concordance was measured with Kappa. Results were considered significant at \( P \leq .05 \). Our protocol was approved by Institutional Ethics Committee. Informed consent was obtained from the parents in all cases.

Results: Prediction of normal hearing was 0.84 for the right ear and 0.78 in left ear, while for hearing loss of an unspecified grade, it was 0.98 for the right ear and 0.96 in the left ear. Kappa value was 0.7–0.6 for the right ear and left ear.

Conclusions: The acoustic reflex is of little diagnostic utility in predicting the degree of hearing loss, but it predicts more than 80% of normal hearing. The clinical utility of the reflex is indisputable, as it is an objective method, simple and rapid to use, that can be performed from birth and whose results are independent of the cooperation and willingness of the subject. It is proposed as an obligatory part of hearing screening.
© 2013 Elsevier España, S.L.U. and Sociedad Española de Otorrinolaringología y Patología Cérvico-Facial. All rights reserved.
Utilidad diagnóstica del reflejo acústico para predecir audición en población pediátrica

Resumen

Introducción y objetivos: La sensibilidad de predicción del reflejo acústico determina el nivel de pérdida auditiva, útil sobre todo en población pediátrica. Se basa en la diferencia entre el umbral del reflejo estapedial con tono puro y con ruido blanco contralateral. El umbral con ruido blanco es de 60 dB y con tono puro de 80 dB.

El objetivo de este estudio fue determinar la utilidad diagnóstica de la sensibilidad de predicción del reflejo acústico.

Métodos: Previo consentimiento informado, se estudió a niños menores de 10 años, de octubre del 2011 a mayo del 2012, midiendo el reflejo estapedial con ruido blanco y tono puro. Se realizaron pruebas de contraste con χ² y t de Student. La concordancia se midió con kappa. Se consideró significativo un valor de p < 0,05. El proyecto fue aprobado por el Comité de Ética. En todos los casos se obtuvo el consentimiento informado de los padres.

Resultados: Predicción de audición normal: 0,84 para el oído derecho y 0,78 en el oído izquierdo y para hipoacusia sin especificar el grado: 0,98 para el oído derecho y 0,96 en el oído izquierdo. Valor de kappa de 0,7 para el oído derecho y 0,6 para el oído izquierdo.

Conclusiones: La utilidad diagnóstica del reflejo acústico tiene muy poco valor para predecir el grado de pérdida auditiva, pero predice en más del 80% la audición normal. Por lo que se sugiere utilizar como una prueba objetiva obligada como parte del Cribado auditivo.

© 2013 Elsevier España, S.L.U. y Sociedad Española de Otorrinolaringología y Patología Cérvico-Facial. Todos los derechos reservados.

Introduction

Sensitivity prediction by acoustic reflex (SPAR) is based on the difference between the acoustic reflex threshold with pure tones and broad-band noise (BBN). In addition, the increase in the acoustic reflex threshold with white noise in sensory or cochlear hearing loss, without modifying the thresholds with pure tone, is considered.

Niemeyer and Sesterhenn (1974) observed that, in neurosensory hearing loss, the threshold of stapedial reflex with white noise was less than the threshold of pure tones and that the difference in decibels (dB) between the 2 thresholds is related to the degree of auditory loss. Consequently, the threshold of stapedial reflex with white noise presents 20 dB before the threshold with pure tone.

The noise-tone difference arises from the electrophysiological principle of spatial summation. The almost total stimulation of the basilar membrane, from the sum of a number of “n” of critical white noise, generates action potentials in a greater number of preganglionic fibres than the single critical band of a pure tone; this translates into the need for a lower amount of energy or sound pressure to reach the reflex threshold activation.

One of the ways to calculate the SPAR is the Jerger method. In this, the threshold of reflex with broad-band noise is subtracted from the mean threshold of pure tone in the contralateral frequency of 500, 1000 and 2000 Hz. Subjects with normal hearing show a SPAR (D) value of 20.

When the threshold of acoustic reflex with white noise is greater than 95 dB, an auditory loss can always be predicted.

Stach proposes using this test as a screening that makes it possible to differentiate the population with auditory loss from that which has none. These measurements can be applied to small children from 3 weeks old up.

Another clinical application can be found in the case of simulators and dissimulators.

Factors That Affect the Results of the Sensitivity Prediction by Acoustic Reflex

The variation in the size of the external auditory canals and sensorineural auditory loss at high frequencies introduces variability in data from adults, although it does not seem to be so large in small children.

Hall and Kovatti reported that the rate of predictive accuracy in patients with abnormalities in tympanometric curves was (20%-30%). In patients with cerebral palsy, Keath reported accuracy of 97% in identifying auditory loss. According to Pamela B. Poole (1982), hearing level predictions have an accuracy of 57% in individuals with mental retardation.

In the presence of alterations in central auditory processing, the contralateral reflex threshold is elevated or absent. Hall, in 1980, found that there is a tendency for “false positives” in estimations; this author proposed that it was reasonable to expect that complex signals would have a greater propensity to present alterations in the presence of central auditory problems.

The main objective of this study was to establish the diagnostic usefulness of SPAR as compared with conventional tonal audiometry in children.
Methods

Patients of 6, 7 and 8 years of age with hearing loss and bilateral normal hearing, who had come to the Audiology Service in the period from October 2011 to May 2012, were studied.

Appropriate middle ear function was studied and corroborated using type A, As or Ad Jerger curves. Patients with atresia of the external auditory canal, that did not cooperate or that did not wish to perform the audiological studies were excluded.

For the physical examination and cleaning the external auditory canal, we used a Welch Allyn otoscope and a straight cerumen spoon. Auditory function was assessed with the support of the GSI TymStar™ version 2 impedance tympanometer with insertion audiophones and the Madsen Orbiter 922 version 2 audiometer, equipped with TDH-39 earphones. The studies were carried out in a soundproof booth, calibrated according to the ANSI S3.6-1996 standard.

After taking a clinical history focusing on otorhinolaryngological aspects, tonal audiometry was performed using the conventional technique, by the descending method, obtaining the mean pure tones in dB; speech audiometry was also assessed using monosyllabic stimuli on the base of the average of audible tones.

To calculate the SPAR value following tympanometry, the thresholds of the contralateral stapedial reflex with broadband noise were taken and subtracted from the means of the thresholds of contralateral stapedial reflex in pure tones for the frequencies of 500, 1000 and 2000 Hz.

Acoustic reflex response was taken as positive when the signal intensity provoked a deflexion of 0.02 ml in the reflex curve.

For an exact SPAR value, a correction factor based on 10 subjects with normal hearing, using the physiological calibration of the impedance metre, was applied.

The correction factor obtained was 6 dB.

To calculate the values of the SPAR noise-tone difference, the method described by Jerger et al. was used:

\[ D = \left( l + m + n \right)/3 + \text{Correction factor} \]

where

\[ D = \text{noise-tone difference}; a = \text{reflex threshold at 500 Hz}; b = \text{reflex threshold at 1000 Hz}; c = \text{reflex threshold at 2000 Hz}; d = (a + b + c)/3; e = \text{lowest threshold among a, b, c}; f = \text{reflex threshold for BBN}; l = d – f; m = a – f; n = e – f. \]

The results were classified on the basis of Tables 1 and 2.

The sample was chosen by census type. We calculated sample size, considering the article by Tsappis (1977), and the following formula:

\[ n = \frac{2pq(Z \times 0.05 + Z\beta)2}{\delta^2} \]

\[ p=0.74; q=1-p=0.26; Z \approx 0.05=1.96; Z\beta=0.2=0.84; \delta=0.20; n=92. \]

The database was organised in tables with the programme Excel. The database was analysed and, once clean, we carried out contrast tests, threshold of acoustic reflex with pure tone and threshold with white noise vs tonal audiometry with the SPAR \( \chi^2 \) test vs antecedents (exanematous diseases, familial antecedents of hearing loss, use of ototoxic agents, antecedents of otorrhea, tympanogram, external auditory canal characteristics) with Student’s t-test or the Kruskal–Wallis test. SPAR vs tonal audiometry with Student’s t-test. Concordance was measured with kappa.

A value of \( P \leq 0.05 \) was considered significant.

Ethical considerations: This project was reviewed and approved by the Ethics Committee. The study was catalogued as of greater risk than the minimum, given that the subjects received a tympanogram and that the external auditory canal was cleaned with a spoon or washed. Each head of family was presented with the informed consent and it was explained; likewise, each procedure carried out was explained to every patient. Once all doubts and questions were satisfied, they were asked to sign the form.

Results

A total of 200 patients (400 ears), 97 females (48%) and 103 males (52%) were analysed, with the mean age being 7 years.

The dominant tympanometry curve was Type A; in 88% it was in the left ear (LE) and in 85%, the right ear (RE) (Fig. 1).

Familial antecedents of hearing loss were present in 44 patients; the presence of the antecedent with the finding of hearing loss coincided in only a small number (20 patients).

Otorrhea antecedents were found in 14 patients (7%). Of these, we found only 4 patients with both otorrhea antecedent and hearing loss (Table 3).

The use of ototoxic agents was reported for 28 patients (14%). In 17 patients ototoxic use coincided with the diagnosis of hearing loss; this was a statistically significant (\( P=\times 0.000 \)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Criteria for Predicting Auditory Loss.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>BBN Sound Pressure Level (SPL)</td>
</tr>
<tr>
<td>20 or greater</td>
<td>Any</td>
</tr>
<tr>
<td>15–19</td>
<td>80 dB or less</td>
</tr>
<tr>
<td>15–19</td>
<td>81 dB or more</td>
</tr>
<tr>
<td>10–14</td>
<td>Any</td>
</tr>
<tr>
<td>Less than 10</td>
<td>89 dB or less</td>
</tr>
<tr>
<td>Less than 10</td>
<td>90 dB or more</td>
</tr>
<tr>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>BBN: broad-band noise.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Criteria for the Auditory Loss in Agreement With the Pure-tone Average.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Criteria</td>
</tr>
<tr>
<td>Normal</td>
<td>PTA less than 20 dB HL</td>
</tr>
<tr>
<td>Superficial-medium</td>
<td>PTA 20–60 dB HL</td>
</tr>
<tr>
<td>Severe</td>
<td>PTA 61–80 dB HL</td>
</tr>
<tr>
<td>Profound</td>
<td>PTA 81 dB HL or more</td>
</tr>
</tbody>
</table>

HL: hearing loss; PTA: pure-tone average.
fact for identifying hearing loss in patients that had been administered ototoxicics at some time.

In 106 patients (53%), we found the antecedent of exanthematous diseases (Table 4).

The majority of the patients (83%) had normal external auditory canals and there were no problems to identify hearing loss and normal hearing. However, in patients with some kind of alteration, such as narrow auditory canals, some difficulties were observed in obtaining the SPAR.

Auditory threshold for the RE: 55 ears (27.5%) presented hearing loss; for the LE: 54 (27%) (Fig. 2).

The prediction of auditory threshold using SPAR by degree of hearing loss, confirmed through audiometry for the RE and the LE, is shown in Tables 5 and 6 and Figs. 3 and 4. We obtained a kappa value of 0.5 for the RE and 0.4 for the LE, which makes us think about a low SPAR reliability level when classifying patients based on the degree of auditory loss is desired.

If the values were taken to classify the results in just 2 large groups, normal hearing and hearing loss (without specifying the degree of hearing loss), it turned out that, for the RE (Fig. 5), of the 123 ears in which normal hearing was predicted, 122 (99%) were effectively confirmed as having normal hearing. Of the 77 ears that were predicted to have hearing loss, 54 (70%) presented some degree of hearing loss.

For the LE (Fig. 6), of the 116 ears that were predicted to have normal hearing, this was confirmed for 114 (98%).

Figure 1 Type of tympanometry curve based on the Jerger classification in all patients.

Figure 2 Data obtained using conventional tonal audiometry.

Figure 3 SPAR prediction by degree of hearing loss for the right ear.

Figure 4 SPAR prediction by degree of hearing loss for the left ear.

Figure 5 SPAR sensitivity; RE kappa: 0.7.

### Table 3 Frequency of Otorrhea by Ear.

<table>
<thead>
<tr>
<th>Otorrhea</th>
<th>No. of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>9</td>
</tr>
<tr>
<td>Left</td>
<td>3</td>
</tr>
<tr>
<td>Bilateral</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 4 Frequency of Exanthematous Diseases.

<table>
<thead>
<tr>
<th>Exanthematous disease</th>
<th>No. of patients</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickenpox</td>
<td>95</td>
<td>48</td>
</tr>
<tr>
<td>Measles</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>German measles</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Scarlet fever</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Parotitis</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>No exanthemata</td>
<td>94</td>
<td>46.5</td>
</tr>
</tbody>
</table>

Data obtained using conventional tonal audiometry.
Of the 84 ears that were predicted to have hearing loss, some degree of hearing loss was confirmed in only 52 ears (62%).

A kappa value of 0.7 for the RE and of 0.6 for the LE was obtained. This demonstrates that the reliability level for the SPAR increases when the patients are classified by only the presence of normal hearing or hearing loss without classifying the degree of the latter.

We considered, in the contingency table, normal hearing (healthy) as positive and hearing loss as negative. Consequently, the sensitivity identified normal hearing and the specificity identified hearing loss. The diagnostic usefulness of the SPAR, compared with that of tonal audiometry, is shown in Table 7.

Fig. 7 shows the direct lineal correlation that the value for noise-tone difference has against the SPAR value. The smaller the noise-tone difference, the smaller the SPAR value, and vice versa.

### Table 5  SPAR Prediction by Degree of Hearing Loss for the Right Ear Confirmed by Audiometry.

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>123</td>
</tr>
<tr>
<td>Superficial-moderate hearing loss</td>
<td>30</td>
</tr>
<tr>
<td>Severe</td>
<td>26</td>
</tr>
<tr>
<td>Profound</td>
<td>21</td>
</tr>
</tbody>
</table>

SPAR: sensitivity prediction by acoustic reflex.

### Table 6  SPAR Prediction by Degree of Hearing Loss for the Left Ear Confirmed by Audiometry.

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>116</td>
</tr>
<tr>
<td>Superficial-moderate hearing loss</td>
<td>40</td>
</tr>
<tr>
<td>Severe</td>
<td>20</td>
</tr>
<tr>
<td>Profound</td>
<td>24</td>
</tr>
</tbody>
</table>

SPAR: sensitivity prediction by acoustic reflex.

### Table 7  Diagnostic Usefulness of SPAR Compared With Audiometry Tonal.

<table>
<thead>
<tr>
<th></th>
<th>SPAR for right ear</th>
<th>SPAR for left ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>Predictive value (+)</td>
<td>0.70</td>
<td>0.61</td>
</tr>
<tr>
<td>Predictive value (−)</td>
<td>0.99</td>
<td>0.98</td>
</tr>
</tbody>
</table>

SPAR: sensitivity prediction by acoustic reflex.

### Discussion

Based on the results obtained in this study, there was a large proportion of errors from degree of hearing loss in normal-hearing subjects, who appeared moderate auditory loss. The accuracy for patients with severe loss is greater, just as for the normal-hearing patients. This coincides with the studies carried out by Hall and Koval (1982)\(^1\) and Hall and Bleakney (1981).\(^1\)

According to Jerger et al.\(^6\) SPAR is unhelpful if one wishes to know the exact hearing threshold of the patient or classify the hearing loss in the various degrees of hearing loss. In our study, we found that this test is sensitive for diagnosing normal hearing and, in its defect, hearing loss, without the ability to specify the patient’s degree of loss.

The results of our study show that the diagnostic usefulness of SPAR to establish whether or not there is normal hearing in patients aged less than 10 years is greater than 80%. Consequently, it is a very trustworthy test for use in auditory screening.

So as not to modify SPAR accuracy, obtaining a normal tympanogram is an indispensable requirement, given that modifications in the pressure reduce the reflex threshold or prevent its response, lowering its trustworthiness.\(^6\)\(^-\)\(^8\)\(^,\)\(^1\)

In our study, it was easier to identify the reflex threshold in patients with normal tympanograms.

Likewise, excessive patient movement when recording the reflex threshold can change the reflex response or yield a response when there is none.\(^6\)\(^-\)\(^8\)\(^,\)\(^1\) During our study, a trustworthy result was impossible to obtain in very restless patients.

The SPAR system identifies the great majority of patients with the antecedent of ototoxic agent use; this is due to the fact that the acoustic reflex pathway can be affected by using ototropics at the beginning of the auditory pathway, above all in afferent connections to inner ciliated cells.\(^1\)

We confirmed, in agreement with the literature, that the RE is affected more frequently and hearing loss is identified more easily in comparison with the LE.

Insofar as the noise-tone difference of the reflex thresholds, we found that this value was less than 20 in all the patients with hearing loss, while it was greater in normal patients. This coincides with the studies by Jerger.

There is a direct lineal correlation between the noise-tone difference against the SPAR value; however, despite this, it is impossible to use the noise-tone difference on its own to establish whether the patient presents normal hearing or hearing loss, given that it is necessary to apply the correction factor and the specific formula for the result to be reliable.\(^7\)\(^-\)\(^8\)\(^,\)\(^1\)
Diagnostic Utility of the Acoustic Reflex

The threshold for the stapedial reflex with white noise was greater in patients with hearing loss than in patients with normal hearing; this coincides with Jerger, who reported that the threshold with noise is always greater for ears with hearing loss.\(^6\)

In both ears, the sensitivity of the test is high: RE: 0.98; LE: 0.96. This indicates a high probability of detecting hearing loss. In contrast, the specificity is low: RE: 0.84; LE: 0.78; this indicates that there is low probability of detecting normal hearing.

However, the predictive value (+) is low (RE: 0.70; LE: 0.61; low probability of detecting hearing loss), while the predictive value (−) is high (RE: 0.99; LE: 0.98; high probability that the patient really has normal hearing).

The positive likelihood ratio was 6.17 in the RE and 4.37 in the LE (it is more probable that patients with altered SPAR values present hearing loss). The negative likelihood ratio was 0.021 in the RE and 0.047 in the LE, which makes it possible to confirm that it is a good screening test.

Conclusions

The usefulness of the stapedial acoustic reflex is much more exact for diagnosing normal hearing and profound hearing loss, as long as the tympanogram is normal. However, it is of little value in predicting the degree of auditory loss.

The clinical usefulness of the acoustic reflex is undeniable, given that it is a quick, simple and objective method, which can be performed from the moment of birth. Its results are also independent of patient collaboration and willingness, while it is also applicable for discovering patients that are simulating.

This diagnostic test should be introduced as another in the battery of objective studies for the diagnosis of normal hearing-hearing loss. It can, in fact, form part of the group of diagnostic tests for hearing screening.

Conflict of Interests

The authors have no conflicts of interests with any organisations or individuals to declare.

Acknowledgements

We wish to thank the authorities at the National Institute of Rehabilitation for allowing this research to be performed.

References