Special Feature: Closed Head Injury

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Coma Stimulation: The Role of the Speech Pathologist

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The advances in emergency care and neurosurgical management of the traumatically brain injured in recent years have enabled more individuals to survive. The field of rehabilitation of the traumatically head injured is charged with facilitating and structuring improvement, and achieving functional outcomes for the survivors and their families. Studies have indicated that early intervention by rehabilitation specialists is essential to expediting progress and that this intervention should begin at the coma level. Within the past five years rehabilitation services for traumatically brain injured have expanded to include highly specialized, highly structured coma intervention programs. The speech pathologist should be considered a key member of the interdisciplinary coma management team.

Physiologic Aspects of Coma

Coma occurs when the reticular activating system of the brain stem is injured. The reticular activating system is responsible for arousal, defined as an organism's general state of readiness to respond to the environment. It is often difficult to assess cerebral cortical functioning at this level. Patients exhibit wake-sleep cycles with some evidence of attention or arousal. Severe and diffuse cortical and subcortical injury can also produce coma, perhaps through the disruption of descending influences on the arousal system (Plum, 1972). Often the terms "coma" and "persistent vegetative state" (PVS) are used interchangeably although they are not synonymous. Medically, the persistent vegetative state is used to describe the patient who exhibits "wakeful unresponsiveness" (Berrol, 1982) and who remains neither conscious nor in coma. In the care and rehabilitation of the patient considered to be "in coma," the term "coma" refers to deficits in arousal and sustained attention. The Glasgow Coma Scale (Teasdale & Jennett, 1974), the standard for clinical assessment of depth and duration of impaired consciousness and coma induced by head injury, rates three aspects of behavior - the degree of eye opening, verbal performance, and motor responsiveness. This scale has been found to be one of the best predictors of later outcome (Heiden, et al., 1983). The Glasgow Outcome Scale (Jennett & Bond, 1975) utilizes five categories, ranging from persistent vegetative state to good recovery, to identify recovery patterns after head injury (Heiden, et al., 1983).

Coma Rehabilitation

Coma is not an "all or none" concept in rehabilitation but rather is more accurately defined by levels. In the rehabilitation setting this is generally determined using the Ranchos Los Amigos Scale of Cognitive Levels and Expected Behavior (RLA) (Hagen, 1984). This eight level scale is presented in Table 1. By the time the patient reaches Level III, responses are directly related to the type of stimulus presented, as in turning the head toward a sound source or focusing on an object presented. The patient may withdraw an extremity and/or vocalize when presented with a painful stimulus. He may follow simple commands in an inconsistent, delayed manner, such as closing his eyes, squeezing, or extending an extremity. Once external stimuli are removed, he may lie quietly. He may show a vague awareness of self and body by responding to discomfort, by pulling at a nasogastric tube or catheter, or resisting restraints. He may also show a bias toward responding to some persons (especially family or friends) but not to others.

Sensory Stimulation

In addition to medical and pharmacologic treatment of disorders of arousal, a structured sensory stimulation program is initiated at Levels I - III. The rationale for such a program is as follows:

Table 1. Ranchos Los Amigos Scale of Cognitive Levels and Expected Behavior.

Level I. - NO RESPONSE: Patient appears to be in a deep sleepand is completely unresponsive to any stimuli.

Level II. - GENERALIZED RESPONSE: Patient reacts inconsistently and nonpurposefully to stimuli in a nonspecific manner. Responses are limited and often the same, regardless of stimulus presented. Responses may be physiological changes, gross body movements, and/or vocalization.

Level III. - LOCALIZED RESPONSE: Patient reacts specifically, but inconsistently, to stimuli. Responses are directly related to the type of stimulus presented. May follow simple commands such as, "Close your eyes" or "Squeeze my hand" in an inconsistent, delayed manner.

Level IV - CONFUSED-AGITATED: Behavior is bizarre and nonpurposeful relative to immediate environment. Does not discriminate among persons or objects, is unable to cooperate directly with treatment efforts, verbalizations are frequently incoherent and/or inappropriate to the environment, confabulation may be present. Gross attention to environment is very short, and selective attention is often nonexistent. Patient lacks short term recall.

Level V. - CONFUSED, INAPPROPRIATE, NON-AGITATED: Patient isable to respond to simple commands fairly consistently. However, with increased complexity of commands, or lack of any external structure, responses are nonpurposeful, random, or fragmented. Has gross attention to the environment, but is highly distractible, and lacks ability to focus attention on a specific task; with structure, may be able to converse on a social-automatic level for short periods of time; verbalization is often inappropriate and confabulatory; memory is severely impaired, often shows inappropriate use of subjects; may perform previously learned tasks with structure, but is unable to learn new information.

Level VI. - CONFUSED-APPROPRIATE: Patient shows goal-directed behavior, but is dependent on external input for direction; follows simple directions consistently and shows carry-over for relearned tasks with little or no carry-over for new tasks; responses may be incorrect due to memory problems, but appropriate to the situation; past memories show more depth and detail than recent memory.

Level VII. - AUTOMATIC-APPROPRIATE: Patient appears appropriate and oriented within hospital and home settings, goes through daily routine automatically, but is frequently robot-like, with minimal-to-absent confusion; has shallow recall of activities; shows carry-over for new learning, but at a decreased rate; with structure, is able to initiate social or recreational activities; judgment remains impaired.

Level VIII. - PURPOSEFUL AND APPROPRIATE: Patient is able to recall and integrate past and recent events, and is aware of and responsive to the environment, shows carry-over for new learning and needs no supervision once activities are learned; may continue to show a decreased ability, relative to premorbid abilities in language, abstract reasoning, tolerance for stress and judgment in emergencies or unusual circumstance.

(From Hagen, 1984. By permission of Little, Brown & Co. and College-Hill Press.)

1. Sensory stimulation will increase input into the reticular activating system and thereby might increase arousal to the threshold necessary for responsiveness in patients so underaroused as to make them incapable of responding under ordinary circumstances.

2. Once patients spontaneously recover to a point where minimal awareness or responsiveness is possible with maximal stimulation, although responses may be inconsistent and of no functional significance, leaving them without any stimulation while waiting for further improvement would amount to environmental deprivation.

3. At the very least, stimulation programs allow for frequent monitoring of patients so that the ability to respond to a small but functional extent does not go unnoticed.

The goals for a sensory/sensorimotor stimulation program include the establishment of a structured environment so that there are as few distractions as possible, increasing recognition of the environment, and increasing functional and adaptive behaviors. A truly interdisciplinary approach is needed to facilitate the attainment of goals, and it is recommended that a team approach be utilized to maintain consistency of service delivery, familiarity, and continuity of care. The family should be considered a key member of the team.

The speech pathologist, as an integral member of the treatment team, can provide education and instruction to family/friends in how to structure time spent with the patient. Family members should be encouraged to participate actively in the rehabilitation process at this level, as in all higher levels of cognitive/physical functioning. The family will need guidance, instruction, and reassurance in order that they may be effective facilitators of progress in the rehabilitation effort. Table 2 offers examples of the family's involvement in facilitating the patient's recovery.

The principles of sensory stimulation techniques have not been established to date by scientific data but are based to some degree on what is known about individuals recovering from brain injury (Whyte, 1986). It is generally recommended that coma sensory stimulation programs in patients who still require intracranial pressure monitors should be avoided or minimized (Yabko, 1985). The principles of sensory stimulation include the following:

Table 2. Examples of family involvement during early stages of recovery.

1. Decorate the patient's room with familiar items and photographs from home.
2. Never assume that the patient cannot see, hear or understand, even though he may be unresponsive.
3. Structure communication in short intervals.
4. Upon entering the patient's room, call the patient by name, identify yourself, orient to date, time and place.
5. Indicate what procedure will be performed, step by step, if applicable.
6. If there is no response to voice or touch, deep tactile stimulation (raising volume of voice and cupping the hand to provide vibration to the chest) may be used (if not medically contraindicated) to elicit arousal.
7. Document responses.

1. Control the environment so that there are as few distractions as possible.
2. Apply one stimulus at a time and observe for a response. If a response is observed, try to elicit the same response with a different stimulus, such as, simple command, gesture, or tactile encouragement. If a response is not observed, request the desired response either verbally or gesturally, with the hope that the stimulus may have increased arousal to a point where a response could be elicited by request. Time must be allowed for extremely delayed processing of information.
3. Sessions should be brief (15-30 minutes).
4. Stimuli that have emotional significance to the patient may be most likely to elicit responses. The accounts of family/friends of observed or elicited responses should not be discounted as wishful thinking. The use of tape recorded messages from family/friends can be utilized as well as pre-morbid preferences for music or a favorite cologne.
5. Stimulation should be attempted in all five senses. Stimulation should vary in nature and intensity to maximize the possibility of increasing arousal. However, it must be remembered that sensory loss or distortion of sensation is common after brain and brain stem injury and that apparent pleasurable stimuli may be perceived as extremely unpleasant. The loss or distortion of the olfactory sense and its relationship to taste is the most common sensory change after brain injury.
6. Sensorimotor stimulation such as rocking may be utilized to elicit a motor response, decrease tone, provide sensation of movement, or relax the patient; however, vigorous vestibular stimulation may cause vomiting with the risk of aspiration.
7. Once consistent responses begin to be documented, the speech pathologist may direct the program toward the attainment of more functional goals, such as the establishment of a "yes-no" communication system.

It should be emphasized that the role of the speech pathologist should ideally begin upon admission to the program and serve not only to complement the other disciplines but also to provide and structure language and cognitive stimulation in the early stages of recovery. Sensory stimulation kits are utilized by speech pathology, occupational therapy and, with instruction, the family. Examples of items included in a sensory stimulation kit are outlined by each sense in Table 3. A response form similar to the model in Appendix A may be utilized on a daily basis to document responses.

Oro-Motor Stimulation

The issue of oro-motor stimulation, desensitization, and primitive reflex inhibition of the oro-motor reflexes is addressed by speech pathology, occupational therapy, and specially trained nursing staff (generally for good oral care). Oral facilitation and reflex inhibition can be performed at the RLA Levels I-III and ideally should begin at these levels unless contraindicated. Contraindications to oro-motor stimulation include: a patient who cannot be positioned in an upright position (at least 45 degrees) for oral facilitation; a patient who is at risk for aspiration of their own secretions; or a patient whose

Table 3. Examples for a sensory stimulation kit.

TACTILE	Soft and rough textures and shapes, such as velcro (soft and firm), fine sandpaper, fur, brushes, combs, etc.
TASTE	Extracts, vinegar, lemon, peppermint or any of the many flavors currently available.
OLFACTORY	Pungent and pleasant scents, such as extracts, herbs and spices (garlic, cloves, cinnamon, etc.), vinegar or colognes and perfumes (preferably those worn by or familiar to the patient).
VISUAL	Colorful items, familiar photographs, television (without volume or with low volume) in short increments.
AUDITORY	Bells, horns, clapping, tape recorded messages fromfamily/friends and music (should be used in short increments, consider premorbid preferences and never when other activities are being addressed unless as a form of reinforcement for responses).

respiratory status is unstable (this does not include a patient with a tracheostomy). A bedside oro-motor assessment should be performed for patients at RLA Levels I-II specifically to evaluate the presence/absence and frequency of a spontaneous swallow and the strength of the swallow reflex. This can be ascertained by placing the hand on the submandibular or laryngeal areas for a period of up to five minutes. This will also give some indication of how the patient manages his own secretions. To facilitate a swallow or trigger the swallow reflex, a cold laryngeal mirror, size 00 (preferably teflon coated), is repeatedly touched to the base of the anterior faucial arch. Gently, but firmly, stroking the laryngeal area in a downward pattern and holding for 30 seconds or using gentle fingertip pressure under the submandibular area just inferior to the chin will help facilitate a swallow (Logemann, 1983). Passive and resistive manipulation of all structures helps increase oral skills necessary for a pre-feeding assessment.

A bedside feeding assessment is generally not appropriate for the RLA Levels I-II patient; however, on occasion a Level II patient may present with good automatic, spontaneous movement which would warrant a feeding assessment. When this occurs, it is recommended that a modified barium swallow (Logemann, 1983) be performed to document safe deglutition and determine appropriate food textures/consistencies. A modified barium swallow procedure will also help rule out or confirm silent aspiration, a concern for any neurologically involved patient and a contra-indication to a feeding or prefeeding program. The presence of a trach should not deter a competent dysphagia therapist from either performing a feeding assessment or proceeding with a feeding program based on the results. As always, decisions to attempt a feeding or prefeeding evaluation should be made by the dysphagia management team which often consists of the physician, the speech pathologist, the occupational therapist, the respiratory therapist, and the dietician.

A patient who is functioning at a RLA Level III and who demonstrates through an oro-motor assessment and bedside feeding evaluation to be safe for a specified diet should be fed initially by only trained individuals, specifically the speech pathologist and/or occupational therapist. When the patient is able to be fed an entire meal in 45 minutes for one week, the speech pathologist and/or occupational therapist may train designated nursing staff and/or family to assist with feeding under close supervision. This decision is made by the members of the dysphagia management team. The speech pathologist and/or occupational therapist continually monitor a feeding program for patient safety and diet progression.

It is important to stress that a nasogastric (NG) tube, gastrostomy tube (G-tube), or jejunostomy tube (J-tube) should not be removed until oral intake is sufficient to maintain nutritional status, and the patient is able to manage free water adequately to maintain good hydration and kidney function. This is especially critical in the acute head injured individual who generally has high caloric and nutritional needs. Since the presence of an NG tube continually stimulates the gag reflex, and thus depresses its function, consideration should be given to the placement of a G-tube or J-tube for nutritional status maintenance if the need for a feeding tube will be prolonged. It should be noted that the recommendations/suggestions for oral facilitation and dysphagia treatment are not comprehensive but rather are presented more as an overview of general guidelines. (For additional information see Logemann, 1983).

Summary

In summary, a mock daily schedule is provided in Appendix B as a suggestion for structuring a coma stimulation program. Since very little research has been published on the effects of coma stimulation, it will be important to establish how and to what degree these programs affect and facilitate progress toward recovery of the head injured individual.

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Appendix A

Greenery Rehabilitation Center
Generalized Response Tracking
of Sensory Stimulation Modalities

Patient Name:______________________________

Date:______________ Evaluator:______________________________

Responses to Modality	Olfactory	Auditory	Visual	Tactil	Gustatory
Facial Grimace					
Withdrawal					
Associated Reaction					
Head Orientation					
Momentary Focusing					
Blinking					
Nystagmus					
Oral Movements					

Appendix B

Example of a daily schedule utilizing a coma stimulation program

12:00 - 12:30a	Nursing rounds/Positioning/Splint application or check.
2:00 - 2:30a	Nursing care/Positioning/Turn/Vital Signs
4:00 - 4:30a	Nursing care/Positioning/Turn/Splint Schedule
6:00 - 6:30a	Nursing care/Positioning/Turn/Orientation
6:00 - 7:00a	Music
7:00 - 7:30a	Nursing care
8:00 - 8:30a	Bath/Up in chair
8:00 - 9:00a	Physical therapy in department
9:00 - 9:30a	Sensory stimulation
9:00 - 10:00a	Music or taped messages
10:00 - 11:00a	Back to bed for rest/Nursing care
11:00 - 11:30a	Oro-motor stimulation/Orientation/Language Stim.
11:30 - 1:30p	Tube Feeding or Feeding Program/Rest
1:00 - 1:30p	Occupational therapy in department
1:30 - 2:00p	Sensory stimulation
2:00 - 2:30p	Therapeutic recreation
2:30 - 3:30p	Back to bed/Nursing care/Music
3:30 - 4:00p	Physical therapy bedside
4:00 - 4:30p	Oro-motor stimulation/Orientation/Language Stim.
4:30 - 5:00p	Quiet time
5:00 - 6:00p	Tube feeding and/or Feeding program
6:00 - 7:00p	Rest time
7:00 - 7:30p	Reality orientation
7:30 - 8:30p	Music/Taped Messages/Family read to patient
8:30 - 12:00a	Nursing care/ROM/Sleep

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

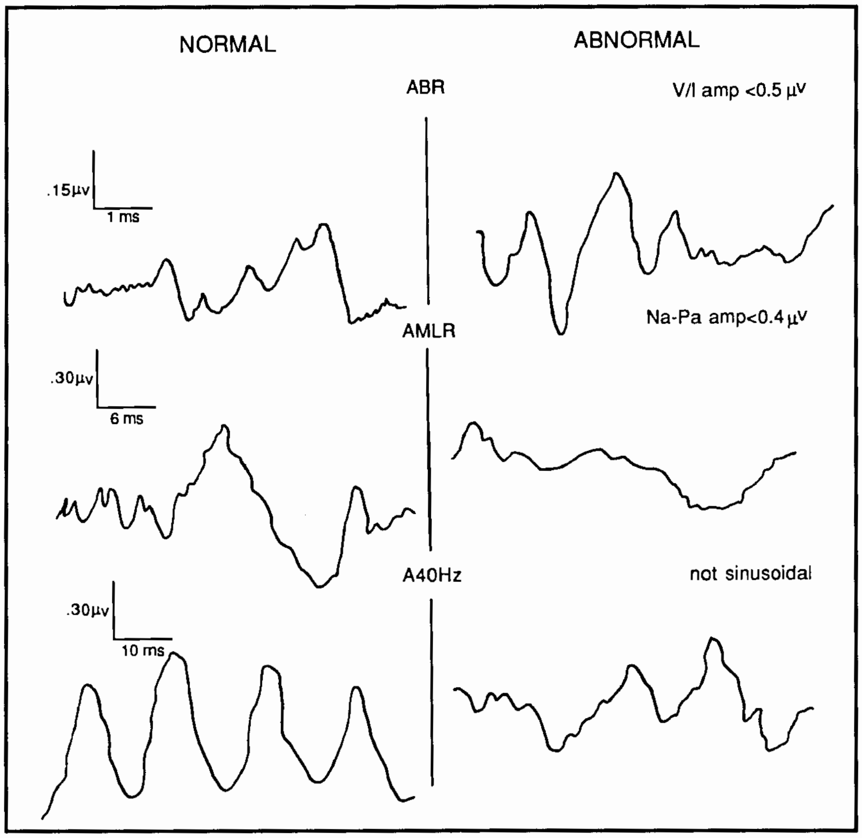
Four categories of test procedures were selected from two general areas of audiologic methods:

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)

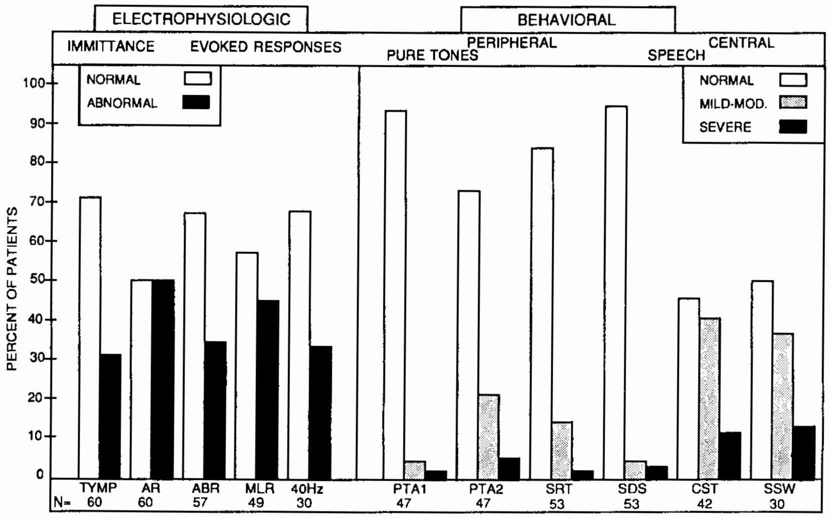
AERs are bioelectic potentials that can be recorded by computer averaging of auditory nervous system activity detected by scalp electrodes. Typically, AERs are elicited by click or tone burst stimuli, and classified according to latency of response. Early responses occur at 0 to 15 ms, and are presumed 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

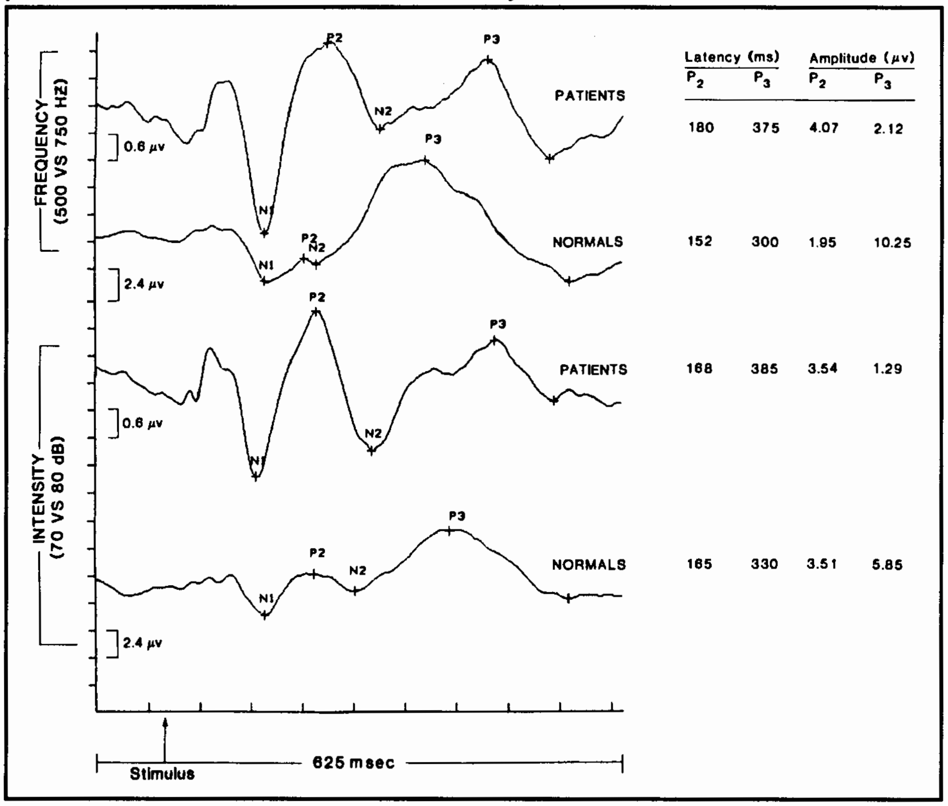
Figure 2 summarizes the major results of audiologic evaluations for the 60 head injury patients. The figure is divided into two sections corresponding to the electrophysiologic and behavioral methods employed. The number of patients evaluated by each procedure is listed under the abbreviated names of 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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