Central Auditory Processing in a Patient with Bilateral Temporal Lobe Tumors: Case Report

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Abstract
The purpose of this article is to report the audiologic and central auditory processing abilities of a 34-year-old male with a right temporal lobe tumor and a history of bilateral tumors of the temporal lobes. The patient was evaluated presurgical re-exploration and again at 2.5 months and 4 months postoperatively. Test results demonstrated little change in peripheral hearing abilities; however, marked fluctuations were recorded on several tests administered postoperatively. Overall, this patient demonstrated a wide range of performance on tests of central auditory function, notably scores that decreased postoperatively and returned to better than baseline on the SCAN-A and repeated abnormal scores on the Pitch Pattern Sequence Test and the Symbol Digit Modality Test. Auditory Fusion Test-Revised results were initially normal, were markedly abnormal immediately postoperative, and returned to normal during the second postoperative visit. Our purpose in conducting this case study was to demonstrate, with central auditory processing test findings as well as magnetic resonance images, functional disorders of communication in a pre- and postoperative patient with a temporal lobe tumor.

Key Words: Central auditory processing disorder, magnetic resonance imaging, SCAN-A, temporal lobe

Abbreviations: AFG = auditory figure ground, AFT-R = Auditory Fusion Test-Revised, CAP = central auditory processing, CAPD = central auditory processing disorder, CS = competing sentences, CW = competing words, FW = filtered words, MR = magnetic resonance, PPST = Pitch Pattern Sequence Test, SDMT = Symbol Digit Modality Test, SCAN-A = Test of Auditory Processing Disorders in Adolescents and Adults

Assessment of central auditory processing (CAP) represents an attempt to determine how persons interpret auditory information that is transmitted in the complex neural pathways beyond the cochlea. According to Phillips (1995), a normal cochlea is necessary to convert the mechanical stimulus into neural impulses that are transmitted to the brain through the auditory nerve and brain stem. Disruption of an auditory pathway at any level can cause difficulty in the interpretation of auditory information and thus becomes known as a central auditory processing disorder (CAPD).

The auditory nervous system includes the primary auditory reception area of the cerebral cortex and association areas. Decussating neural tracts are located at all levels throughout the system from the trapezoid body in the caudal pons to the interhemispheric pathways of the corpus callosum. Various auditory nuclear centers throughout the system are known to receive and integrate signals from the two ears by way of numerous direct and collateral pathways (Musiek and Baran, 1986). Due to this complexity, auditory dysfunction is sometimes difficult to identify and may only be recognized through appropriate tests of specific design features.

In general, for patients with tumors of the temporal lobe, we know that the ear opposite the lesion will have depressed performance, compared
to the ear ipsilateral to the tumor. At times, performance in both ears or only the ipsilateral ear may be compromised. When speech signals are used, there will be particular consequences to performance in the right ear, opposite the language dominant hemisphere. When non-speech signals are used, there will be depression of performance in the left ear, opposite the non-dominant right hemisphere (Lynn and Gilroy, 1977).

The development of sophisticated imaging techniques, including magnetic resonance (MR) scans, provides new opportunities for knowledge regarding precisely the size and location of tumors preoperatively. As a result, there is a decreased need for diagnostic identification of central auditory lesions using behavioral auditory tests. There does remain a need to identify functional disorders related to structural damage, identify the social and vocational needs of patients, and provide information about “functional disorders of communication” (Bergman et al, 1987). Identification of central auditory disorders among patient populations results in counseling of affected individuals and their families, changes in the person's listening environment (both physical and psychological changes), and other specific recommendations for rehabilitation. In addition, modern imaging technology provides the ability to correlate the relationship between the presence of temporal lobe tumors and performance on a behavioral central auditory test battery. Phillips (1995) reported that “With the present state of knowledge, awareness of lesion locus is useful in that it may provide new evidence on the basic science question of structure-function relations in the nervous system...”

Previous research has documented various test result outcomes, pre- and postoperatively, with temporal lobe involvement. Cranford et al (1996) summarized several studies on pre- and postoperative temporal lobe tumor patients and reported that “...Taken as a whole, studies indicate that very little, if any, improvement in central auditory functioning can be expected following temporal lobe surgery.” However, Musiek et al (1990) reported opposite findings in a patient following temporal lobe surgery. Additionally, Cranford et al (1996) reported on central auditory test findings on five children who received partial temporal lobectomies. They concluded that “With few exceptions, the performances of individual children on all test measures were no poorer following the surgery than before surgery.”

One of the main purposes of this article is to show how measures of central auditory function can be used to describe changes in auditory processing in a patient pre- and postoperatively. To do this, we describe pre- and postoperative central auditory test findings in a patient with a temporal lobe tumor and a history of bilateral temporal lobe tumors, which are the behavioral outcomes of surgical intervention.

**METHOD**

**Subject**

The patient is a 34-year-old, right-handed male who presented in 1993 with a generalized seizure. MR scan demonstrated bilateral temporal lobe signal changes consistent with bilateral low-grade gliomas. In 1993, he underwent right temporal craniotomy and anterior temporal lobectomy. The pathology was consistent with a low-grade astrocytoma. He then underwent MR-guided biopsy of the left temporal/insular mass. The resulting pathology was also read as a low-grade astrocytoma. No further surgery was recommended for the left-sided tumor due to its location. He subsequently received external beam radiotherapy to a dose of 5400 cGy, which encompassed the bilateral signal abnormalities. A postradiation MR scan showed a partial response of both tumors.

The patient was followed with serial MR scans and remained neurologically intact. In February 1997, a MR scan showed progression of signal changes in the right temporal lobe and right insula (Fig. 1A). The left temporal lobe lesion was noted to be stable. He underwent surgical re-exploration with a right temporal craniotomy approach resulting in a subtotal resection of recurrent tumor that involved the inferior, middle, and superior temporal gyri (Fig. 1B). The pathology was consistent with a low-grade oligodendroglioma. Finally, he received systemic chemotherapy.

**Test Protocol**

MW was seen in 1997 for audiologic evaluations 4 days presurgical re-exploration, approximately 2.5 months postoperatively, and again 4 months postoperatively. Audiologic assessment was conducted as follows: on his presurgical re-exploration visit, MW received pure-tone air- and bone-conduction testing, speech audiometry, and acoustic immittance measures. On the first and second postoperative visits, only pure-tone air-conduction and immittance testing was done.

MW was administered the following central auditory test battery on his presurgical re-exploration visit: A Test for Auditory Processing...
Disorders in Adolescents and Adults (SCAN-A), Auditory Fusion Test-Revised (AFT-R), and the Symbol Digit Modalities Test (SDMT). At the time of his postoperative evaluations, the Pitch Pattern Sequence Test (PPST) was added. A brief description of each test is below:

1. **SCAN-A Test of Auditory Processing Disorders in Adolescents and Adults** (Keith, 1994). *Filtered Words (FW)*—In this subtest, the subject is asked to repeat words that sound “muffled.” The test stimuli consist of monosyllabic words that have been low-pass filtered at 500 Hz. *Auditory Figure Ground (AFG)*—This subtest evaluates the subject’s ability to understand words in the presence of background noise. Monosyllabic words were recorded in the presence of multitalker speech babble noise at 0-dB signal-to-noise (S/N) ratio. The subject is asked to repeat the words and ignore the noise. *Competing Words (CW)*—In this subtest, the subject hears two monosyllabic words, one word presented to each ear. The subject is instructed to repeat the words presented in each ear, repeating the word heard in the right ear first. Then the subject is instructed to repeat the word heard in the left ear first. *Competing Sentences (CS)*—In this subtest, pairs of sentences unrelated in topic are presented to the right and left ears. The sentence pairs have simultaneous onset and offset times. The subject is instructed to direct attention to the stimuli presented in one ear while ignoring stimuli presented to the other ear.

2. **Auditory Fusion Test-Revised** (McCroskey and Keith, 1996). This test of temporal processing disorders is comprised of a series of pure tones at several frequencies presented in pairs. The silent time interval between each pair of tones increases and decreases in duration from 0 to a maximum of 300 msec. As the time interval changes, the listener reports whether the stimulus pairs were heard as one tone or two.

3. **Pitch Pattern Sequence Test** (Pinheiro, 1977). This test is comprised of three 150-msec tones with 200-msec intertone intervals. The tones in each frequency pattern are a combination of two sinusoids, 880 Hz and 1122 Hz, which are designated low and high, respectively. MW verbally reported the sequence that was heard. He was given the option of responding with hand signals, by writing, by humming, or by responding verbally. He chose a verbal response mode.

4. **Symbol Digit Modalities Test** (Smith, 1982). This test of neuropsychology involves the conversion of meaningless geometric designs into written and/or oral number responses in a 90-sec interval. This is a quick measure of cognitive function and is highly sensitive to cerebral dysfunction. This test was administered in order to monitor cerebral function from presurgical subtest, the subject is asked to repeat words that sound “muffled.” The test stimuli consist of monosyllabic words that have been low-pass filtered at 500 Hz. *Auditory Figure Ground (AFG)*—This subtest evaluates the subject’s ability to understand words in the presence of background noise. Monosyllabic words were recorded in the presence of multitalker speech babble noise at 0-dB signal-to-noise (S/N) ratio. The subject is asked to repeat the words and ignore the noise. *Competing Words (CW)*—In this subtest, the subject hears two monosyllabic words, one word presented to each ear. The subject is instructed to repeat the words presented in each ear, repeating the word heard in the right ear first. Then the subject is instructed to repeat the word heard in the left ear first. *Competing Sentences (CS)*—In this subtest, pairs of sentences unrelated in topic are presented to the right and left ears. The sentence pairs have simultaneous onset and offset times. The subject is instructed to direct attention to the stimuli presented in one ear while ignoring stimuli presented to the other ear.

**Figure 1A** 1997 — progression of tumor growth (oligodendroglioma) in the right temporal lobe and insula.

**Figure 1B** 1997 — a right temporal craniotomy approach resulting in a subtotal resection of recurrent tumor that involved the inferior, medial, and superior temporal gyri.
re-exploration to the first and second postoperative evaluations. The test results allowed comparison of central auditory findings to cerebral function. MW responded with a written response.

RESULTS

Audiologic Findings

Results of MW’s basic audiologic test results are summarized in Table 1. MW’s hearing appeared to fluctuate slightly in the right ear between the presurgical re-exploration and first postoperative visit. The thresholds were 10 dB poorer at 250, 500, and 2000 Hz. He returned to presurgical re-exploration status at the second postoperative evaluation. For the left ear, hearing remained stable from presurgical re-exploration to the first postoperative visit but decreased 15 to 20 dB at 6000 and 8000 Hz when evaluated on the second postoperative visit.

Central Auditory Processing Results

MW’s CAP test results from February 20, 1997, May 1, 1997, and June 24, 1997 are summarized in Tables 2 and 3.

PPST

Although some fluctuation was noted from the first and second postoperative evaluations, scores remained in the abnormal/disordered range for both ears, a finding that is consistent with his temporal lobe injury and history of bilateral temporal lobe tumors.

SDMT

Performance on the SDMT was abnormal during the presurgical re-exploration visit, decreased at the first postoperative visit, and improved slightly at the second postoperative visit. The SDMT results never returned to the initial performance level. Scores were in the abnormal/disordered range at every visit for a person of his age and education level. Test results indicated abnormal cerebral function pre- and postoperatively.

AFT-R

The AFT-R was within normal limits during presurgical re-exploration and the second postoperative visit. MW was unable to perform the AFT-R during the first postoperative visit. He repeatedly fell asleep, an indication of this patient’s inability to sustain attention for a nonverbal task that is less interactive than other tests in this battery.

SCAN-A

The FW subtest scores decreased at the first postoperative evaluation and increased above baseline levels at the second postoperative visit. The AFG subtest scores did not fluctuate significantly during MW’s three visits. His CW subtest score was well within normal limits during presurgical re-exploration and decreased to questionable test results at the first and second postoperative visits. CS subtest scores were abnormal/disordered during presurgical re-exploration and at the first postoperative visit. However, the CS test results improved to normal performance for the second postoperative visit. The total test score on SCAN-A went from the borderline performance on the presurgical re-exploration study, fell to the 1st percentile during the first postoperative visit, and increased to within normal limits on the final visit.

In addition to the above test results, several observations regarding this patient were noted. On all three evaluations, the patient demonstrated unusual social interactions including inappropriate responses to questions during testing and laughing aloud for no apparent reason. These behaviors were noted primarily during

| Table 1 Audiologic Test Results for MW Summarized for Three Visits |
|-----------------------|----------------------|-----------------|
| **PTA (Four Frequency)** | **Tympanograms** | **Word Recognition** |
| Visit 1 (preop) | R = 6 dB, L = 13 dB | WNL | R = 100% at 50 and 90 dB |
| | | | L = 100% at 50 dB, 92% at 90 dB |
| Visit 2 (2.5 months postop) | R = 9 dB, L = 14 dB | WNL | DNT |
| Visit 3 (4 months postop) | R = 8 dB, L = 10 dB | WNL | DNT |

PTA = pure-tone average, R = right ear, L = left ear, WNL = within normal limits, DNT = did not test.
Table 2  Summary of MW's Test Results on the PPST, SDMT, and the AFT-R for All Three Visits

<table>
<thead>
<tr>
<th>Visit</th>
<th>PPST</th>
<th>SDMT</th>
<th>AFT-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (preop)</td>
<td>DNT</td>
<td>&gt; 2 SD below mean</td>
<td>Normal limits</td>
</tr>
<tr>
<td>2 (2.5 mos postop)</td>
<td>R = 50%</td>
<td>&gt; 3 SD below mean</td>
<td>Could not respond*</td>
</tr>
<tr>
<td></td>
<td>L = 75%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 (4 mos postop)</td>
<td>R = 68%</td>
<td>3 SD below mean</td>
<td>Normal limits</td>
</tr>
<tr>
<td></td>
<td>L = 60%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Patient repeatedly fell asleep.

The presurgical re-exploration visit and the first postoperative visit. He was noticeably fatigued at all three visits and fell asleep during both postoperative evaluations. When sleep occurred, he was awakened and brought back into focus, and the test was readministered when possible. At both postoperative evaluations, the patient was questioned regarding his memory of the previous visit. Each time, MW reported little memory for the preceding visit, especially during his first postoperative evaluation. At his second postoperative evaluation, the patient reported vague memories of "hearing tests" and being in the clinic with the examiner.

As noted previously, performance in both ears may be compromised with tumors of the temporal lobe, as demonstrated with the patient presented in this case report. MW's poor performance, bilaterally, on speech and nonspeech tests may result from his original history of astrocytomas of the right and left temporal lobes.

DISCUSSION

This patient was presented to demonstrate how central auditory test results can be used to describe auditory processing abilities and functional disorders of communication pre- and postoperatively. In this case, the results showed that auditory processing, as shown by the total test score on SCAN-A, was significantly affected by the surgical procedure, but subsequently returned to above baseline levels. Results of the SDMT found a decrease in performance at the first postoperative evaluation with some improvement on the final visit, although it never returned to the baseline level. The AFT-R was initially normal, the patient was unable to respond during the first postoperative visit, and final results returned to normal. The significant decreases in test performance shown during the first postoperative evaluation on several tests (SCAN-A, SDMT, and AFT-R) may likely be due to the temporary changes in auditory processing resulting from surgical intervention (e.g., edema or fatigue). The improvements may be hypothesized to be due to the healing process after invasive surgery. In that regard, our patient was similar to those described by Musiek et al (1990) in that performance improved after postoperative recovery occurred. Our patient performed differently than those described by Cranford et al (1996), in that MW's test measures were poorer, on some tests, following surgical re-exploration. Several factors might have impacted these results, including the age difference between our subject and those in the Cranford et al study. In addition, our patient was undergoing a second invasive procedure.

As noted above, it may be hypothesized that edema at the first postoperative visit played a role in the generalized poor performance, and the improved performance at the second postoperative visit was due to the reduction in edema after invasive surgery. An alternative hypothesis is that generalized fatigue during the first

Table 3  SCAN-A Test Results Summarized for MW for All Three Visits, Broken Down by Subtest and Total Test Score

<table>
<thead>
<tr>
<th>SCAN-A</th>
<th>FW</th>
<th>AFG</th>
<th>CW</th>
<th>CS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>SS = 8, PR = 25</td>
<td>SS = 9, PR = 37</td>
<td>SS = 12, PR = 75</td>
<td>SS = 1, PR = 1</td>
<td>SS = 81, PR = 10</td>
</tr>
<tr>
<td>Visit 2</td>
<td>SS = 7, PR = 16</td>
<td>SS = 8, PR = 25</td>
<td>SS = 7, PR = 16</td>
<td>SS = 1, PR = 1</td>
<td>SS = 67, PR = 1</td>
</tr>
<tr>
<td>Visit 3</td>
<td>SS = 9, PR = 37</td>
<td>SS = 8, PR = 25</td>
<td>SS = 7, PR = 16</td>
<td>SS = 9, PR = 37</td>
<td>SS = 87, PR = 37</td>
</tr>
</tbody>
</table>

SS = standard score, PR = percentile rank.
postoperative evaluation contributed to decreased scores and, in the case of the AFT-R, completely compromised the results. The improvements noted on some tests at the second postoperative evaluation may be contributed to a reduction in overall fatigue. Although MW did fall asleep at the second postoperative evaluation, he was able to be roused and testing was completed.

The pattern of results reported here may not be typical of all patient's auditory processing abilities pre- and postoperatively. In other cases, the performance may decrease postoperatively and show no improvement at subsequent visits. Some patients may show immediate or gradual improvement in auditory processing skills as postoperative edema and/or fatigue resolve. Results may also differ for patients with right-and left-sided hemispheric lesions. In all cases, the use of central auditory test results allows audiologists to describe the patient's auditory processing abilities pre- and postoperatively. In other cases, the performance may decrease postoperatively and show no improvement at subsequent visits. Some patients may show immediate or gradual improvement in auditory processing skills as postoperative edema and/or fatigue resolve.

For adult patients with CAPD, there are several intervention or management options. According to Masters et al (1998), auditory training and signal enhancement, including FM trainers, telephone amplification, and room amplification systems, are two such strategies. Recent enactment of the Americans with Disabilities Act (1991) provides accessibility of assistive listening devices in public places. In addition, language and cognitive intervention strategies are available. Academic/vocational modifications are usually beneficial, and in conjunction with career counseling and transition programming may prove to be the key to success for the individual with acquired central auditory processing deficits. Self-advocacy training is also important. As Masters et al (1998) state, "An employee who is not able to advocate for one's needs may find that he or she is at risk for job loss or employment termination because of perceived employee ineffectiveness." The management process used with MW was in the form of counseling. Communication strategies to use at home and at work (MW had returned to work on a part-time basis) were discussed, especially those that would enhance his abilities to understand in less than ideal listening situations. For example, we advised MW to pay attention to verbal cues, to ask for repetition when needed.

All patients who experience auditory processing disorders, and their families, benefit from understanding their auditory capabilities and learning day-to-day activities that can be used to ameliorate their effects. This was true for MW, but, unfortunately, we were unable to get this patient's family in for informational counseling.

As previously stated, the presurgical re-exploration and postoperative pattern of CAP test results reported for this patient may not be typical of all patients with temporal lobe tumors. Future research of auditory processing abilities within this population is recommended.

REFERENCES


