Auditory Brainstem Response and Magnetic Resonance Imaging for Acoustic Neuromas

Costs by Prevalence

Martin S. Robinette, PhD; Christopher D. Bauch, PhD; Wayne O. Olsen, PhD; Michael J. Cevette, PhD

**Objective:** To compare hypothetical costs for identification of acoustic tumors when using magnetic resonance imaging with gadolinium Gd 64 (MRI-64Gd) as a sole diagnostic test and when using auditory brainstem response (ABR) testing followed by MRI-64Gd (ABR+MRI-64Gd) for those with positive ABR findings.

**Patients and Methods:** Retrospective review of the medical records of 75 patients having surgically confirmed acoustic neuromas to categorize them into 3 subgroups relative to their risk of having a cerebellopontine angle tumor based on history, symptoms, and routine pure-tone and speech audiometric findings. Hypothetical costs associated with identification of patients with acoustic neuroma in each subgroup were calculated for MRI-64Gd alone and ABR+MRI-64Gd. Auditory brainstem response sensitivity and specificity data for the 75 patients with acoustic neuroma and 75 patients without a tumor matched for hearing loss were applied to the hypothetical subgroups. Tumor size was considered also.

**Setting:** Tertiary care center.

**Main Outcome Measure:** Comparison of costs for MRI-64Gd and ABR+MRI-64Gd.

**Results:** Fourteen patients with acoustic neuroma were assigned to the high-risk category (30% probability); 45 were in the intermediate-risk category (5% probability); and 16 were in the low-risk category (1% probability). Auditory brainstem response testing correctly identified 100% of the large tumors (>2.0 cm), 93% of the medium-sized tumors (1.1-2.0 cm), and 82% of the small tumors (<1.0 cm). The hypothetical costs for identifying 14 patients with acoustic neuroma among 47 patients in the high-risk category using MRI-64Gd would be $70,500; ABR+MRI-64Gd costs for the 13 patients identified by ABR would be $39,600. Hypothetically 900 patients would be tested to identify the 45 acoustic neuromas in the intermediate-risk category. Magnetic resonance imaging with 64Gd screening would reach $1.35 million for this sample. Auditory brainstem response testing and MRI-64Gd would be $486,000, but 4 acoustic neuromas would be missed. For the low-risk subgroup MRI-64Gd screening of 1600 patients to identify 16 acoustic neuromas would total $2.4 million; ABR+MRI-64Gd to identify 15 of them would be $787,500. In this sample of 75 acoustic neuromas, large tumors were more prevalent in the low-risk subgroup than in the high- or intermediate-risk subgroups.

**Conclusions:** Decisions regarding assessment of patients at risk for acoustic neuromas must be made on a case-by-case basis. Use of ABR+MRI-64Gd allows considerable savings when patients are in the intermediate- or low-risk subgroups. New MRI and ABR testing techniques offer promise for reducing costs.


**RESULTS**

Symptoms reported by the 75 patients having acoustic neuromas and the basic audiologic test results considered for categorizing them according to the Welling et al criteria are as follows: tinnitus, vertigo, and the feeling of fullness; asymmetric sensorineural hearing loss; and poor word recognition scores. Differences between ears of 15 dB or greater averaged across 500, 1000, 2000, and 3000 Hz, and/or differences of 15 dB or greater in speech recognition thresholds were our criteria for asymmetric sensorineural hearing loss. Our criterion for poor word recognition was a score of less than 30% on a phonetically balanced monosyllabic word recognition tests. Other symptoms included diplolia, facial pain, facial numbness, facial paresthesia, and headache. In addition to hearing loss, tinnitus, or vertigo as cited...
PATIENTS AND METHODS

The sample consisted of 75 patients having surgically confirmed acoustic neuromas reported by Bauch et al 4 who were retrospectively categorized into the 3 risk groups for such lesions using the criteria described by Welling et al 5 given in Table 1.

Bauch et al 4 reported on a continuous series of 417 patients who underwent ABR testing because of suspicion of cerebellopontine angle lesions. Seventy-five of these patients were found to have acoustic neuromas that subsequently were removed surgically. At the time of surgery the tumors were categorized in size as small (<1.0 cm), medium (1.1-2.0 cm), or large (>2.0 cm). Twenty-two patients (29%) had small tumors, 30 (40%) had medium-sized tumors, and 23 (31%) had large tumors.

Overall, ABR test results correctly identified 92% of the eighth nerve tumors. Its accuracy was highest for the large tumors (100%), intermediate for the medium-sized tumors (93%), and poorest for the small tumors (82%). Very similar results have been reported by Chandrasekhar et al 6 from the 342 patients found not to have acoustic neuromas on the basis of other otologic, neurologic, and/or diagnostic imaging results. Bauch et al 4 matched 75 of them with 75 patients with eighth nerve tumor for average hearing loss at 2000, 3000, and 4000 Hz. This pairing of patients was undertaken to compare ABR test results for ears with and without tumor having the same degree of high-frequency hearing loss. Abnormal ABR test findings were observed for 9 (12%) of these 75 ears without a tumor. Thus, for these samples of 75 ears with eighth nerve tumor and 75 ears without a tumor, matched for high-frequency hearing loss, true-positive ABR test results were obtained for 69 of the ears with a tumor (92% true-positive rate), and false-positive ABR test tracings were observed for 9 of the ears without a tumor (12% false-positive rate).

Symptoms did not always fit into the Welling et al 5 criteria exactly and we exercised some interpretation for the assignment of patients to a given category. The criteria used, the number of patients meeting them, and the number assigned to the 3 risk categories are given in Table 1. Fourteen patients (19%) were judged to be in the high-risk subgroup, 45 patients (60%) were in the intermediate-risk subgroup, and 16 patients (21%) were in the low-risk subgroup.

Table 2 was constructed to provide information relating to the following questions. First, assuming the prevalence of acoustic neuromas as a function of symptoms following the Welling et al 5 criteria, how many patients would need to be evaluated to obtain the group of 75 patients with tumors in the study of Bauch et al 4? Second, if MRI-64Gd were the test of choice for all patients, what would be the cost to identify the patients with tumors in each prevalence group? Third, if ABR were used as a screening test and only those with positive ABR test findings were given an MRL-64Gd, what would be the cost to identify the patients with acoustic neuroma in each prevalence group? Fourth, how many patients with cerebellopontine angle tumors would have been missed by the ABR screening strategy? Finally, what is the total cost for each strategy?

The cut-in headings in Table 3 list the probability that patients in the 3 risk categories of Welling et al 5 do in fact have acoustic neuromas. For our calculations we used prevalence rates of 30% for high-risk patients, 5% for intermediate-risk patients, and $1500 for an MRI-64Gd. While charges may vary by region and by practice over time, it is assumed that the relative difference in charges between the 2 tests of 3:1 offers a suitable reference point.

The charges were estimated at $300 for an ABR test and $1500 for an MRI-64Gd. While charges may vary by region and by practice over time, it is assumed that the relative difference in charges between the 2 tests of 3:1 offers a suitable reference point.

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### Table 3. Hypothetical Costs for Identification of 75 Patients With Acoustic Neuromas Based on Risk Category *

<table>
<thead>
<tr>
<th>Protocol/ Tumor Size</th>
<th>No. of Patients Examined to Yield Tumors</th>
<th>No. (%) of Patients</th>
<th>True-Positive</th>
<th>False-Positive</th>
<th>Cost per Tumor, $</th>
<th>Total Cost, $</th>
<th>No. of Tumors Missed</th>
<th>Added Costs of MRI-64Gd on All Patients, $</th>
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<tr>
<td></td>
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<td>High-Risk Level (Probability 30%)</td>
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<tr>
<td>MRI-64Gd</td>
<td>47</td>
<td>&gt;99</td>
<td>14</td>
<td>&lt;1</td>
<td>5036</td>
<td>70 500</td>
<td>0</td>
<td>0</td>
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<tr>
<td>ABR + MRI-64Gd</td>
<td>47</td>
<td>3 (22)</td>
<td>92</td>
<td>13</td>
<td>3046</td>
<td>39 600</td>
<td>30 900</td>
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<td>Intermediate-Risk Level (Probability 5%)</td>
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<td>MRI-64Gd</td>
<td>900</td>
<td>&gt;99</td>
<td>45</td>
<td>&lt;1</td>
<td>30 000</td>
<td>1350 000</td>
<td>0</td>
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<tr>
<td>ABR + MRI-64Gd</td>
<td>900</td>
<td>15 (33)</td>
<td>91</td>
<td>12</td>
<td>11 854</td>
<td>486 000</td>
<td>4</td>
<td>858 000</td>
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<td>Low-Risk Level (Probability 1%)</td>
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<tr>
<td>MRI-64Gd</td>
<td>1600</td>
<td>&gt;99</td>
<td>16</td>
<td>&lt;1</td>
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<td>2400 000</td>
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<td>0</td>
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<tr>
<td>ABR + MRI-64Gd</td>
<td>1600</td>
<td>4 (25)</td>
<td>93</td>
<td>12</td>
<td>52 500</td>
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* MRI-64Gd indicates magnetic resonance imaging with gadolinium Gd 64; ABR, auditory brainstem response test; and ellipses, not applicable. Small tumors measured less than 1.0 cm; medium-sized, between 1.1 and 2.0 cm; and large, more than 2.0 cm.

for intermediate-risk patients, and 1% for low-risk patients. Column 1 indicates the 2 strategies being compared. Column 2 gives the hypothetical number of patients that would need to be evaluated to yield the number of tumors in each risk subgroup. These numbers and costs change if different prevalence rates are applied. If prevalence rates of 10% or 15% were assumed for the intermediate-risk subgroup, the number of patients tested, the number of false-positive results, and total expense would decrease by a factor of 2 and 3, respectively. Similarly, if prevalence rates of 2% or 3% were assumed for the low-risk subgroup, the number of patients evaluated, the number of false-positive results, and overall costs would be reduced by a factor of 2 and 3, respectively. Column 3 reports the number and percentage of patients with small, medium, and large tumors within each of the risk subgroups in the study of Bauch et al. For example, the overall true-positive rate for ABR screening for the intermediate probability subgroup is 91% owing to the high percentage of small tumors (33%) in this subgroup, while an overall true-positive rate of 93% is calculated for the low probability subgroup owing to the high percentage of large tumors (44%) in this subgroup. Column 5 shows the number of correct identifications of acoustic neuromas. Columns 6 and 7 report the false-positive rate and the number of false-positive results associated with the patients matched for hearing loss. Column 8 indicates the hypothetical cost in identifying each patient with an acoustic neuroma in each risk category. Column 9 reports the hypothetical total cost for each strategy for each subgroup. Column 10 gives the number of patients with tumors missed by the 2 protocols. The last column suggests the hypothetical additional costs associated with conducting MRI-64Gd studies on all patients rather than only those screened and found positive for eighth nerve lesions on the ABR test.

In the subgroup of 14 patients with cerebellopontine angle tumors having symptoms that placed them in the high-risk category, there were 3 small, 9 medium, and 2 large tumors (column 3). The overall true-positive rate of the ABR test in this group was 92%, suggesting that 1 of the 14 tumors would have been missed by the ABR screening strategy. Given a 30% prevalence rate of acoustic neuromas for patients with symptoms placing them in the high-risk category for such lesions, 47 patients would be tested to identify these 14 patients with tumor. Column 8 shows that the cost to identify each of 14 tumors would be $5036, and column 9 gives the total cost, $70 500, when all 47 patients at high risk were examined by MRI-64Gd. The cost to identify 13 of the 14 patients at high risk for acoustic neuromas by screening with the ABR test would be $39 600. Testing all patients to identify the 14th tumor would add $30 900 (column 11) to the cost of assessing 47 patients considered to be at high risk for eighth nerve lesions.

There is a dramatic increase in costs to identify cerebellopontine angle tumors when the risk for such pathologic features is decreased. Conversely, the dollar savings with ABR screening grow dramatically. The 45 patients with symptoms placing them in intermediate-risk category for acoustic neuromas included 15 small, 17 medium, and 13 large tumors. For this subgroup of patients, it is estimated that ABR testing would miss 4 tumors, 3 of them for patients with small tumors. The overall true-positive rate for this subgroup was 91%. Assuming a 5% prevalence rate for this subgroup at intermediate-risk for eighth nerve tumors, it is estimated that...
900 patients would need to be evaluated to identify the 45 patients with tumors. The cost would be almost 3 times greater to identify each tumor when testing only with MRI-64Gd ($1.35 million) relative to screening first with ABR testing, followed by MRI-64Gd for those patients found to have abnormal ABR test findings ($486,000). The cost to identify the 4 patients missed by ABR testing increases by $858,000 when all patients in the intermediate-risk category are evaluated with MRI-64Gd.

On the basis of their symptoms, 16 of the patients with cerebellopontine angle tumors in the study by Bauch et al were at low risk, considered here to have a 1% prevalence rate of such lesions. Hypothetically then, 1600 patients would need to be evaluated to identify these 16 patients with tumors. In this subgroup there were more large tumors than small tumors, resulting in an overall true-positive rate of 93% with ABR screening; in other words, ABR screening is projected to identify all but 1 of the tumors in this sample. Total costs for MRI-64Gd for all 1600 patients would be $2.4 million; ABR+MRI-64Gd costs would be $787,500. The additional cost to identify the patient with a tumor missed by ABR screening is estimated at $1.6 million, if all 1600 patients underwent MRI-64Gd.

Although ABR test sensitivity in identifying acoustic neuromas is poorer for small tumors, the effect in the study of Bauch et al was minimal because the number of small tumors and large tumors was about the same, 22 and 23, respectively. Furthermore, as indicated in column 1 of Table 3, tumor size was not directly related to symptoms. In fact, large tumors represented the lowest percentage (14%) in the high-risk subgroup, and were the highest percentage (44%) in the low-risk subgroup. At least for this sample of 75 patients with acoustic neuroma, symptom severity was not correlated with tumor size; minimal symptoms did not preclude the presence of a large cerebellopontine angle tumor.

In practice, neurologists make decisions on a case-by-case basis. Decisions regarding patient referral for MRI-64Gd rest on a number of factors. Clearly, patient complaints, case history, symptoms, as well as the patient’s anxiety in determining a definitive cause for his or her symptoms must be considered. Furthermore, the patient’s access to follow-up evaluations also influences the diagnostic protocol. Nevertheless, data in Table 3 serve to highlight the importance of clinical decisions in an era of medical cost containment coupled with extensive and expensive diagnostic capabilities. The examples given herein demonstrate, we believe, the value of ABR testing as a cost-effective screening measure for patients with symptoms placing them at intermediate or low risk for acoustic neuromas. Of course, patients must be advised to return for further examinations if their symptoms change or worsen even though their ABR test results were normal and/or MRI-64Gd findings were normal earlier.

We acknowledge other factors supporting the choice of MRI examinations for cerebellopontine angle tumors that have received attention recently. As Doyle indicates, the T2-weighted fast spin-echo imaging without enhancement generally costs little more than an ABR test screen. However, the current discussion in the otology and neuroradiology literature indicates that this technique also may fail to detect a few cerebellopontine angle lesions identified by conventional MRI-64Gd.

The recent development of a “stacked ABR” procedure by Don et al indicates higher sensitivity for identification of small acoustic neuromas. Don et al describe their identification of 5 small acoustic neuromas missed by conventional ABR testing through their use of ipsilateral masking and measurement of wave V amplitudes. This technique may warrant serious consideration in the diagnostic evaluation of patients considered at risk for cerebellopontine angle lesions. If further research and experience continue to support the findings of Don et al, we agree with Brackmann that stacked ABR methods may become a primary screening test for acoustic neuromas.

If further research and clinical experience demonstrate the efficacy of T2-weighted fast spin-echo imaging and the stacked ABR procedure, then the test of choice will depend on availability and convenience. A pleasant outcome for all concerned would be reduced costs. In the meantime, ABR tests can serve as a useful screening measure for patients considered to be at intermediate or low risk for acoustic neuromas.

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Corresponding author: Martin S. Robinette, PhD, Mayo Arrowhead, 20199 N 75th Ave, Glendale AZ 85308 (e-mail: robinette.martin@mayo.edu).

REFERENCES