MMR MILITARY MEDICAL RESEARCH

RESEARCH Open Access

The value of neurocognitive testing for acute outcomes after mild traumatic brain injury

Latha Ganti[1*], Yasamin Daneshvar[1], Sarah Ayala[1], Pratik Shashikant Patel[1], Aakash N. Bodhit[1], Keith R. Peters[1]

Abstract

Background: Traditionally, neurocognitive testing is performed weeks to months after head injury and is mostly performed on patients who continue to have symptoms or difficulties. In this study, we sought to determine whether these tests, when administered acutely, could assist in predicting short-term outcomes after acute traumatic brain injury (TBI).

Methods: This is an IRB-approved prospective study of adult patients who came to the emergency department of our Level-1 trauma center with TBI. Patients were enrolled prospectively after providing written informed consent and underwent three separate neurocognitive tests: the Galveston Orientation Amnesia Test (GOAT), the Rivermead Post-Concussion Survey Questionnaire (RPCSQ), and the Mini Mental Status Examination (MMSE).

Results: A lower GOAT score was significantly associated with hospitalization (P=0.0212) and the development of post-concussion syndrome (PCS) at late follow-up (P=0.0081). A higher RPCSQ score was significantly associated with hospital admission (P=0.0098), re-admission within 30 days of discharge (P=0.0431) and evidence of PCS at early follow-up (P=0.0004). A higher MMSE score was significantly associated with not being admitted to the hospital (P=0.0002) and not returning to the emergency department (ED) within 72 hours of discharge (P=0.0078). Lower MMSE was also significantly associated with bleeding or a fracture on the brain CT (P=0.0431).

Conclusions: While neurocognitive testing is not commonly performed in the ED in the setting of acute head injury, it is both feasible and appears to have value in predicting hospital admission and PCS. These data are especially important in terms of helping patients understand what to expect, thus, aiding in their recovery.

Key words Neurocognitive testing; Mild traumatic brain injury; Treatment outcome

Introduction

In the United States, 1.7 to 3.8 million cases of traumatic brain injury (TBI) occur each year[1]. Because of the highly variable mechanisms of TBI, it is a common discharge diagnosis in the emergency department (ED)[2]. Despite the high incidence of TBI, acute outcomes following TBI are difficult to predict due to the differences in individual responses to trauma and other contributing factors that are unique to individuals. Coupled with the lack of evidential correlation between TBI and acute outcomes, determining acute outcomes requires an approach that is as unique to the individual as it is to the injury itself. To overcome some of the unknown factors associated with TBI recovery, this study examined how early neurocognitive testing can be used to determine connections between injury and outcome.

Traditionally, neurocognitive tests are administered by neuropsychologists for patients who continue to have symptoms or difficulties weeks to months after head injury. Ideally, the results of a neurocognitive test performed prior to injury would be available for comparison with the post-injury neurocognitive test results. However, considering the nature of emergency medicine, control test results are unlikely to be available. The neurocognitive tests administered in this study provide a "new baseline" that can be used to determine whether neurocognitive testing has merit as an acute predictive indicator of acute effects and outcomes following TBI.

Methods

This study examined a subset of patients from a prospective cohort study that spanned a 10-month period from August 2012 to May 2013[3,4]. The study was conducted at a level one trauma center in the southeastern United States. The patients were screened in the ED. Subjects were considered eligible if they were 18 years of age or older and had sustained a head injury of any kind within 24 hours of presentation to the emergency department. Pregnant women, children, and prisoners were excluded.

*Correspondence: lathagantimd@gmail.com; latha.ganti@va.gov
[1]OrlandoVeterans Affairs Medical Center, Orlando, Florida 32827, USA

Patients were enrolled prospectively after providing written informed consent and underwent 3 separate neurocognitive tests: the Galveston Orientation Amnesia Test (GOAT)[5], the Rivermead Post-Concussion Survey Questionnaire (RPCSQ)[6,7], and the Mini Mental Status Examination (MMSE)[8,9]. The GOAT is a 20-question instrument (Appendix 1) that is scored from 0 to 100. The RPCSQ is a 16-question instrument that examines post-concussion symptoms rated by the patient according to the increase in their frequency compared with premorbid levels. The total score is calculated based on 2 domains (cognitive and emotional-somatic) and ranges from 0 to 72. The questionnaire asks the sufferer to assess the following symptoms: headaches, feeling of dizziness, nausea and/or vomiting, hyperacusis, sleep disturbance, fatigue, tiring more easily, irritability, being easily angered, feeling depressed or tearful, feeling frustrated or impatient, forgetfulness, poor memory, poor concentration, taking longer to think, blurred vision, light sensitivity, double vision, and restlessness (Appendix 2).

The MMSE contains six domains of cognition: orientation, registration of new information, attention and calculation, recall, language and visuospatial construction (Appendix 3). The MMSE score ranges from 0 to 30. Independent variables included raw scores on each of these tests, and dependent variables included hospital admission, development of post-concussion syndrome, and 30-day readmission.

Demographic information was collected directly from the patient prior to discharge from the emergency department using standardized instruments. Head injury severity was classified using the Glasgow Coma Scale, with a GCS score of 13-15 indicating mild head injury. The post-injury symptoms that were collected included loss of consciousness (LOC), the duration of the LOC, alteration of consciousness (AOC), posttraumatic amnesia (PTA), seizure, vomiting, and headache. An AOC was considered to have occurred if the patient reported feeling dazed or confused or having difficulty thinking or if the neurologic exam revealed a decreased mental status. Data regarding the mechanism of the injury, including a fall, traffic accident, sports injury, and assault, were also collected. Two phone follow-ups were conducted after discharge, one at 3-15 days (termed early follow up) and one at 30-45 days (termed late follow up; Appendix 4). Patients were asked whether they had any symptoms suggestive of post-concussion syndrome (PCS), including headache, vomiting, dizziness, tinnitus, sensitivity to light/noise, numbness/tingling, blurred vision/diplopia/flashing lights, drowsiness, fatigue/lethargy, sadness/depression, nervousness/irritability, difficulty concentrating or remembering, sleeping problems, and feeling "slowed down," "in a fog" or "dazed." A positive response to any of these questions was considered to indicate the presence of PCS. Outcome variables included CT abnormality, hospital admission, return visit to the ED within 72 hours of discharge[10], readmission to the hospital within 30 days of discharge, and presence of PCS at early or late follow-up.

Data were entered into our Clinical and Translation Science Institute's REDCap (Research Electronic Data Capture) database. REDCap is a secure, web-based application designed to support traditional case report form data capture. Statistical analyses were performed using JMP 10 for Mac. Normally distributed variables are presented as the means and standard deviations, while skewed variables are reported as medians and interquartile ranges (IQR).

Results

The study cohort included 118 patients, and 55% were male. The median age of the patients was 30.5 years (IQR 21-50 years, range 18-95 years). The racial composition of the cohort was 72% white, 19% black, 6% Hispanic, 2% Asian, and 2% other, which is consistent with our county's demographic make-up.

The following mechanisms of injury were reported when the patients presented to the ED: fall, 43%; motor vehicle crash (MVC), 52%; assault or head injury caused by being struck on the head with an object, 3%; and head injury caused by a sports activity, 2%.

In terms of alcohol consumption, 66% of patients reported that they drank alcohol in general. Of these, 13% consumed alcohol within 6 hours of the injury, 18% within 6-18 hours of the injury, and 69% more than 24 hours prior to the head injury. At the time of emergency department evaluation, 13% of patients were intoxicated with alcohol, and overall 7% had a urine dipstick positive for amphetamines (3%), cocaine (3%), cannabis (3%), and opiates (6%).

Forty-five percent of patients experienced LOC, and 60% of patients reported alteration of consciousness. Thirty-six percent of patients experienced post-traumatic amnesia, and it was followed by anterograde PTA in 91% of these patients and retrograde PTA in 30% of these patients. Eight percent of patients reported vomiting, and 59% reported a headache associated with their head injury.

Seventy-nine percent (n=91) of patients underwent brain computed tomography (CT), and an abnormality was found in 30% (n=28) of these patients. The CT abnormalities included soft tissue swelling (14%), skull fracture (2%), and bleeding (5%). No patients underwent surgical intervention for their

head injury.

The median GOAT score was 99, with an IQR of 97.5-100 and a range of 84-100. A lower GOAT score was significantly associated with hospitalization (P=0.0212) and evidence of PCS at the early follow-up (P=0.0081, R^2=11.9%). Figure 1 summarizes the frequency of each outcome by GOAT score.

The median RPCSQ score was 12, with an IQR of 5-24.5 and a range of 0-61. A higher RPCSQ score was significantly associated with hospital admission (P=0.0098), re-admission to the hospital within 30 days of discharge (P=0.0431) and

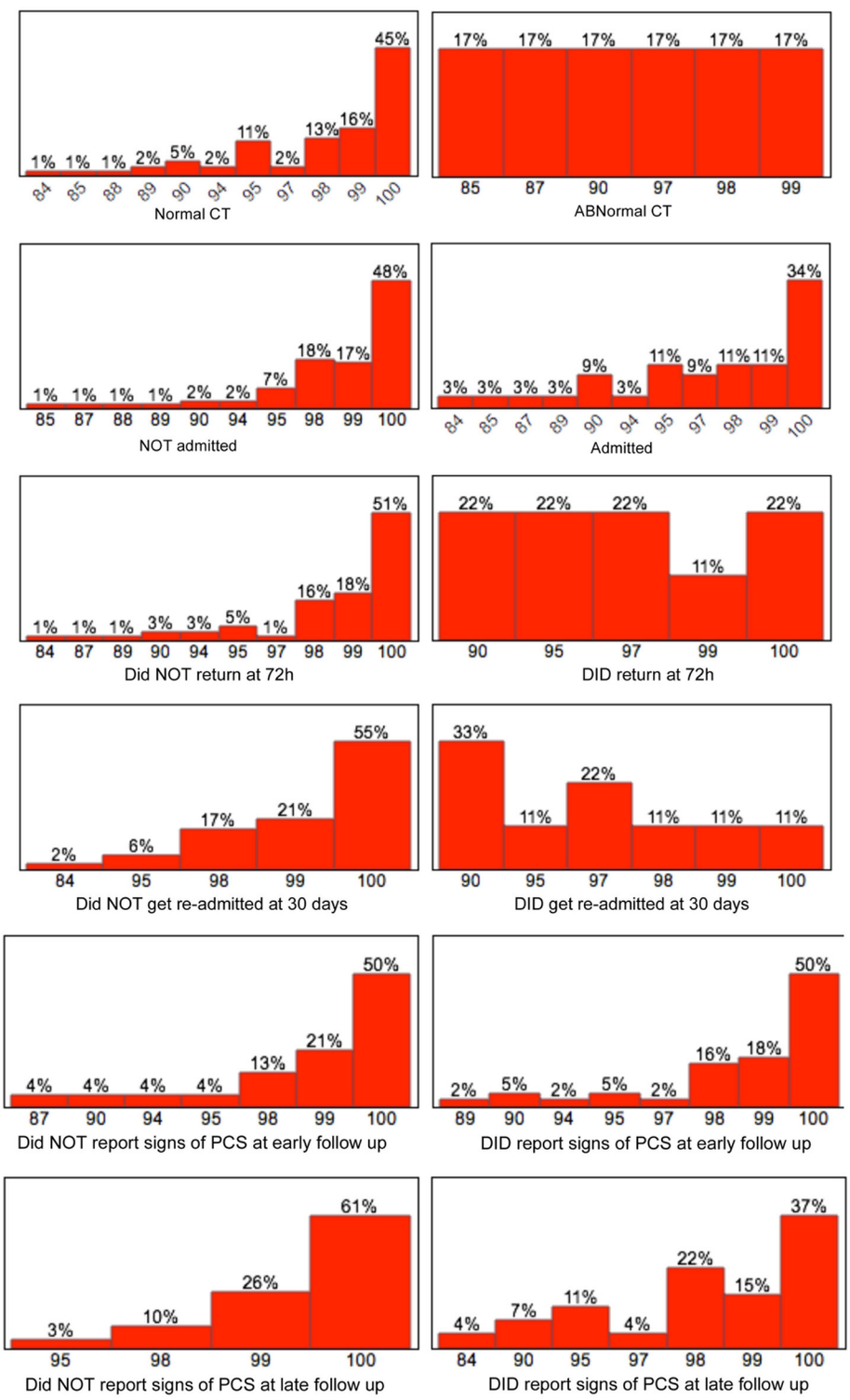

Figure 1. Frequency of outcomes by GOAT score.

evidence of PCS at early follow-up (P=0.0004, R^2=17.2%). In addition, a higher RPCSQ score was significantly associated with a report of LOC (P=0.0470). Figure 2 summarizes the frequency of each outcome by RPCSQ score.

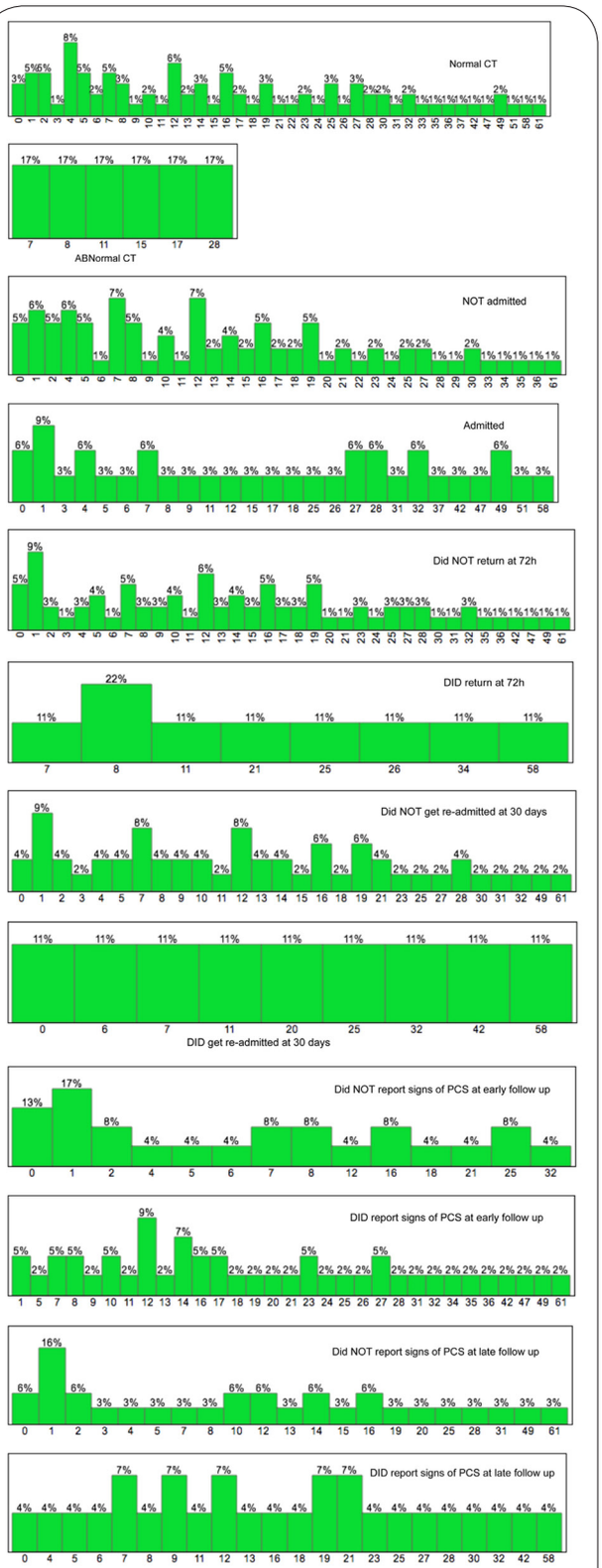

Figure 2. Frequency of outcomes by RPCSQ score.

The median MMSE score was 28, with an IQR of 26-29 and a range of 19-30. Having a higher MMSE score was significantly associated with not being admitted to the hospital (P=0.0002) and not returning to the ED within 72 hours of discharge (P=0.0078). In addition, younger patients were more likely to present with a lower MMSE score (P=0.0356). A lower MMSE score was also significantly associated with bleeding or a fracture on the brain CT (P=0.0431). Figure 3 summarizes the frequency of each outcome by MMSE score. Figure 4 summarizes the associations of the three neurocognitive tests with patient signs and outcomes.

Discussion

Neurocognitive testing for mild TBI in the emergency department setting is a relatively novel concept. Subjects in this cohort underwent neurocognitive testing during the course of their emergency department stay, which was within minutes to hours of their head injury. Neurocognitive tests are traditionally performed weeks to months after head injury, are usually administered by neuropsychologists and are mostly administered to patients who continue to have symptoms or difficulties after acute treatment.

The current belief is that testing may be unreliable during the hyperacute phase because the patient's mTBI is too "fresh," and too many other evaluations are being performed for the patient to be able to undergo neurocognitive testing. However, a more probable explanation for the lack of performance of neurocognitive testing in the ED for patients with TBI is that the evaluation of mTBI in the emergency department is relatively new, with most EDs performing little more than a brain CT, if even that is performed. The concept that emergency physicians rather than neuropsychologists can perform neurocognitive testing and that it can be performed in a busy emergency department is relatively novel.

To date, only a handful of studies have investigated the utility of neurocognitive testing in the hyperacute phase of mild traumatic brain injury. In a study of adults presenting to the ED with mTBI, the Standardized Assessment of Concussion (SAC) was administered to 66 subjects whose CT was positive for an intracranial injury[11]. The SAC is a sports sideline evaluation tool designed to determine whether a concussion has occurred and is composed of brief subtests of orientation, immediate recall, concentration, and delayed recall. The study found that the SAC score did not correlate with a positive CT scan. A study of children 10-17 years of age with and without mTBI showed that neurocognitive function, as tested in the ED using the Children Orientation and Amnesia Test (COAT), was more than 2 standard deviations lower in the group with mTBI

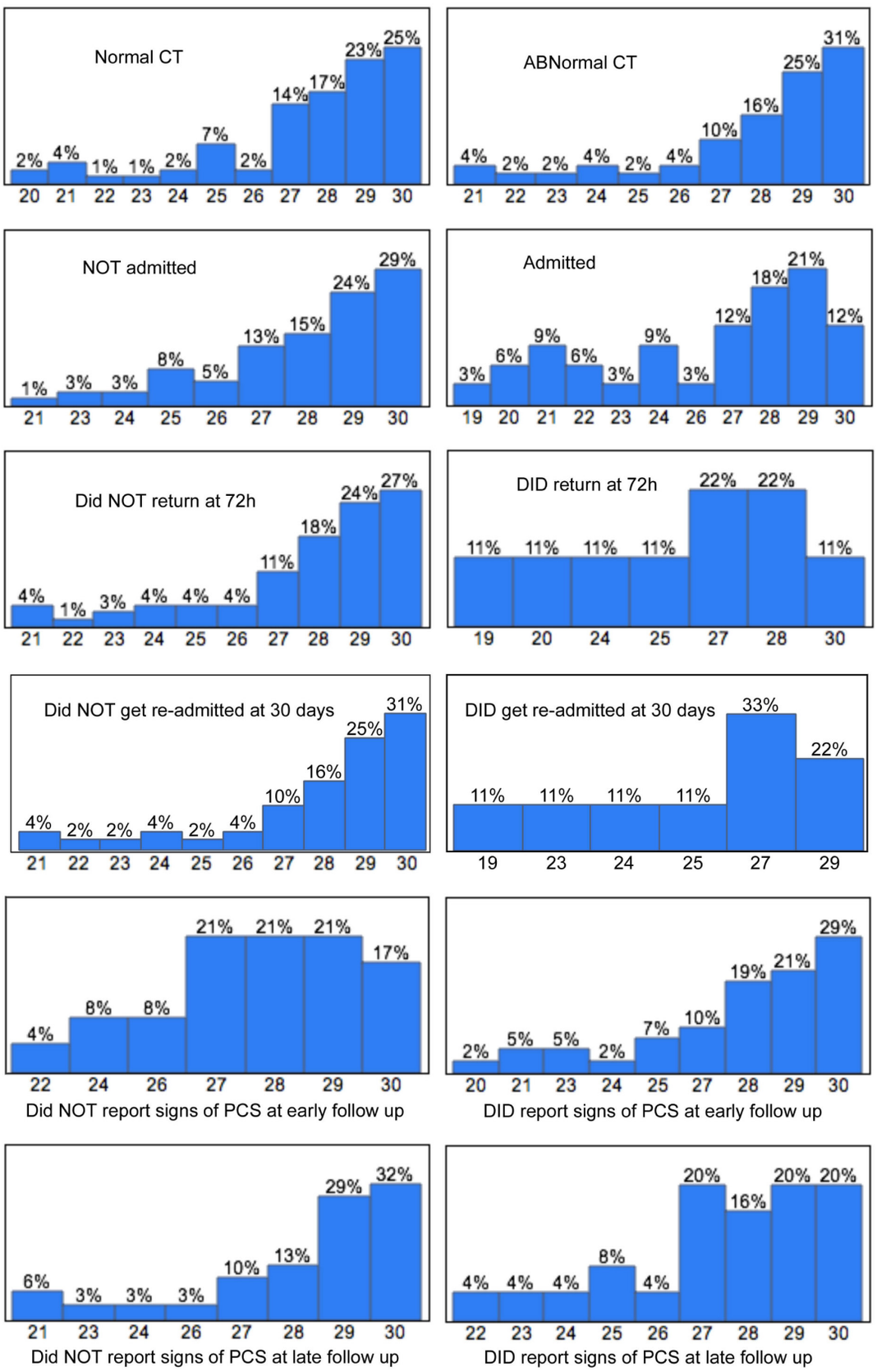

Figure 3. Frequency of outcomes by MMSE score.

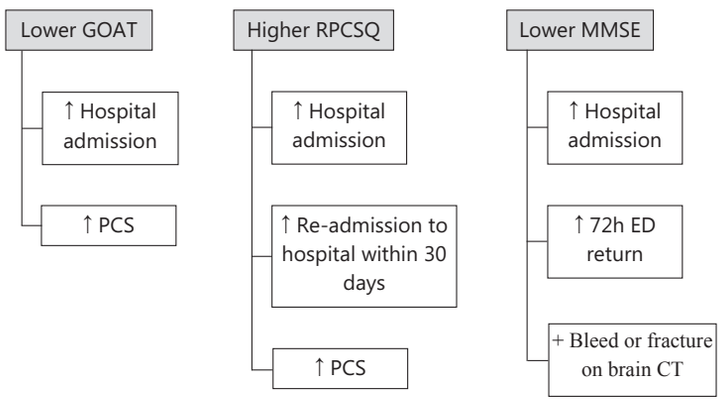

Figure 4. Summarizes the associations of the three neurocognitive tests with patient signs and outcomes.

compared to the controls, suggesting significant amnesia in the patients with mTBI[12]. A prospective cohort study of patients 11 to 17 years of age presenting to the ED within 12 hours of a head injury found that while there was no correlation for traditional concussion grading, for the neurocognitive domains of verbal memory, processing speed, and reaction time, there was a significant correlation between ED and follow-up scores trending toward clinical improvement[13]. The authors concluded that immediate neurological assessment in the ED can predict neurocognitive deficits at follow-up and has potential for individualizing management and testing different therapeutic interventions. A similar study in adults had the same findings: compared with non–head-injured patients, ED mild traumatic brain injury patients demonstrated subtle but discernible neurocognitive deficits[14]. The current study builds on these findings by including additional neurocognitive tests in the ED and examining the following outcomes in addition to CT findings and the development of PCS: hospital admission, 72 hour return to the ED, and hospital re-admission within 30 days of discharge.

Strengths and limitations

The strengths of the current study include its prospective design, the level of detail of the information obtained for each patient, the capturing of injury characteristics within the hyperacute period of the injury, i.e., within 24 hours for the entire cohort and within 12 hours for the majority of patients. The limitation of this study is that it was conducted at a single institution; thus, the patient population may have had unique characteristics. Therefore, the findings of this study may not be externally generalizable to populations that differ substantially from that of this study. However, the purpose of this paper was to demonstrate that neurocognitive testing is feasible in the ED and yields some potentially useful clinical information; therefore, the specific demographics of age and race may not be pivotal.

Abbreviations

AOC: Alteration of consciousness; COAT: Children Orientation and Amnesia Test; CT: Computed tomography; ED: Emergency department; GOAT: Galveston Orientation Amnesia Test; IQR: Interquartile ranges; LOC: Loss of consciousness; MMSE: Mini Mental Status Exam; MVC: Motor vehicle crash; PCS: Post-concussion syndrome; PTA: Posttraumatic amnesia; REDCap: Research Electronic Data Capture; RPCSQ: Rivermead Post-Concussion Survey Questionnaire; SAC: Standardized Assessment of Concussion; TBI: Traumatic brain injury

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

LG, ANB, PSP, and YD conceived the study. LG, ANB, PSP, SA and YD collected the data. ANB, YD and LG performed the statistical analyses, and PSP and SA cross-checked the data. LG and KRP supervised the conduct of the research and data collection. LG drafted the manuscript, and all authors contributed substantially to its revision. All authors read and approved the final manuscript.

Acknowledgement

This work was supported by an endowment from The Toral Family Foundation, 13131 SW 19th Street, Davie, Florida 33325, USA (toralfamilyfoundation.org).

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Appendix 1. The Galveston Orientation and Amnesia Test (GOAT) developed by Harvey S.

Question	Error Score	Notes
What is your name?	-2 ____	Must give both first name and surname.
When were you born?	-4 ____	Must give day, month, and year.
Where do you live?	-4 ____	Town is sufficient.
Where are you now:		
(a) City	-5 ____	Must give actual town.
(b) Building	-5 ____	Usually in hospital or rehab center. Actual name necessary.
When were you admitted to this hospital?	-5 ____	Date.
How did you get here?	-5 ____	Mode of transport.
What is the first event you can remember after the injury?	-5 ____	Any plausible event is sufficient (record answer)
Can you give some detail?	-5 ____	Must give relevant detail.
Can you describe the last event you can recall before the accident?	-5 ____	Any plausible event is sufficient (record answer)
What time is it now?	-5 ____	-1 for each half-hour error.
What day of the week is it?	-3 ____	-1 for each day error.
What day of the month is it? (i.e., the date)	-5 ____	-1 for each day error.
What is the month?	-15 ___	-5 for each month error.
What is the year?	-30 ___	-10 for each year error.
Total Error:		
Total Actual Score = (100 - total error) = 100 -____ = Can be a negative number.		
76-100 = Normal / 66-75 = Borderline / <66 = Impaired		

Levin, Ph.D., Vincent M. O'Donnell, M.A., & Robert G. Grossman, M.D can be administered daily. A score of 78 or more on three consecutive occasions is considered to indicate that post-traumatic amnesia (PTA) has resolved. The instrument is freely available here: http://www.utmb.edu/psychology/Adultrehab/GOAT.htm.

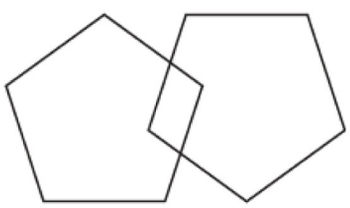
Appendix 2. The Rivermead Post-concussion Symptom Questionnaire (RPSQ).

For each symptom, circle the number which is closest to subject's answer: 0 = Not Experienced at All; 1 = No More of a Problem Than Experienced Before the Accident; 2 = A Mild Problem; 3 = Moderate Problem; and 4 = A Severe Problem.					
Somatic					
Headaches	0	1	2	3	4
Feelings of Dizziness	0	1	2	3	4
Nausea and/or Vomiting	0	1	2	3	4
Noise Sensitivity (Easily Upset by Loud Noises)	0	1	2	3	4
Sleep Disturbances	0	1	2	3	4
Fatigue (Tiring More Easily)	0	1	2	3	4
Blurred Vision	0	1	2	3	4
Double Vision	0	1	2	3	4
Light Sensitivity (Easily Upset by Bright Lights)	0	1	2	3	4
Total Somatic Score					
Emotional					
Restlessness	0	1	2	3	4
Being Irritable or Easily Upset or Angered	0	1	2	3	4
Feeling Depressed or Tearful	0	1	2	3	4
Feeling Frustrated or Impatient	0	1	2	3	4
Total Emotional Score	0				
Cognitive					
Forgetfulness or Poor Memory	0	1	2	3	4
Poor Concentration	0	1	2	3	4
Taking Longer to Think	0	1	2	3	4
Total Cognitive Score					
Total RPQ Score					

Reproduced from Springer Science + Business Media: King NS, Crawford S, Wenden FJ, Moss NE, Wade DT. The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol. 1995; 242: 587-92.

Appendix 3. The Mini Mental Status Examination (MMSE).

Maximum	Score	
		Orientation
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we (state) (country) (town) (hospital) (floor)?
		Registration
3	( )	Name 3 objects: 1 second to say each. Then ask the patient all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials _____
		Attention and Calculation
5	( )	Serial 7's. 1 point for each correct answer. Stop after 5 answers. Alternatively spell "world" backward.
		Recall
3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct answer.
		Language
2	( )	Name a pencil and watch.
1	( )	Repeat the following "No ifs, ands, or buts"
3	( )	Follow a 3-stage command: "Take a paper in your hand, fold it in half, and put it on the floor."
1	( )	Read and obey the following: CLOSE YOUR EYES
1	( )	Write a sentence.
1	( )	Copy the design shown.



_____ Total Score

ASSESS level of consciousness along a continuum _____

Alert Drowsy Stupor Coma

"MINI-MENTAL STATE." A PRACTICAL METHOD FOR GRADING THE COGNITIVE STATE OF PATIENTS FOR THE CLINICIAN. *Journal of Psychiatric Research*, 12(3): 189-198, 1975. Used by permission.

Appendix 4. Phone script for telephone follow-up.

Subject #: _____

PHONE FOLLOW-UP # 1 (3-15 days)
PHONE FOLLOW-UP # 2 (30-45 days)

Date: _____ Time: _____ Interviewer's name: _____

Hello, this is _____calling from Center for Brain Injury & Research. May I speak with Mr./Mrs./Miss _____?
As part of your consenting to be in the research study, I'm contacting you as a part of the follow-up. Is it okay if I take few minutes of your time to ask following questions about your recent head injury?

Did you return to Emergency Department within 72hrs of last ED visit? O Yes O No

Are you taking all medications as prescribed on discharge from ED? O Yes O No

Have you started any new medications since discharge from ED? O Yes O No
If "Yes", please mention name of medications:_____

Did you receive any assistance from the Social Services dept.? O Yes O No

Did you develop any new symptoms since your discharge from hospital? O Yes O No
If "Yes", please specify from symptom list below: _____

Did any of your previous symptoms intensify or become more frequent? O Yes O No
If "Yes", please specify from symptom list below: _____

List of symptoms:

☐ Headache	☐ Nausea	☐ Vomiting	☐ Balance problems/dizziness	☐ Tinnitus
☐ Sensitivity to light/noise	☐ Numbness/Tingling	☐ Blurred Vision/diplopia/flashing lights		☐ Drowsiness
☐ Fatigue/Lethargy	☐ Sadness/depression	☐ Nervousness/Irritability		☐ Sleeping more than usual
☐ Trouble falling asleep	☐ Feeling "slowed down"	☐ Feeling "in a fog" or "dazed"		
☐ Difficulty concentrating	☐ Difficulty remembering			

Activities of Daily Living (Using Katz Index):

ACTIVITIES	INDEPENDENCE NO supervision, direction or personal assistance (1 Point)	DEPENDENCE WITH supervision, direction, personal assistance or total care (0 Points)
Bathing Points = _____	(1 POINT) Bathes self completely or needs help in bathing only a single part of the body such as the back, genital area or disabled extremity.	(0 POINTS) Needs help with bathing more than one part of the body, getting in or out of the tub or shower. Requires total bathing.
Dressing Points = _____	(1 POINT) Gets clothes from closets and drawers and puts on clothes and outer garments complete with fasteners. May have help tying shoes.	(0 POINTS) Needs help with dressing self or needs to be completely dressed.
Toileting Points = _____	(1 POINT) Goes to toilet, gets on and off, arranges clothes, cleans genital area without help.	(0 POINTS) Needs help transferring to the toilet, cleaning self or uses bedpan or commode.
Transferring Points = _____	(1 POINT) Moves in and out of bed or chair unassisted. Mechanical transferring aides are acceptable.	(0 POINTS) Needs help in moving from bed to chair or requires a complete transfer.
Continence Points = _____	(1 POINT) Exercises complete self-control over urination and defecation.	(0 POINTS) Is partially or totally incontinent of bowel or bladder.
Feeding Points = _____	(1 POINT) Gets food from plate into mouth without help. Preparation of food may be done by another person.	(0 POINTS) Needs partial or total help with feeding or requires parenteral feeding.
TOTAL POINTS = _____	6 = High (*patient independent*)	0 = Low (*patient very dependent*)

Were you able to drive before injury? O Yes O No

Are you able to drive after injury? O Yes O No

Thank you for your time today.

Completed by: _____
Initials Date