Audiologic Assessment of Traumatic Head Injury Patients in Rehabilitation: Methods and Findings

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The Texas Head Injury Foundation reports that head trauma is the leading cause of serious injury and death in the United States for persons under the age of 34. Each year head injury resulting in traumatic brain damage affects approximately 700,000 Americans, and one out of 80 children born this year will die of head trauma if the "Silent Epidemic" continues unchecked. The cost of care over a lifetime for each survivor of severe head injury is currently estimated at 4 million to 9 million. Due to the complexity of physical, behavioral, and cognitive disorders that frequently follow traumatic brain injury, rehabilitation is often a long and difficult process requiring the efforts of many professionals including speech-language pathologists, occupational therapists, physical therapists, and cognitive rehabilitation specialists. Our experiences with recovering head injury patients indicate that the audiologist can and should be an integral member of the treatment team.

This article presents an overview of audiologic test results for 60 head injury patients consecutively admitted to a rehabilitation hospital. Many of the tests mentioned below will be routine for the audiologist, however a few of the auditory evoked response and central auditory test procedures may be less familiar. The speech-language pathologist may have only passing knowledge of any of the audiologic methods that were used. Therefore, brief information will be provided for each procedure to show how therapeutically relevant results can be obtained. We feel that the data clearly demonstrate the need for cooperative efforts between speech and hearing professionals involved in the diagnosis and treatment of head injury.

Table 1. Rancho Los Amigos Scale of Cognitive Recovery levels for 60 consecutively admitted traumatic head injury rehabilitation patients.

Scale Level	Cognitive Function	Number of Patients
I	No response - Unresponsive to all stimuli	0
II	Generalized response - inconsistent, nonpurposeful reactions to stimuli.	3
III	Localized response - Inconsistent reaction related directly to the type of stimulus.	3
IV	Confused, agitated response - Disoriented and unaware of present events; frequent bizarre behavior.	1
V	Confused, inappropriate, nonagitated response - Fragmented responses when task complexity exceeds patient's abilities; unable to accomplish new learning.	6
VI	Confused, appropriate response - Behavior is goal directed. Responses are appropriate to immediate situation. Responses requiring memory are flawed.	11
VII	Automatic, appropriate response - Patient follows daily routines automatically. Insight, judgment, and problem-solving skills are compromised.	36
VIII	Purposeful, appropriate response - No supervision required. Carryover of new learning, but abstract reasoning and stress tolerance are limited.	0

Table 2. Audiologic procedures used in the present study to evaluate head injury patients. (+) test results often affected by dysfunction; (-) test results seldom affected by dysfunction; (+/-) rest results sometimes affected by dysfunction.

Procedure	Anatomy					Active participation required	Min RLAS level
	Peripheral			Central			
	middle ear	inner ear	eighth nerve	brain-stem	cerebrum		
ELECTROPHYSIOLOGIC							
Immittance audiometry							
tympanometry	+	-	-	-	-	no	I
acoustic reflexes	+	+/-	+	+/-	-	no	I
Auditory evoked responses							
brainstem	-	+/-	+	+	-	no	I
middle latency	-	-	-	-	+	no	I
40 Hertz	-	-	-	+/-	+	no	I
BEHAVIORAL							
Pure tone audiometry							
air conduction	+	+	+	-	-	yes	VI
bone conduction	-	+	+	-	-	yes	VI
Speech audiometry							
speech threshold	+	+	+	-	-	yes	V
speech discrimination	-	+/-	+	+/-	-	yes	V
Competing Sentences	-	-	-	+/-	+	yes	VI
Staggered Spondees	-	-	-	+/-	+	yes	VI

Patient Sample

Audiologic evaluations were conducted for 60 traumatic head injury patients consecutively admitted to a 150-bed brain injury rehabilitation hospital located in Austin, Texas. These patients came from a wide variety of geographic locations throughout the United States and generally reflected epidemiologic patterns common to head trauma. Age range was 11-57 years (*M*=28 years), and 72% were male. Months post-onset ranged from 1 to 126 (*M*=47 months). Patients from levels II through VII on the Rancho Los Amigos Scale of Cognitive Recovery (RLAS) (Hagen, 1984) were included (Table 1). Forty-two of the 60 patients were at level VI or VII of the RLAS and were able to participate in each of the four categories of testing described below.

Audiologic Methods

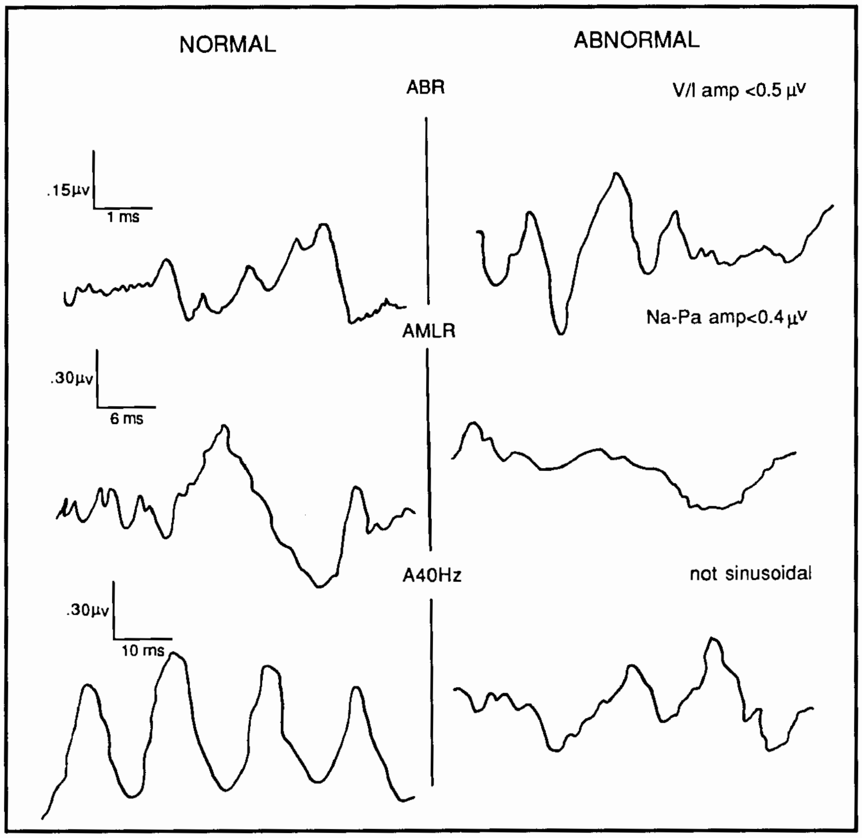
Four categories of test procedures were selected from two general areas of audiologic methods:

A. Electrophysiologic methods encompassing (1) testing of middle ear mobility and acoustic reflexes by immittance audiometry, and (2) measurement of auditory evoked response including brainstem, middle latency, 40 Hertz, and P300 auditory-cognitive potentials.

B. Behavioral methods including (3) evaluation of the peripheral auditory system through pure tone audiometry, and (4) assessment of speech reception threshold, speech discrimination, and central auditory processing by means of speech audiometry.

All 60 patients were able to be evaluated by electrophysiologic procedures from categories 1 and 2 because measures of immittance and auditory evoked responses depend on physiologic responses and are recorded electronically and do not require active participation on the part of the patient. Consequently, even comatose or confused patients could be evaluated by these methods. On the other hand, when behavioral audiometric procedures from categories 3 and 4 were employed, the reliability of test results depended on the patient's ability to remember directions, attend to stimuli, and produce responses such as pushing a button or repeating speech stimuli on cue. Table 2 lists the four categories of audiologic procedures and shows anatomic sites of lesion that may be suspected according to test results for each procedure. Table 2 also shows whether or not active patient participation is needed to accomplish each particular test and what minimum patient level on the RLAS may be required for reliable results. The following is a very brief description of the audiologic methods used to evaluate the series of 60 head

Figure 1. Examples of normal and abnormal waveforms for ABR, AMLR, and A40Hz evoked responses.



injury rehabilitation patients. The reader is referred to the following references for further details on these methods (Campbell et al., 1986; Bergman et al., 1987; Brunt, 1978; Glattke, 1983; Hall, 1985; Kileny, 1985; Martin, 1975; Rosenberg, Wogensen, & Starr, 1984; Spydell, Pattee, & Goldie, 1985.)

Electrophysiologic Methods

Immittance Audiometry

The immittance audiometer introduces combinations of sound stimuli (tones or noise) and air pressure into the ear canal to measure characteristics of the canal, ear drum, and middle ear. Tympanometry assesses ear canal volume, ear drum compliance, and middle ear air pressure. Acoustic reflex measurements assess the sound intensity threshold of the stapedius muscle reflex, and the patency of the brainstem reflex arc between the seventh and eighth cranial nerve branches which mediate the reflex (Hall, 1985).

Auditory Evoked Responses (AER)

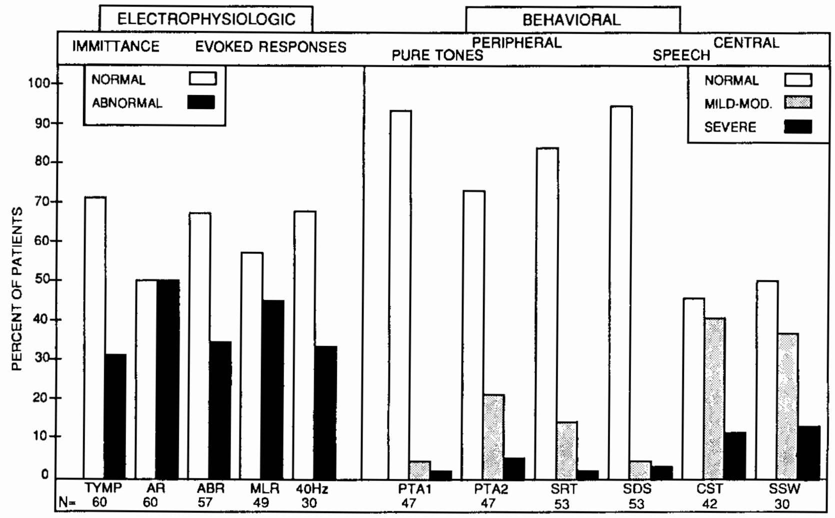
AERs are bioelectic potentials that can be recorded by computer averaging of auditory nervous system activity detected by scalp electrodes. Typically, AERs are elicited by click or tone burst stimuli, and classified according to latency of response. Early responses occur at 0 to 15 ms, and are presumed to originate the caudal brainstem. Middle latency responses occur at 15 to 50 ms, and may reflect subcortical and cortical activity within the auditory nervous system. Late latency responses occur beyond 50 ms, and probably represent more generalized CNS responses to auditory stimulation (Glattke, 1983; Hall & Tucker, 1986; Kileny, 1985). Figure 1 shows examples of normal and abnormal short (ABR) and middle (AMLR, A40Hz) latency auditory evoked responses for the current patient sample. Late latency response examples (P300) are shown in Figure 3.

Behavioral Methods

Behavioral audiometry involves the measurement of hearing sensitivity and speech discrimination according to responses made by the patient. Stimuli are presented via earphones so that each ear can be tested separately, and the patient should be seated in a sound-treated room to minimize environmental noises. Pure tone audiometry assesses hearing sensitivity for frequencies spanning the range important to speech discrimination (250-8000 Hz). Tone thresholds are determined by air conduction (earphones) and bone conduction (mastoid vibrator). These two sets of thresholds can be compared to determine the presence and extent of conductive hearing loss due to middle ear damage, or sensorineural hearing loss due to inner ear damage (Martin, 1975).

Speech audiometry included assessment of speech reception threshold (SRT), speech discrimination score (SDS), and for the present patient sample, evaluation of central auditory processing. Comparison of test results for these procedures can aid in the differential diagnosis of peripheral versus central auditory dysfunction (Musiek & Pinheiro, 1985). The Staggered Spondiac Word Test (SSW) (Katz, 1962) and the Competing Sentences Test (CST) (Willeford, 1977) were selected as the central auditory speech processing assessments for our head injury patients. Experience has shown us that most patients at RLAS levels VI and VII could follow directions and attend to stimuli for these two tests. Even so, the procedure for the CST had to be modified so that a greater number of these higher level patients could complete the test. We found that many patients could not repeat any of the words in the sentence stimuli presented to the left ear, when a competing sentence

Figure 2. Patterns of audiologic findings for 60 traumatic head injury patients consecutively admitted to a rehabilitation hospital.



TYMP tympanometry, AR ipsilateral acoustic reflex, ABR auditory brainstem response, 40 Hz 40 Hertz response, PTA1 tone threshold 500-2K Hz, PTA2 tone threshold 2K-8K Hz, SRT speech reception threshold, SDS speech discrimination score, CST competing sentences test, SSW staggered spondee test.

was presented to the right ear at the level suggested by the test author (competing ear 15 dB greater than message ear). Consequently, at the beginning of the test sequence for each message ear, we set the stimuli at 0dB difference between ears relative to the SRT. If the message sentence was correctly repeated, stimulus intensity in the competing ear was increased 5dB. If not, intensity was decreased 5dB. We found this approach to be effective in determining "thresholds of interference" (interhemispheric auditory suppression) in brain injury patients (Bergman et al., 1987). Also, more patients could complete the modified CST than was possible with the original protocol.

Patterns of Audiologic Test Results

Figure 2 summarizes the major results of audiologic evaluations for the 60 head injury patients. The figure is divided into two sections corresponding to the electrophysiologic and behavioral methods employed. The number of patients evaluated by each procedure is listed under the abbreviated names of the procedures along the abscissa. Percentages of patients receiving normal and abnormal scores for each procedure are shown on the ordinate. Criteria for classifying test results (normal, abnormal, mild-moderate, severe) were based on widely used current clinical standards (Hall & Tucker, 1986; Katz, 1978; Martin, 1975; Moller & Moller, 1985; Willeford, 1977), and on norms for the evoked response test equipment (Nicolet Compact Four) used at the rehabilitation hospital. P300 auditory-cognitive evoked response test results are not displayed in Figure 2, but are shown in Figure 3 and discussed below.

The data in Figure 2 show that the greatest percentages of abnormalities were found for the two measures of central auditory processing (CST, SSW), the acoustic reflex, and the three measures of auditory evoked responses (ABR, AMLR, A40Hz). Over 55% of patients demonstrated some degree of abnormality for the CST, and 50% had abnormal SSW scores. Also, 50% of patients had abnormally elevated acoustic reflex thresholds or no detectable reflex. Auditory evoked potential test results showed at least unilateral abnormalities for 34% of ABRs, 44% of AMLRs, and 33% of A40Hz responses. ABR test results for 3 of the 60 patients were not included for analysis due to audiometric signs of maximal conductive abnormalities or severe sensorineural hearing loss, which could have caused the latencies of ABR waves to be prolonged due to peripheral otologic influences, rather than brainstem neurologic dysfunction (Glattke, 1983).

Figure 3 shows auditory-cognitive (P300) evoked response group data for 20 of the head trauma patients at RLAS level VII and 10 normal subjects evaluated with the same procedures and equipment. In a normal subject, the P3 component of the response is a large wave with a latency of approximately 300 ms that can be recorded only when the subject tries to discriminate between a target stimulus that occurs infrequently and non-target stimuli that occur more often. For this reason the P300 response is termed an "event-related" potential that reflects auditory attention, discrimination, and memory (Kileny, 1985). The data in Figure 3 indicate that for both P300 tasks (discrimination of loudness between clicks, and frequency between tones), the 20 high level head trauma rehabilitation patients showed markedly reduced P3 amplitudes and prolonged P3 latencies, when compared to the normal subject group.

Discussion

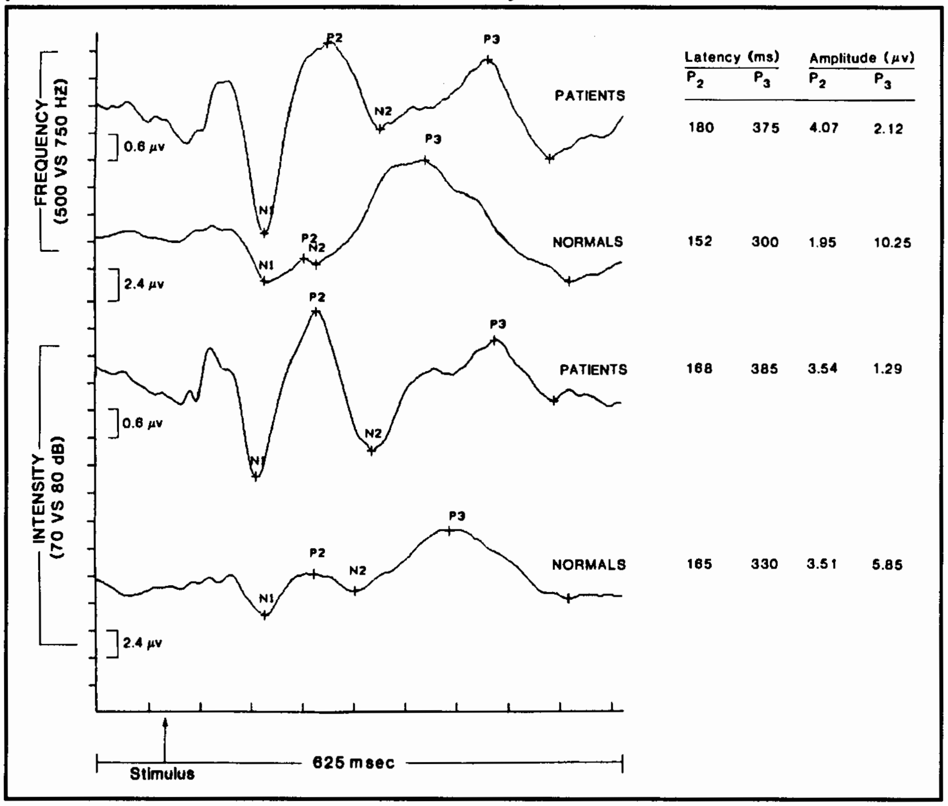


Figure 3. Auditory-cognitive (P300) evoked response group data for 20 head trauma patients at RLAS level VII and 10 normal subjects.

The results of audiologic evaluations for the 60 consecutively admitted head injury rehabilitation patients indicated that substantial numbers of audiologic abnormalities were demonstrated across the patient sample. More frequent and more severe abnormalities were found for measures of central auditory processing and auditory evoked responses than for measures of hearing sensitivity and speech discrimination. This pattern of results strongly supports our view that detailed audiologic evaluations are necessary to fully identify auditory dysfunctions which may be significant to prognosis and rehabilitative programming. Less detailed procedures, such as pure tone hearing screenings and speech audiometric tests with non-competing stimuli, will fail to identify central auditory processing problems, which we found to be prevalent in over 50% of our patient sample. Also, if immittance audiometry and/or auditory evoked response testing are not done, information on the auditory status of comatose or confused patients will be lacking.

Perhaps the most interesting and therapeutically relevant pattern of test scores obtained for the head injury patients in our sample were the central auditory test results for 47 individuals in the combined RLAS levels VI and VII. The major trend was a pronounced reduction in left ear performance, with the right ear within normal limits. This pattern is very compatible with the observation that many head injury patients do not show classic language processing disorders such as aphasia, where auditory processing would be affected bilaterally due to focal lesions of the auditory cortex (Adamovich, Henderson, & Auerback, 1985; Ylvisaker & Holland, 1985). Rather, the diffuse neural lesions associated with closed head trauma may lead to inefficient auditory processing mechanisms, particularly in structures with less numerous and less direct neural links with the auditory cortex. As a result, left ear information may be suppressed by competing right ear information, since the right ear has the more direct pathway to language dominant left hemispheric structures (Kimura, 1961; Musiek & Sach, 1980).

We believe that this pattern of inefficient auditory processing holds three major implications for therapy. First, the greater the magnitude of the inefficiency, the greater the need for a highly controlled auditory environment in formal therapies and in the living situation of the patient. Second, the nature and amount of auditory input presented in any given act of communication needs to be individually structured to suit the patient's auditory processing abilities. Third, the patient's auditory abilities should be kept in mind whenever group therapy is considered. Individual attention may be required to help the patient manage the communicative demands that occur in group settings.

In closing, the patterns of audiologic findings for the 60 head injury patients represent only the first layer of data to be analyzed. A word of caution about the generality of this data must be provided in that these patients were admitted to a hospital that specialized in cases where a history of behavior problems and failure in other placements exists. Consequently, the patient sample may not represent a cross-section of individuals encountered in more typical rehabilitative settings. However, the initial summary of audiologic test results for these patients indicated that further data analysis and follow-up testing may yield valuable information on the possible relationships between patterns of audiologic abnormalities, types of interventions, and outcome of severe traumatic head injury. Also, it is clear from the data that close cooperation between speech and hearing professionals is essential to maximize treatment of communication disorders in head injured patients.

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