Brain-stem auditory evoked responses in 56 patients with acoustic neurinoma

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The brain-stem auditory evoked responses (BAER's) recorded from 56 patients with acoustic neurinomas were analyzed. Ten of the patients had intracanalicular tumors and 46 had extracanalicular tumors. It was possible to obtain BAER's following stimulation of the affected side in 28 patients and after stimulation of the unaffected side in all 56. Five patients (11%) had normal BAER's following stimulation of both sides; three of these patients had intracanalicular tumors.

Among BAER's obtained following stimulation of the affected ear, the mean interpeak latency (IPL) for peaks I to III associated with extracanalicular tumors was significantly prolonged relative to controls (p < 0.001), and linear regression analysis revealed a significant positive correlation between tumor size and IPL of peaks I to III (p < 0.05). Analysis of the 56 BAER’s recorded after stimulation of the unaffected side revealed a significant positive correlation between the IPL's of peaks III to V and tumor size (p < 0.001). This correlation was not strengthened when accounting for the degree of brain-stem compression.

Finally, evidence of preserved function within the auditory pathway, even in the presence of partial hearing loss, is presented. This finding suggests that more patients might benefit from surgical procedures that spare the eighth cranial nerve.

Key Words • acoustic neurinoma • brain-stem auditory evoked potential • interpeak latency • cerebellopontine angle

Recording the brain-stem auditory evoked response (BAER) has become a standard screening device for the detection of cerebellopontine angle tumors. Abnormal evoked responses from both the side of the tumor and the unaffected side have been described in humans as well as animals.

The use of BAER's to screen for acoustic neurinomas has not only proven clinically useful, but has also enabled researchers to gain a better understanding of neural pathways involved in the generation of BAER's.

We analyzed BAER's following stimulation of the affected and unaffected ears of 56 patients with acoustic neurinomas. In addition to determining the incidence of false-negative results for our series, we also examined the incidence of normal physiological function among specific components of the auditory pathway, even in the presence of hearing loss.

Finally, we explored the relationship between various BAER abnormalities and tumor size, and compared our findings to those reported previously. We also correlated these abnormalities with various other tumor and posterior fossa dimensions, as proposed by Wada and Matsukado. Based on these findings, new proposals are set forth as to the mechanisms of abnormal BAER's in patients with acoustic neurinomas.

Clinical Material and Methods

The BAER studies of 56 consecutive patients treated at our institution for acoustic neurinoma were reviewed. Patients with bilateral tumors as well as those in whom no vertex-positive components (peaks I, III, or V) could be identified from either ear were excluded. Among the 56 patients studied, there were 36 males and 20 females harboring 29 right-sided tumors and 27 left-sided tumors. Ten (18%) of the patients studied had intracanalicular tumors measuring less than 0.65 cm in greatest diameter and 46 had extracanalicular tumors.

Auditory brain-stem responses were elicited by 100-μsec clicks (condensation) delivered through shielded headphones at a rate of 10/1/sec. The click intensity was 60 dB above hearing threshold. Left and right ears were stimulated separately, the unstimulated ear being
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of 56 patients had normal BAER's, three of whom had intracanalicular tumors, yielding a 30% false-negative rate for patients with tumors 0.65 cm or smaller. Audiograms in the five “false-negative” patients revealed a mean pure-tone average (PTA) at 0.5, 1, and 2 kHz of 29 dB (SD ± 13 dB) on the affected side. Two of the patients, one with an intracanalicular tumor and one with an extracanalicular tumor, had PTA’s exceeding 35 dB. The remaining three patients had PTA’s of less than 25 dB.

**BAER’s Following Stimulation of the Affected Ear**

There were 28 patients in whom BAER’s could be obtained following stimulation of the affected ear. In 21 of the patients, all of the vertex-positive components peaks (I, III, and V) could be identified. Among them, 18 (86%) had an abnormal IPL for either peaks I to III, peaks III to V, or both. In three additional cases peaks I and III were identified and in four other cases peaks III and V were detected.

Of the 24 patients in whom peaks I and III could be recorded after stimulation of the affected ear, five had intracanalicular tumors and 19 had extracanalicular tumors. All intracanalicular cases were associated with IPL’s for peaks I to III that were within a 3-msec SD of the norms. The mean IPL for this group (2.22 ± 0.17 msec) did not differ significantly from that of our laboratory controls (2.20 ± 0.14 msec). The mean IPL for peaks I to III in patients with extracanalicular tumors (2.94 ± 0.58 msec) was significantly prolonged relative to our laboratory norms (p < 0.001). In order to determine the relationship between tumor size and the IPL’s of peaks I to III recorded after stimulation of the affected ear, linear regression analysis was performed. A significant positive relationship was demonstrated (p < 0.05) as shown in Fig. 1.

Of the 25 cases in which peaks III and V could be identified, six were from patients with intracanalicular

masked with 50 dB white noise. The BAER's were recorded from Cz-A1 and Cz-A2 derivations. The data were filtered (150 to 3000 Hz) and 1200 artifact-free sweeps (of 12.3 msec duration each) were replicated three times and averaged on a QSI 9000 system. Ipsilateral responses to clicks at 60 dB above hearing threshold were recorded from each ear, and interpeak latencies (IPL’s) for peaks I to III and III to V were determined. In analyzing the BAER’s, results were considered normal only when peaks I, III, and V could be discretely identified in both ears, and when the IPL’s for peaks I to III and III to V were within a 3-msec standard deviation (SD) of previously published norms from our laboratory. *

In all 56 cases, the measurement of maximum tumor diameter was made from magnetic resonance (MR) images or computerized axial tomography (CT) scans. In an effort to determine the effect of brain-stem compression on changes in BAER components, additional tumor and posterior fossa dimensions were measured from the CT scans of the last 23 consecutive patients whose maximum tumor diameter exceeded 2.0 cm. In each of these 23 cases, measurements of the tumor diameter in a lateral-to-medial direction (“medial extension”) and the maximum tumor diameter (regardless of direction) were made. The distance between the left and right internal auditory canals (IAC’s), the “inter-IAC distance,” was also measured in an effort to determine whether interepistrous distances might affect the degree of brain-stem compression caused by a tumor.

**Results**

The BAER’s could be recorded from 28 patients when the affected ear was stimulated, and from all 56 patients when the unaffected ear was stimulated. Five

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* QSI 9000 system manufactured by Quantified Signal Imaging, Inc., Toronto, Ontario, Canada.
BAER’s in patients with acoustic neurinoma

![Diagram](image)

**Fig. 2.** Typical brain-stem auditory evoked responses, recorded after stimulation of the unaffected ear, demonstrating the sensitivity of the interpeak latency (IPL) for peaks III to V to tumor size. **Upper:** In this tracing from a patient with a 0.6-cm acoustic neurinoma, the IPL for peaks III to V is 1.68 msec. **Lower:** In this tracing from a patient with a 3.5-cm acoustic neurinoma, the IPL for peaks III to V is 2.40 msec.

Sensitivity of BAER’s to Tumors

The mean IPL of peaks III to V was slightly more prolonged for the extracanalicular group (2.60 ± 0.77 msec) than the intracanalicular group (2.49 ± 0.87 msec). The mean IPL for each group was significantly prolonged relative to our laboratory norms (1.88 ± 0.14 msec, p < 0.001).

Audiograms were available for review in all of the patients with extracanalicular tumors. They revealed a mean PTA of 28 ± 13 dB on the affected side compared to 13 ± 4 dB on the unaffected side. Thirteen of the patients with extracanalicular tumors had audiograms available for review. The mean PTA for this group (29 ± 14 dB) was not significantly different from that of the intracanalicular group. Finally, among the total 18 audiograms reviewed, three (17%) were associated with normal IPL's for peak I to III, despite PTA's of 46 dB or greater.

**BAER’s Following Stimulation of the Unaffected Ear**

The BAER's were recorded from all 56 patients when the unaffected ear was stimulated. Forty-eight patients had IPL's for peaks I to III and III to V that were both ± 3 msec SD of laboratory norms. The IPL for peaks I to III was prolonged in two cases and that for peaks III to V was prolonged in six cases.

The mean IPL for peaks I to III in the 10 patients (18% of the total) with intracanalicular tumors (2.22 ± 0.24 msec) did not differ significantly from our laboratory norms (2.20 msec), nor did the mean for the

46 patients with extracanalicular tumors (2.21 ± 0.26 msec). Linear regression analysis failed to demonstrate a significant relationship between tumor size and the IPL's for peaks I to III recorded after stimulation of the unaffected ear (r = −0.18, p > 0.1).

The IPL’s for peaks III to V recorded after stimulation of the unaffected side were remarkably sensitive to tumor size (Fig. 2). While the intracanalicular tumor group had a mean IPL for peaks III to V (1.84 ± 0.16 msec) that was not prolonged relative to controls (1.88 msec), the mean IPL in the extracanalicular tumor group (2.64 ± 0.29 msec) was significantly prolonged (p < 0.001). The difference in mean IPL’s for peaks III to V of intracanalicular (1.84 ± 0.16 msec) versus extracanalicular (2.04 ± 0.29 msec) tumor groups was statistically significant (p < 0.02). Linear regression analysis revealed a significant positive correlation (r = 0.578, p < 0.001) between the IPL’s for peaks III to V and tumor size (Fig. 1).

**Medial Tumor Extension and Posterior Fossa Measurements**

A review of the CT scans of the last 23 consecutive patients with acoustic neurinomas larger than 2 cm revealed that the greatest diameter of an irregularly shaped tumor frequently occurs in a direction other than lateral to medial (into the brain stem). This is particularly true for tumors that fan out along the inner margin of the petrous bone (Fig. 3). Analysis of these 23 cases revealed the mean maximum tumor size to be 2.8 ± 0.5 cm and the mean medial tumor extension to be 2.2 ± 0.6 cm.

These CT measurements were analyzed with respect to the IPL’s for peaks III to V recorded after stimulation of the unaffected ear. Linear regression analyses revealed a strong correlation between the maximum tu-
mor size and the IPL’s \( r = 0.615, p < 0.002 \) and between the medial tumor extension and the IPL’s \( r = 0.567, p < 0.005 \). The mean inter-IAC distance was \( 4.8 \pm 0.7 \text{ cm} \). Linear regression analysis also revealed a significant correlation between IPL’s for peaks III to V and the inter-IAC distance minus the medial tumor extent for each case.

**Discussion**

*False-Negative BAER’s*

A recent literature review by Legatt, et al.,\(^6\) illustrated that while BAER’s are highly accurate in detecting acoustic tumors, false-negative results do occur. The 11% false-negative rate reported in our series is consistent with that found by other investigators. As in our series, most false-negative results are associated with small tumors. Bockenheimer, et al.,\(^7\) reported a 26% false-negative rate in a study limited to small tumors. Differences in the reported incidence of false-negative BAER’s can be attributed to differing populations with respect to tumor size and to various criteria used to interpret BAER’s as “negative.” Another factor that may account for differences in false-negative rates is that some centers are more liberal in their use of CT and MR imaging than others. Thus, several cases of small tumors, for example, might be diagnosed in one series (and be reported as false-negative BAER’s) and left undetected in another. Legatt, et al., recommended the routine use of latency-intensity studies when performing BAER’s to screen for acoustic neurinomas. While such refinements may improve the sensitivity of BAER’s, we agree with Telian, et al.,\(^14\) who recommended that patients with subjective and objective evidence of persistent auditory disturbance, even in the absence of BAER abnormalities, undergo prompt radiographic evaluation. In light of the particularly high incidence of false-negative BAER’s associated with intracanalicular tumors, we suggest that MR imaging be used to evaluate suspicious cases. The efficacy of MR imaging in the detection of intracanalicular tumors has been well described,\(^4,8\) and its sensitivity has been further enhanced by the use of nonmagnetic intravenous contrast agents.

All of the patients in this series underwent BAER testing in our laboratory only after a firm diagnosis of acoustic neurinoma had been made on the basis of abnormal audiograms and either CT or MR studies. This explains why no findings of abnormal BAER’s associated with normal audiograms were reported in this study.

**Relationship Between IPL’s for Peaks I to III and Tumor Size**

Our series demonstrated a significantly prolonged mean IPL for peaks I to III following stimulation of the affected side in patients with extracanalicular tumors. Furthermore, we showed a statistically significant linear relationship between tumor size and a prolonged IPL for peaks I to III. This suggests that larger tumors are associated with greater ipsilateral cochlear nerve and nucleus dysfunction, which conflicts with previous reports suggesting that delayed conduction is independent of tumor size and might instead be attributable to the tumor’s intracanalicular extent.\(^2,10\)

**Relationship Between IPL’s for Peaks III to V and Tumor Size**

Patients with extracanalicular tumors were found to have prolonged IPL’s for peaks III to V when either the affected or the unaffected ear was stimulated. This pattern has been described previously and is indicative of an intrinsic brain-stem abnormality, probably in the region of the lateral lemniscus and inferior colliculus.\(^5,10,11,18,19\)

The IPL’s for peaks III to V recorded after stimulation of the side contralateral to the tumor were the most sensitive to changes in tumor size. This is consistent with previous work which also demonstrated a strong correlation between prolonged IPL’s and increased tumor size.\(^11,18\) MacKay, et al.,\(^7\) attributed this delay in IPL to mechanical compression and distortion of the brain stem. Zappulla, et al.,\(^20\) found similar changes in rats and demonstrated that they were reversible following decompression of the brain stem. Other investigators have described BAER abnormalities in the setting of acutely expanding posterior fossa mass lesions and have attributed these changes to brain-stem ischemia and neural damage.\(^19\) Such changes appeared to be secondary to brain-stem distortion which occurred when critical thresholds for infratentorial intracranial pressure (ICP) and posterior fossa mass volume were exceeded.

**Relationship Between Medial Tumor Extension and BAER’s**

Wada and Matsukado\(^15\) previously analyzed 40 cases of cerebellopontine angle tumors, 20 of which were acoustic neuromas. In an effort to determine the effect of brain-stem compression on changes in BAER components, they correlated BAER recordings from the side opposite the tumor with numerous CT measurements of the tumor and the posterior fossa. Their analysis revealed that BAER abnormalities in these patients did not correlate well with maximum tumor diameter. However, a strong correlation between BAER abnormalities and the ratio of tumor size to the brain stem was demonstrated.

Among our 56 patients with acoustic neuromas we found a strong positive correlation between maximum tumor size and prolonged IPL for peaks III to V following stimulation of the unaffected side. This correlation was not strengthened when we accounted for the degree of medial tumor extension and the inter-IAC distance. This suggests that the chronic effect of high total tumor volume within the infratentorial compartment...
BAER's in patients with acoustic neuromas may play as great a role in the production of latency changes as does the tumor:brainstem ratio. Recording posterior fossa ICP measurements in these patients or monitoring ICP in animal models with chronically implanted cerebellopontine angle masses of various sizes might clarify this issue.

Clinical Implications

Our analysis of BAER's recorded after stimulation of the side of the tumor in 28 patients revealed that all of the patients with intracanalicular tumors had normal IPL's for peaks I to III (despite an elevated mean PTA) and that three patients who had PTA's exceeding 46 dB also had normal IPL's for peaks I to III. These facts, together with our finding of an 11% false-negative rate overall and a 30% false-negative rate (three of 10) among patients with intracanalicular tumors, have important implications. This information indicates that a substantial number of patients with acoustic neuroma, even those with hearing deficits, continue to have at least partial function of the auditory pathway in the region of the cochlear nerve and nucleus.

Many surgeons operating on acoustic neuromas adhere to the principle that the eighth cranial nerve is only worth preserving in patients with 50 dB or better pure-tone audiometry and greater than 50% speech discrimination. Our electrophysiological findings suggest that even patients with substantial hearing loss may have functional cochlear nerves; therefore, aggressive attempts at nerve preservation should be made in more cases. As microsurgical techniques improve and nerve preservation becomes possible in a larger number of patients, the rate of hearing preservation may improve beyond that reported in a previous era. Further clinical correlation with our physiological findings will be possible as the number of tumors resected by skilled microsurgeons increases.

References


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