Vietnam Head Injury Study

Preliminary Analysis of the Functional and Anatomical Sequelae of Penetrating Head Trauma

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An overview is presented of the multidisciplinary design, specific methods of motor and functional assessment, and selected preliminary data trends from the Vietnam Head Injury Study. This longitudinal study combines analyses of retrospective records with current, comprehensive inpatient examinations and investigates the anatomical and functional sequelae of penetrating head trauma in 700 Vietnam Veterans at an average of 14 years after injury. Preliminary data analysis of results from the first 160 subjects demonstrates good functional recovery despite large brain lesions. Motor abnormalities have persisted in 28 percent of the sample and are correlated with lesions involving the frontoparietal area of the cortex and the deep midline brain structures. Design concepts and long-term outcome trends will be useful to therapists in neurological rehabilitation. The study provides a model for health-team members interested in designs for longitudinal collection of outcome data.

Key Words: Head injuries; Outcome and process assessment (health care); War; Wounds, penetrating.

The functional outcome after head trauma continues to be the primary focus and long-term concern of the entire rehabilitation team of patient, family, and health-care professionals. Although outcome data after closed head injury have been reported in the pediatric1,2 and adult3-5 populations, the use of computerized tomography (CT) to correlate lesion site with long-term sensorimotor and functional sequelae following penetrating craniocerebral trauma has not been previously described.

This report presents the sample characteristics, methods, and preliminary motor and functional performance data from the Vietnam Head Injury Study (VHIS), an ongoing inpatient follow-up study of the long-term sequelae of penetrating head injuries incurred between the years 1967 and 1970 of the Vietnam Conflict. The Vietnam Head Injury Study analyzes the following sequelae 11 to 16 years after head injury: 1) anatomical deficits (Fig. 1); 2) long-term outcome in neurological, sensorimotor, cognitive, communicative, and perceptual function; and 3) interrelationships between location and extent of brain injury, sensorimotor and cognitive status, and ultimate functional impairment. The primary purpose of this presentation is to outline the study's interdisciplinary model and to detail the specific methods of the motor and functional performance examination. In addition, this report describes selected preliminary results, introduces characteristics of the identified lesions, and presents long-term outcome trends in the early stages of data analysis.

METHOD

Using experience gained by managing battlefield casualties during the Korean Conflict, Caveness developed a standardized registry form for documenting the site and extent of brain lesion, initial neurological status, and neurosurgical intervention of combat casualties.6 The VHIS evolved from this registry of 1,221 records completed by military surgeons in Vietnam.
TABLE 1

Multidisciplinary Assessment Categories

<table>
<thead>
<tr>
<th>Medical history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurologic physical examination</td>
</tr>
<tr>
<td>Computerized tomography</td>
</tr>
<tr>
<td>Skull radiography</td>
</tr>
<tr>
<td>Electroencephalography</td>
</tr>
<tr>
<td>Visual, auditory, and somatosensory evoked responses</td>
</tr>
<tr>
<td>Formal visual field testing</td>
</tr>
<tr>
<td>Audiology examination</td>
</tr>
<tr>
<td>Speech and language assessment and communication history</td>
</tr>
<tr>
<td>Neuropsychological testing and psychiatric history</td>
</tr>
<tr>
<td>Motor and functional performance assessment and rehabilitation history</td>
</tr>
</tbody>
</table>

...on veterans sustaining closed and penetrating head injuries.

Population

Excluding the veterans with closed head injury, the population from the registry under investigation was the remaining group of 1,133 Vietnam veterans (mean age at injury: 21.3 ± 3.4 years) with penetrating head trauma. Of this group, 700 consented to participate in the study. From a randomized list of 5,500 noninjured Vietnam veterans, a group of 225 were matched for age, date of service in Vietnam, and scores in cognitive testing (Armed Forces Qualification Test) taken on entry into the military. Of this matched group, 125 noninjured veterans consented to participate as controls for the study.

Data Collection

This preliminary report is based on a two-phase data collection process. Phase 1 involved a retrospective review and computer entry of data from military and VA medical records of the entire head injury registry population (1,221). Completed in 1979 at the National Institute of Neurological and Communicative Disorders and Stroke, National Institutes of Health, Bethesda, Maryland, the record review represented a mean follow-up time after head injury of 3.47 ± 2.62 years. From this Phase 1 data, multiple analyses of medical and surgical complications from combat-related head injuries have been reported.7-12

Phase 2 in the data collection process involves a comprehensive, one-week inpatient examination of the current medical and functional status of all subjects at an average of 14 years after injury. This ongoing clinical phase of investigation began at Walter Reed Army Medical Center, Washington, DC, in August 1981 and will end when the total sample of approximately 825 Vietnam Veterans has been tested (September 1984).

The transportation of subjects, and a family member if necessary, to the inpatient examination phase of the study was arranged through the US Air Force aeromedical evacuation system after a home visit and family interview conducted by an American Red Cross caseworker trained in the specific field work activities of the study. The American Red Cross Field Study was conducted to gather data on demographics, social history, and prevalence of seizure disorders in the family. The caseworker coordinated the travel arrangements to Walter Reed Army Medical Center and served as the local point of contact.

Multidisciplinary Design

The comprehensive inpatient data were collected by a team from the disciplines of neurology, neurosurgery, neuropsychology, neuroradiology, audiology, speech pathology, physical therapy, ophthalmology, and biostatistics. Table 1 outlines the general categories in the multidisciplinary assessment of the brain-injured subjects.

Motor and Functional Performance Methods

The physical therapist conducted a four-hour examination of the motor and functional abilities of
Table 2

Motor and Functional Assessments

<table>
<thead>
<tr>
<th>Block 1</th>
<th>Block 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2 hours)</td>
<td>(2 hours)</td>
</tr>
<tr>
<td>Functional assessment with equipment</td>
<td>Range of motion</td>
</tr>
<tr>
<td>Swallowing/cough control</td>
<td>Muscle tone, Part 1</td>
</tr>
<tr>
<td>Prehension level</td>
<td>Heterotopic ossification</td>
</tr>
<tr>
<td>Grip/pinch strength</td>
<td>Components of isolated movements</td>
</tr>
<tr>
<td>Perceptual screening</td>
<td>Upright control test</td>
</tr>
<tr>
<td>Purdue Pegboard test</td>
<td>Level of selective/synergistic motor control</td>
</tr>
<tr>
<td>Primitive reflex integration</td>
<td>Muscle tone, Part 2</td>
</tr>
<tr>
<td>Righting/equilibrium/protection reactions</td>
<td>Cognitive level</td>
</tr>
<tr>
<td>Observational/computerized gait analysis</td>
<td>Rehabilitation history</td>
</tr>
<tr>
<td></td>
<td>Four-hundred meter endurance walk (1/4 mile)</td>
</tr>
</tbody>
</table>

Fig. 2. Computerized gait analysis measuring step length, velocity, and swing and stance time using an instrumented walkway with accompanying microprocessor.14

The assessment was divided into 2 two-hour blocks on separate days and sequenced to minimize fatigue by ordering the subtests to allow changes in pace and body position (Tab. 2). (Data forms are available on request from the second author.)

The neurologist examined the sensory system to assess reaction to vibration, light touch, and superficial pain and to determine the presence of proprioception, stereognosis, graphesthesia, tactile extinction, and finger agnosia. Right-left discrimination and limb praxis were also analyzed by the neurologist. Although a comprehensive assessment of perceptual function was conducted by the neuropsychology staff, a screening of other perceptual functions (e.g., unilateral neglect of extremities and ability to cross midline) was included in the physical therapy battery. Oral motor control was examined in detail by the speech pathology staff, but swallowing control and cough function were assessed by the physical therapist.

The traditional, orthopedically-oriented, individual muscle strength examination was inappropriate to use with this population because the motor deficit after brain injury results in incoordination as well as muscle weakness. The procedures used in this study assessed the following areas in the functional behavior, motor control, and musculoskeletal categories.

1. Level of function (independent, supervised, assisted, dependent) with equipment in skills.
   a) Self-care: dress; eat; manage toileting; groom; bathe.
   b) Mobility:
      (1) Bed: roll; maneuver to sitting; sit without own arm support; stand at bedside.
      (2) Wheelchair: manage brakes and foot pedals; propel for distance of 3.1 m (10 ft) and return.
      (3) Ambulation: on level surfaces; on irregular terrain; on 16 stairs with and without rail or ambulation aid, rise from floor with and without ambulation aid or furniture; cross street safely.
      (4) Driving an automobile.
   (5) Using public transportation.
   c) Independent living: strip/make bed; wash/dry clothes; prepare light meal (1 hot item)/clean up; prepare full meal (2 hot items)/clean up; locate emergency number in telephone book; dial emergency phone number.
   d) Community living: write legal signature; write check/record transaction; make purchase/calculate change; manage checking account; participate in community outing; maintain salaried employment.

2. Swallowing control: tolerate regular/soft diet; require gastrostomy feeding; presence of gag reflex; swallowing trial with 5cc water.

4. Quality, endurance, and functional level in ambulation.
   a) Observational gait analysis: trunk, pelvis, hip, knee, ankle, and toes in swing and stance phases.
   b) Functional ambulation profile (modified and adapted from a personal communication with J. Tucker, Kessler Institute for Rehabilitation, West Orange, NJ) using a computerized gait mat—a rubberized walkway imbedded with ribbon switches connected to a control box containing a microprocessor with memory and digital circuitry (Fig. 2). Individual values, means, and standard deviation were determined for bilateral step length, step time, stance time, swing time, and double stance time. Average velocity, stride length, and cadence were calculated.

5. Upper extremity control.
   a) Level of prehension skill level: demonstration of palmar, cylindrical, and lateral-pincer and tip-pincer grasp/release.
   b) Level of functional use: summary of skill level demonstrated during prehension, motor, and functional examination (selective normal function, functional assist only in two-handed activities, stabilizer of objects against table or body, or nonfunctional).
   c) Strength: Grip measurements made with a hand dynamometer; lateral and tip pinch measurements made using a pinch gauge. Normative data from the Sister Kenny Institute, Minneapolis, MN used for comparison.
   d) Timed, unilateral and bilateral manipulative skills: The Purdue Pegboard Test.

6. Perceptual screening: unilateral disregard of extremities; crossing of midline with upper extremities.

7. Predominant level of selective or synergistic motor control in all extremities: selective movement independent of synergy; combination of selective and synergistic movement; or synergistic movement only.

8. Measurement of patterned strength in lower extremities using Upright Control Test from Rancho Los Amigos Hospital: grading system of synergy strength (week, moderate, or strong) at hip, knee, and ankle.

9. Analysis of components of active, isolated movement at each major joint in all extremities: modified from the analysis of movement protocol by Bobath for adult hemiplegics (Fig. 3).

10. Measurement of range of motion (ROM) in all joints including documentation of joints reported to be painful with ROM.

11. Assessment of the type and distribution of muscle tone (normal, hypotonic, hypertonic) in all muscle groups.
   a) Part 1: measured in supine position during ROM assessment by
      (1) palpation of muscle belly consistency;
      (2) presence or absence of resistance to passive ROM; and
      (3) presence or absence of resistance of muscle group to quick stretch in the lengthened position.
   b) Part 2: recorded after analysis of components of isolated movement in supine, sitting, and standing positions to identify the hypertonic muscle groups interfering with selective movement.


13. Analysis of neck righting, trunk equilibrium, and protective reactions of arms modified from the adult hemiplegia protocol by Bobath (Fig. 4).
   a) Independence in maintaining static positions of prone on forearms, sitting, quadruped, half-kneeling, and standing.
   b) Neck righting and trunk equilibrium reactions during facilitated (displacement of balance lat-
Fig. 4. Analysis of neck righting, trunk equilibrium, and protective reactions by lateral displacement of subject’s balance.

erally by examiner) unilateral weight transfer in positions outlined above.

c) Lateral protective reactions of arms in sitting and standing positions: weight-bearing contact recorded for hand or forearm.


a) Asymmetrical tonic neck reflex in quadruped position.

b) Tonic labyrinthine reflex in prone and supine positions.

15. Screening of cognitive level related to functional activities: Level of Cognitive Functioning (8 stages) from Rancho Los Amigos Hospital.

16. History of initial, interim, and current rehabilitation programs derived from subject and family interviews and Phase I medical record review.

After the completion of the above protocol, the significant findings and functional limitations were summarized for all subjects. Specific recommendations for adaptive or ambulatory equipment modifications, spasticity and pain management, short-term rehabilitation trials, and community support group referrals were made as indicated for selected subjects. The protocol summary and recommendations were incorporated into a hospital narrative summary prepared by the neurologist and forwarded to each subject upon his return home.

PRELIMINARY RESULTS

Data collected on the first 160 subjects examined in Phase 2 were analyzed in a preliminary fashion.

Chi-square comparisons of age; intelligence; lesion site; and impairment in consciousness, vision, hearing, speech, memory, cognition, and motor behavior were made to determine if a sampling bias existed between this initial sample of 160 and the total study sample. No statistically significant sampling bias was demonstrated.

Lesion

Analysis of CT scan data revealed that 78 percent of subjects had a single brain lesion, 13 percent had two separate lesions, and 6 percent had three or more separate brain lesions. Three percent of CT scans were obscured by artifact secondary to metal cranioplasty or retained metal fragments. Twenty-two percent of subjects had lesions confined to only one lobe of the brain and 78 percent had multiple lobe lesions. Lesions crossed the midline of the brain in 48 percent of those with multiple lobe injuries. Distribution of lesion by brain site is presented in Table 3. Seventy-two percent were conscious at the time of their initial neurologic exam, an average of six hours after injury.

**TABLE 3**

<table>
<thead>
<tr>
<th>Lesion Sites</th>
<th>No. and %①</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal lobe</td>
<td>90 (66)</td>
</tr>
<tr>
<td>Temporal lobe</td>
<td>66 (48)</td>
</tr>
<tr>
<td>Parietal lobe</td>
<td>55 (40)</td>
</tr>
<tr>
<td>Occipital lobe</td>
<td>26 (19)</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>12 (9)</td>
</tr>
<tr>
<td>Ventricles</td>
<td>88 (64)</td>
</tr>
<tr>
<td>Deep midline structures</td>
<td>67 (49)</td>
</tr>
<tr>
<td>Basal ganglia</td>
<td>49 (36)</td>
</tr>
<tr>
<td>Brain stem</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

① Contains single lobe lesions and multiple lobe lesions crossing and not crossing midline.

**TABLE 4**

Frequency of Contracture and Pain in Joints Accompanied by Hypertonic Musculature (N = 160)

<table>
<thead>
<tr>
<th>Location</th>
<th>No. with Hypertonus</th>
<th>No. (%) with Restricted Passive Motion</th>
<th>No. (%) with Restricted Motion and Associated Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>5</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Trunk</td>
<td>18</td>
<td>13 (72)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Shoulder</td>
<td>33</td>
<td>25 (76)</td>
<td>17 (52)</td>
</tr>
<tr>
<td>Elbow</td>
<td>34</td>
<td>10 (29)</td>
<td>5 (15)</td>
</tr>
<tr>
<td>Wrist</td>
<td>31</td>
<td>4 (13)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Hand</td>
<td>31</td>
<td>8 (26)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Hip</td>
<td>35</td>
<td>14 (39)</td>
<td>4 (11)</td>
</tr>
<tr>
<td>Knee</td>
<td>37</td>
<td>14 (38)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Ankle</td>
<td>35</td>
<td>25 (71)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>
Motor Performance Characteristics

Motor abnormalities were present within the first month after injury in 38 percent of the cases and in 31 percent at reexamination approximately 3.5 years later (Phase 1). Eleven to 16 years after injury, 28 percent were found to have motor deficits in the following distribution: hemiplegia, 20 percent; monoplegia, 3 percent; involuntary movement disorder, 3 percent; and triplegia, 2 percent. Preliminary association of paresis in Phase 2 with lesion site was demonstrated with the parietal lobe (probably the frontoparietal junction or motor strip), \( \chi^2 = 33.64; df = 1; p < .0001 \) and with the deep midline brain structures, (basal ganglia, internal capsule, thalamus, corpus callosum), \( \chi^2 = 23.31; df = 1; p < .0001 \). Muscle hypertonus was present in 23 percent of subjects (82% of those with motor deficits). Hypertonus interfered with function in 16 percent and did not interfere in 7 percent. The prevalence of contracture, defined as a restriction in passive ROM greater than 10 degrees, in joints surrounded by hypertonic muscle groups is presented in Table 4.

Functional Performance

Table 5 presents the frequency of complete independence in functional activities within the entire sample and in only those subjects with selective movement impairment. Swallowing control was functional with a regular diet tolerated in all subjects. Four subjects (2.5%) were not ambulatory; two demonstrated severe involuntary movements (one choreoathetoid and one ataxic) and two were triplegic with severe hypertonus.

Fifty percent were employed in permanent full-time positions, and six percent worked on a part-time basis only. Forty-four percent were not employed at the time of their examination, and 19 percent had never been employed after their head injuries.

Table 6 outlines the functional use of the upper extremity in subjects demonstrating motor deficits with and without impairments in sensation and in those with sensory impairment without motor deficits. Motor deficits only, defined as weakness or weakness and hypertonus, occurred in 4 percent of the subjects. Sensory impairment only, defined as any abnormality in the sensory examination, occurred in 21 percent. Sensory impairment occurred simultaneously with motor deficit in 18 percent of all subjects.

DISCUSSION

In view of the ongoing nature of the VHIS and because fewer than one-quarter of the subjects have completed the Phase 2 inpatient examinations, caution must be taken in interpreting data at this time. These preliminary results introduce the long-term outcome of penetrating head injuries sustained by young healthy adults.

The sample demonstrates a high incidence of multiple lobe lesions (78%) with approximately one-half of multiple lobe lesions extending from one hemisphere to the other. A large percentage (49%) of subjects with lesions extending to and including the deep midline structures of the brain was evident. The anatomical picture that is emerging in most cases is one of a very large focal lesion extending deep toward the midline and, in many instances, involving both cerebral hemispheres. The high-level performance in functional activities demonstrated by most subjects (Tab. 5), despite large lesions, clearly indicates a remarkable degree of functional recovery. Penetrating head injury occurs with less frequency than closed head injury in the civilian population. Some distinct differences are emerging between the penetrating and closed-head-injury groups with respect to lesion type and outcome. In contrast to the focal brain lesions in penetrating injuries, CT scan analysis of the closed injury population often reveals more diffuse brain injury.
damage that is characterized by evidence of early cerebral edema, cerebral atrophy, and hydrocephalus.\textsuperscript{31, 22}

Abnormalities of the motor system that occurred immediately after injury have shown a progressive, though slight, trend toward complete recovery of normal motor strength and coordination beyond the 3.5 year Phase I follow-up. The pattern and speed of recovery in those who subsequently regained all motor faculties are of intense interest. Correlations between immediate postinjury neurologic status, lesion anatomy, premorbid and postmorbid intelligence, and behavioral and perceptual sequelae of recovered and nonrecovered groups are planned to establish the most meaningful clinical predictors of motor recovery.

Functional use of the upper extremity with pure motor and pure sensory impairment demonstrates complete selective control and normal use in up to 70 percent of subjects exhibiting these isolated deficits (Tab. 6). In addition, nearly 50 percent of those with sensorimotor deficit have at least “assistive” function of the impaired upper extremity. Full neurologic recovery of sensory and motor faculties appears not to be as crucial as expected when functional use in daily activity is considered the optimal outcome.

Functional independence in most activities, from self-care to community living, appears to be a frequent outcome in the majority of the sample studied, including the subgroup with persistent, selective motor-control abnormalities. In most activities tested, over 50 percent of subjects without selective motor control were functionally independent. The adaptations to motor disability made by those without selective control suggest a strong desire in the young adult to develop compensatory mechanisms and alternative abilities that can be used to achieve independent living. A comparison of motor outcome from our study to other groups with head injury showed a lower incidence of self-care dependence (15%) and a lower incidence of nonambulatory status (2.5%) in young adults after penetrating brain injury than reported from pediatric\textsuperscript{2} or adult\textsuperscript{2, 4} groups with closed head injury. The presence of ataxia (3%) in our sample was less frequent than reported from closed-head injury studies\textsuperscript{3–4} (pediatric, 60%; adult, 9%). Similarly, the occurrence of hemiplegia (20%) was lower than in pediatric (47%)\textsuperscript{2} and adult (49%) subjects\textsuperscript{3–4} with closed head injuries.

Musculoskeletal examination of subjects revealed that contractures are frequently associated with muscle hypertonus. Table 4 lists the frequency and location of contractures as a probable complication associated with increased muscle tone. Restrictions in passive motion appear with a frequency of more than 70 percent in the trunk, shoulder, and ankle. The prevalence of decreased motion accompanied by pain was most apparent in the shoulder. The occurrence of contracture and pain about the wrist and fingers was surprisingly infrequent in light of the fact that few subjects were participating in supervised exercise programs.

Clinical implications of the musculoskeletal findings are highly speculative at this time. Future analysis is planned for grouping those subjects with associated hypertonus into clearly-defined subgroups with similar degree of contracture, severity of hypertonus, quality of selective movement, functional use, and sensory abnormality. The predictability and functional significance of musculoskeletal complications may be established later after additional data collection. Findings reported here are based on only 23 percent (160) of the total VHIS participants (700). Numerous research questions and hypotheses developed by each discipline within the study are only beginning to be tested, and preliminary trends are therefore subject to cautious interpretation. More detailed reports will be forthcoming as increased numbers of participants are examined, and statistical analysis is applied to the data.

**SUMMARY**

The methods of the VHIS and a preliminary report of the motor behavior and functional outcome of 160 subjects with penetrating head injuries incurred during the Vietnam Conflict have been presented. Preliminary analyses of data show that extensive brain injuries from penetrating missile wounds are associated with unexpectedly high levels of function in subjects 11 to 16 years postinjury.

After the completion of data collection in 1984 and subsequent analyses of data from the sample of approximately 825 subjects, prognostic profiles of anticipated functional level related to the anatomical deficit (location and volume of lesion) on CT scan will be developed. These profiles will assist rehabilitation teams during the acute care period to plan rehabilitation strategies and provide counseling on potential long-term functional outcome.

The study will identify physical, cognitive, communicative, perceptual, and psychological factors interfering with independent living and employment. In addition to providing guidelines to the military medical community on future management of battlefield casualties involving the central nervous system, the VHIS offers a multidisciplinary model for longitudinal collection of data to study the sequelae of neurological injuries.

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REFERENCES