The Sensitivity of Auditory Brainstem Response Testing for the Diagnosis of Acoustic Neuromas

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Objectives: To determine the sensitivity of auditory brainstem response (ABR) testing for detecting acoustic neuromas and to determine whether the test is less sensitive for detecting small tumors.

Design: Retrospective review of the medical charts of 58 patients with acoustic neuroma who had all of the data necessary for inclusion in the study.

Setting: University-affiliated referral practice of one neurotologist.

Patients: Patients with acoustic neuromas who had both ABR tracings and magnetic resonance imaging films available for review.

Main Outcome Measures: Positive ABR and negative ABR results correlated with tumor size.

Results: Tumor size ranged from 0.4 to 7 cm. The overall sensitivity of ABR in diagnosing acoustic neuromas was 90%. However, ABR was progressively less sensitive with decreasing tumor size. Only 7 (58%) of the 12 tumors 1 cm or smaller were detected by ABR.

Conclusion: Auditory brainstem response testing cannot be relied on for detection of small acoustic neuromas and should not be used as a criterion to determine whether magnetic resonance imaging should be performed when an acoustic neuroma is suspected clinically.


Auditory brainstem response (ABR) testing has been considered one of the most sensitive audiologic tests for the diagnosis of acoustic neuromas (ANs) since first described for this use in 1977 by Selters and Brackmann. Subsequent studies have reported detection rates of 93% to 98%.

For the last decade, magnetic resonance imaging (MRI) with gadolinium has led to the detection of ANs of a smaller size. When imaged by MRI with gadolinium, ANs appear as space-occupying lesions of high-signal intensity within the internal auditory canal and cerebellopontine angle on T1-weighted images. They can be differentiated easily from cerebrospinal fluid, which is of low-signal intensity on T1-weighted images. Although there have been reports of both false-negative and false-positive MRI scans, this modality is generally considered nearly 100% sensitive for the detection of ANs.

Recent reports have suggested that smaller ANs are less likely to be detected by ABR. False-negative rates as high as 22% have been reported for tumors with an extrameatal size of less than 15 mm, whereas sensitivity as low as 67% has been reported for intracanalicular tumors.

The ability to detect small tumors is important for several reasons. Outcome with regard to facial nerve function and, more recently, hearing preservation is improved following surgery on small tumors. Also, the total cost to the system in terms of hospital and aftercare costs is less with smaller tumors. One recent article found that patients with large tumors were significantly less likely to return to work after surgical removal of their tumors. The average patient age in that report was 54 years, and those who did not return to work lost approximately 11 years of productivity. Therefore, it is important to determine which studies are most useful for the early detection of ANs.

The purposes of this study were to evaluate the sensitivity of ABR in a group of patients with ANs and to determine the effect of tumor size on sensitivity.

RESULTS

In the 58 patients studied, the average age was 52 years, and the male-female ratio was 1.23:1. The most common presenting...
PATIENTS AND METHODS

We performed a retrospective analysis of 58 patients with ANs, all of whom had both ABR and MRI data available for review. Patients with ANs were excluded if ABR or MRI data were not available. Charts from the senior author's (R.T.S.) practice were reviewed to determine the clinical findings on the patients' initial presentation and audiometric and diagnostic test results, including ABR, MRI, electronystagmography (ENG), and computed tomography scanning.

To determine the sensitivity of ABR, the 58 patients were divided into 2 subgroups, ABR negative and ABR positive. They were evaluated for differences in demographic data, presenting signs and symptoms, audiometric findings, tumor size, and ENG findings.

We also divided the patients into 3 groups based on tumor size: those with tumors 1 cm or smaller, between 1.1 and 1.5 cm, and larger than 1.5. These 3 groups were compared with respect to clinical presentation, audiometric findings, and ABR results.

Although many other authors have grouped tumor sizes as less than or equal to 1.5 cm vs greater than 1.5 cm, we believe that it is useful to look at tumors 1 cm and less separately. These tumors are entirely intracanalicular and are amenable to excision through a traditional (nonextended) middle cranial fossa approach. Detecting tumors while they are so small optimizes the chances of preserving hearing and minimizes morbidity. Because many authors have used 1.5 cm as the cutoff based on suitability for posterior fossa hearing preservation procedures, we have included these data as well. We have also compared the sensitivity of ABR for detecting intracanalicular tumors with its sensitivity for detecting those between 1.1 and 1.5 cm with which they have been combined in most previous reports. An ABR was considered positive if the interaural difference in wave I-V delay (IPD1-V) was greater than 0.2 millisecond; if the interaural difference in absolute wave V latency (IT5) was greater than 0.2 millisecond, when wave I could not be identified with certainty in one or both ears, with the Brackmann' correction factor applied for ears with hearing loss greater than 50 dB at 4000 Hz; or if there were no identifiable waves. Unilateral criteria, such as a wave I-V interpeak latency exceeding the norm, were not considered positive unless they resulted in abnormal interaural latency differences. Although some authors have accepted wave I-V interaural latency differences as long as 0.4 millisecond, we have continued to use 0.2 millisecond as the upper limit of normal established by Selters and Brackmann in 1977. The choice of a 0.2-millisecond difference maximizes the sensitivity of this ABR criterion without producing an unacceptable number of false-positive results. The senior author (R.T.S.) interpreted all audiograms, ABRs, and ENGs. Asymmetry on audiometry was defined as a 10-dB difference in pure-tone thresholds at 3 frequencies. The ENG results were considered positive if there was a greater than 20% reduced vestibular response on caloric testing.

A century ago, many patients with ANs first sought medical attention when increased intracranial pressure secondary to massive tumor size resulted in symptoms. Improvement in diagnostic techniques and increased clinician awareness have made this a rare occurrence today. The use of diagnostic tests such as ABR and MRI have led to detection of smaller tumors. These factors, together with early surgical intervention, have led to improved outcome, particularly with regard to facial nerve function and hearing preservation.

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>No. (%) of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progressive hearing loss</td>
<td>30 (52)</td>
</tr>
<tr>
<td>Sudden hearing loss</td>
<td>10 (17)</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>8 (14)</td>
</tr>
<tr>
<td>Disequilibrium</td>
<td>5 (9)</td>
</tr>
<tr>
<td>Facial paresis</td>
<td>2 (3)</td>
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Only 5 patients (9%) sought attention for vestibular complaints. Six of the 58 patients had normal ABR results, yielding a sensitivity of 90%. The group of 60 patients was designated group A. The other 52 patients were designated group B.

The clinical presentations for groups A and B were similar. Five of the 6 patients in group A and 35 (67%) of 52 in group B reported hearing loss as their chief complaint. Audiometric evaluation of groups A and B revealed that nearly all patients had an asymmetric hearing loss (100% in group A and 96% in group B). A discrimination score in the affected ear of less than 90% was noted in 2 of the 58 patients in each group.

Tumor size was recorded for all 58 patients. The average tumor size for group A was 0.7 cm (range, 0.4-1.3 cm, with 5 of the 6 being ≤1 cm), and for group B, it was 2.08 cm (range, 0.4-7 cm, only 4 of which were >3 cm, including 3.5-, 4-, 4.5-, and 7-cm tumors).

Presenting complaints are correlated with tumor size in the Table. The majority of the patients presented with hearing loss (progressive or sudden), regardless of tumor size.

Asymmetric hearing loss was found in 100%, 93%, and 96% of patients with tumors 1 cm or smaller, between 1.1 and 1.5 cm, and larger than 1.5 cm, respectively. The ABR results, correlated with tumor size, are illustrated in the Figure. The ABR was progressively less sensitive with decreasing tumor size, and only 7 (58%) of the 12 tumors 1 cm or smaller were detected by ABR. Five of the 6 patients with false-negative ABR results had tumors 1 cm or less. Although we do not advocate use of unilateral criteria, in patients with false-negative results, we evaluated absolute latency of waves I, III, and V and interwave latencies of waves I to III, III to V, and I to V. There were no patients in whom these values were abnormal in the presence of normal interaural differences in wave I-V delay.

**COMMENT**

A century ago, many patients with ANs first sought medical attention when increased intracranial pressure secondary to massive tumor size resulted in symptoms. Improvement in diagnostic techniques and increased clinician awareness have made this a rare occurrence today. The use of diagnostic tests such as ABR and MRI have led to detection of smaller tumors. These factors, together with early surgical intervention, have led to improved outcome, particularly with regard to facial nerve function and hearing preservation.
It has been suggested that vestibular complaints may be manifestations of intracanalicular compression of the vestibular nerve by a small tumor before central compensation. Only 9% of our patients presented with complaints of disequilibrium. Furthermore, when the group of patients with tumors less than or equal to 1 cm were considered, none presented with vestibular complaints. Thus, at least in our patient population, vestibular complaints were not seen more often in patients with small tumors.

As expected, the most common presenting complaint in our study was progressive hearing loss. Our 17% rate of sudden hearing loss is also consistent with that reported previously and is more typical than the 3% previously reported by the senior author. Interestingly, the audiometric parameters did not predict tumor size or ABR results in our patients. The positive and negative ABR groups both had asymmetric hearing loss in almost every patient, and 67% had speech discrimination scores less than 90%. These findings are similar to those reported elsewhere.

Dornhoffer et al reviewed their series of 93 patients who underwent AN resection with attempted hearing preservation. Overall, hearing was preserved in 58% of patients. These authors found that this was more likely to occur in patients with tumors extending less than 1 cm into the cerebellopontine angle (60%) and in patients with wave V latency less than or equal to 6.8 milliseconds (68%). Although others have reported similar results, Kemink et al found no correlation between ABR results and ability to preserve hearing.

The sensitivity of ABR was reported initially to be more than 90% for the detection of ANs. Selters and Brackmann found the interaural wave V latency difference to be delayed in 35 of 36 patients with acoustic tumors. The only one missed was a patient with bilateral acoustic neuromas. Similarly, Josey et al reported a 97% detection rate. Average tumor sizes were not stated in these studies; however, in the former the smallest tumor was 0.8 cm, and in the latter the majority of tumors were between 1.5 and 3 cm. This suggests that both patient populations had relatively large tumors.

With gadolinium-enhanced MRI of the internal auditory canals, smaller tumors are being detected, frequently in patients with normal ABR results. Hashimoto et al described 18 patients with ANs smaller than 1.5 cm, 4 (22%) of whom had negative ABR results. Likewise, Wilson et al looked at 40 patients with ANs and found 6 normal ABR results, yielding a sensitivity of 85%. In this same series, the sensitivity of ABR for detecting intracanalicular tumors was 67%. In a large prospective series, Gordon and Cohen found similar results, with a 69% sensitivity for tumors smaller than 1 cm. These results are consistent with our findings of an overall sensitivity of 90%, which decreases as tumor size decreases. Zappia et al reported 89% sensitivity in detecting 37 tumors 1 cm or smaller and 95% sensitivity overall, using an interaural difference in wave V latency of 0.2 millisecond, with no correction factor. The difficulty with this methodology was pointed out by Selters and Brackmann, who noted that unless some correction factor is made for cochlear delay due to high-frequency hearing loss, practically all such losses would be classified by BERA [brainstem evoked response audiometry] as suspected tumors. A practical compromise is to apply a small correction that will reduce the number of false-positive findings while not incurring a false-negative finding in the acoustic tumor group.

This difference in methodology may explain the difference in ABR sensitivity reported by Zappia et al, as compared with our study and the studies by Wilson et al and Gordon and Cohen.

In contrast to these, Dornhoffer et al found that the ABR result was positive in 65 (93%) of 70 patients with tumors 1 cm or smaller with extension into the cerebellopontine angle. The difference between their results and those of the Selters and Brackmann and of the present study is largely due to their subject population. It is important to note that the patients in the study by Dornhoffer et al had tumors extending up to 1 cm into the posterior fossa, meaning that their total tumor size (including the internal auditory canal component) could have been as much as 2 cm. In our study, and in the other reports cited herein, tumor size included the intracanalicular component. Although we detected ABR abnormalities in only 58% of patients with tumors 1 cm or smaller, ABR abnormalities were present in 16 (94%) of 17 tumors between 1.1 and 1.5 cm (similar to the population and results in the study by Dornhoffer et al) and 100% of the 29 larger tumors. For an ABR result to be classified as abnormal, Dornhoffer et al required an interaural wave I-V latency difference of 0.4 millisecond (more strict than our criterion) and/or absolute wave V latency...
latency of greater than 5.9 milliseconds. In comparing literature on this subject, great care must be taken not only to be certain that similar ABR criteria are being used but also that comparable tumor populations are being studied.

Since Selters and Brackmann recommended using interaural wave V latency differences in 1977, nearly every author has used different criteria. For the purposes of this study, we chose an interaural wave V latency difference (IT5) of 0.2 millisecond (or more, with use of the Brackmann correction factor) and/or interaural wave I-V difference (IPD1-5) of 0.2 millisecond based on experience in our laboratory throughout 20 years, principles articulated by Selters and Brackmann, and work done by Kanzaki et al12 in 1991. Kanzaki et al compared various ABR parameters in 2 groups of patients, 1 with ANs and 1 with sensory neural hearing loss without ANs. The value of each parameter was adjusted so that the false-positive rate would be less than 20%, whereas the false-negative rate would be less than 10%. They found that these criteria (as used in our study) yielded the lowest false-negative rates of all the parameters examined. This is consistent with our experience using these criteria since 1980.

An advantage of using ABR as a screening tool is its relatively low cost compared with MRI. In today’s health care climate, this is an issue that cannot be ignored. Newer MRI techniques, such as fast spin echo, may prove to be less costly and very sensitive modalities for detection of ANs. Fast spin echo has the advantage of being rapid, thereby decreasing motion artifact and enhancing patient comfort and compliance. A recent study by Shelton et al19 reported a sensitivity of 98% using this technique, which can detect tumors in the internal auditory canal as small as 2 mm.

**CONCLUSIONS**

The overall sensitivity of ABR for the detection of ANs in our patient population was 90%, but it decreased to 58% for the detection of tumors less than or equal to 1 cm. Patients with ANs and normal ABR results presented in the same way as those with abnormal ABR results. Patients with ANs and normal ABR results were no more likely to present with normal hearing than those patients with abnormal ABR results.

Therefore, ABR is not a satisfactory screening tool for the diagnosis of small ANs, and it cannot be relied on to rule out ANs or to determine the need for further imaging studies.

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**REFERENCES**