MILITARY MEDICINE, 180, 4:380, 2015

TBI ADAPTER: Traumatic Brain Injury Assessment Diagnosis Advocacy Prevention and Treatment From the Emergency Room—A Prospective Observational Study

Latha Ganti, MD, MS; Yasamin Daneshvar, BS†; Aakash Bodhit, MD, MPH‡; Sarah Ayala§; Pratik S. Patel, MD‖; Lawrence L. Lottenberg, MD¶; Donna York, RN**; Colleen Counsell, RN**; Keith R. Peters, MD††*

ABSTRACT There is no standard treatment algorithm for patients who present to the emergency department (ED) with acute traumatic brain injury (TBI). This is in part because of the heterogeneity of the injury pattern and the patient profile, and the lack of evidence-based guidelines, especially for mild TBI in adults. As TBI is seen more and more frequently in the ED, a standardized assessment would be beneficial in terms of efficiency. The authors present their ED approach to mild TBI evaluation in the ED, along with results to date. These data represent a prospective observational cohort study, where each patient provided individual, written informed consent.

BACKGROUND

The Case That Triggered the Study Protocol

A 37-year-old male was involved in a high-speed motor vehicle collision on the interstate. The airbags deployed as the car flips twice and sustained a lot of front-end damage as it struck the median. The patient was unsure if he sustained loss of consciousness (LOC). He had no visible lacerations or contusions to his face or scalp. On evaluation in the Emergency Department (ED), he is not deemed to have a traumatic brain injury (TBI) because there was no documented LOC and no visible or external signs of head trauma. He was not trauma alerted as he did meet criteria. He had arrived on a backboard with a cervical collar. His cervical collar was cleared clinically as he was not intoxicated, had no other distracting injuries, no focal neurologic deficits, and a Glasgow Coma Score (GCS) of 15. He was discharged home with generic head injury instructions which amounted to little more than "come back if you don't feel better." The patient indeed did not feel better, so he returned to the ED the next day, complaining of headache, nausea, and irritability. This time a computed tomography (CT) scan of the brain was done, and it was negative for fracture or bleeding. He was once again discharged from the ED eventhough he was not feeling better. A week later, he was back again in the ED because he was not able to function. He could not go to work. His wife was distraught—she did not think he should be driving, but he disagreed, they argued. They have no primary care doctor and no insurance.

The Problem

At this juncture, our team felt the patient needed specialty evaluation; several calls were made to determine where in the medical center patients such as these could go for follow-up postmild TBI care, or what other ED interventions would be helpful to predict how patients like this do in terms of clinical outcomes. To our surprise, no one had a simple answer or a standard methodology for evaluating or referring such patients. We then looked to other EDs around the country to see what they did for evaluation and treatment of mild TBI. Again, there was no single protocol we could simply adopt.

In a nutshell, the problem is that there is no standard treatment algorithm for patients who present to the ED with acute TBI. This is in part because of the heterogeneity of the injury pattern and the patient profile, and the lack of evidence-based guidelines, especially for mild TBI in adults.

What we did learn during our reaching out to colleagues, however, was of various data and interventions that could potentially be useful in the stratification and referral of patients, including oculomotor and neurocognitive testing, recognition of postconcussion syndrome, and more specific discharge instructions. Putting these various ideas together, we came up with a protocol. This article reports on our preliminary experience with the protocol.

*North Florida South Georgia Veterans Affairs Medical Center, 619 South Marion Avenue, Lake City, FL 32025.

†New York University, 100 Washington Square East, No. 901, New York, New York 10003-6688.

‡Saint Louis University, One North Grand, St. Louis, MO 63103.

§University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093.

‖Department of Emergency Medicine, University of Florida Health, 1600 Archer Road, Gainesville, FL 32610.

¶Department of Acute Care Surgery, University of Florida Health, 1600 Archer Road, Gainesville, FL 32610.

**Department of Nursing, University of Florida Health, 1600 Archer Road, Gainesville, FL 32610.

††Department of Radiology, University of Florida Health, 1600 Archer Road, Gainesville, FL 32610.

This article has been delivered as an oral presentation at the 10th World Congress on Brain Injury, San Francisco, CA, March 2014, as well as at the Florida Society of Acute Care and Rehabilitation Nurses in Orlando, FL, May 2014.

doi: 10.7205/MILMED-D-14-00316

METHODS

The Population and Setting

TBI ADAPTER—this is our protocol to provide streamlined, standardized care to patients who present to the ED with mild TBI. Patients were included in the protocol if they were at least 18 years old, presented to the ED within 24 hours of their head injury from any mechanism, whether witnessed or self-reported, and had a GCS between 13 and 15 at the time of ED presentation. This protocol was conducted at a State of Florida verified level I trauma center, with a catchment area of 14 counties and over 1 million people. Thirty-one percent of those have critical injuries as evidenced by an Injury Severity Score (ISS) >15. All patients with brain and spinal cord injury are reported to the state as part of the statewide registry (Florida Department of Health Brain and Spinal Cord Injury Program[1]). On admission to the trauma center, patients have access to collaborative care between Emergency Medicine, Trauma Surgery, Neurological Surgery, Neurology, and Neuroradiology.

Outcomes Measures

Specific patient-centered outcomes included the following: admission to the hospital; admission to the intensive care unit (ICU); repeat ED visits; and results of neurocognitive testing.

The Protocol (Fig. 1)

(1) Patients are approached for informed consent to enroll in the brain injury registry and to introduce the Center for Brain Injury Research and Education, so that patients have a point of contact for follow-up as needed and access to educational materials and caregiver resources.

(2) The following information is obtained via personal interview and medical records. Data are collected and managed using REDCap electronic data capture tools hosted at the University of Florida. REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support clinical data capture.

–Demographics: date of ED visit, age, gender, race, education level, employment status

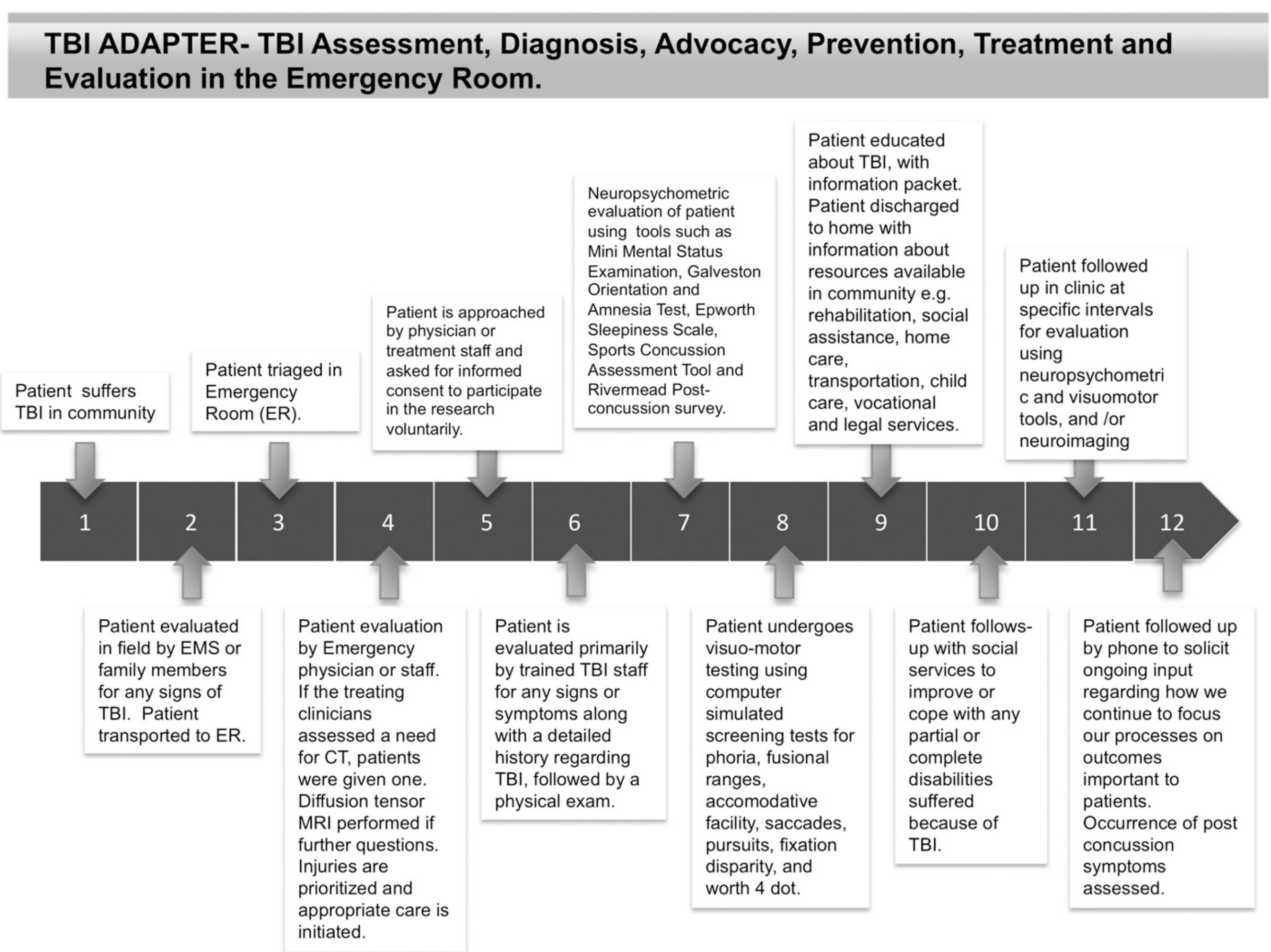

FIGURE 1. TBI-ADAPTER protocol.

–Prehospital variables (if applicable):

- Mode of transportation to the ED
- Prehospital GCS and blood glucose
- Emergency Medical Services (EMS) contact time
- Vitals collected by EMS
- GCS score assigned by EMS on first contact
- Electrocardiographic findings (if any)
- Resuscitation measures used by EMS

–Clinical variables:

Associated signs and symptoms including:

- Vomiting
- Seizures
- Whether LOC occurred and if yes, duration
- Presence of post-traumatic amnesia (whether retrograde, anterograde, or both)
- Alteration of consciousness, which was defined as having any of the following: looking or feeling dazed, confusion, difficulty thinking clearly, difficulty responding to mental status questions, disorientation, and inability to describe immediate events surrounding the traumatic incident
- Headache
- Cause of injury (motor vehicle collision, fall, assault, sports related, direct hit or strike against head, blast, or any other)
- Laboratory investigation values (general chemistry and hematologic investigations, and blood alcohol and urine drug screening results where available)
- Vital signs (pulse, blood pressure)
- Initial GCS score at presentation to ED
- Any neurosurgical interventions
- Past medical history including past head injury and family history of head injury
- Medications on arrival including antiplatelets and anticoagulants
- Neurological system examination including GCS scores and Mini-Mental Status Examination (MMSE)
- Imaging findings (X-rays, CT scans, and brain magnetic resonance imagings including diffusion tensor imaging)
- Calculated ISS

(3) Neuropsychological testing

The following validated survey instruments are used to assess neurocognitive function:

- Galveston Orientation and Amnesia Test (GOAT)[2]: A 20-question instrument that is scored from 0 to 100. Test measures orientation to person, place, time, and memory for events before and after the injury.
- Rivermead Post-Concussion Questionnaire[3]: Table I. The test, which can be self-administered or given by an interviewer, asks patients to rate the severity of 16 different symptoms commonly found after a mild TBI.

TABLE I. Rivermead Post-Concussion Symptom Survey

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 with permission from Springer Science + Business Media: King NS, et al: The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. J Neurol 1995; 242(9): 587–92.

- Epworth Sleepiness Scale[4]: The questionnaire asks the subject to rate his or her probability of falling asleep on a scale of increasing probability from 0 to 3 for eight different situations that most people engage in during their daily lives, though not necessarily every day.
- Sports Concussion Assessment Tool-II[5] if head injury was due to sports.

(4) Vision and visuomotor assessment

This assessment is performed using the computerized binocular assessment[6] system from HTS® (http://visiontherapysolutions.net). This validated system is administered in the ED on a laptop and yields rapid diagnostic information regarding the most common visuomotor disturbances seen after TBI, including:

–Phorias: The relative directions assumed by the eyes during binocular fixation of a given object in the absence of an adequate fusion stimulus.
–Fusional ranges: Fusion is the mechanism by which both eyes blend slightly different images from each eye into a single image.
–Saccades: The series of involuntary, abrupt, rapid, small movements or jerks of both eyes simultaneously in changing the point of fixation.
–Pursuits: The tracking by the eyes of a slowly moving object at a steady coordinated velocity versus jerky movements in saccades.
–Accommodation: The automatic adjustment in the focal length of the lens of the eye to permit retinal focus of images of objects at varying distances.
–Suppressions: Cortical inhibition of perception of objects in all or part of the visual field of one eye during binocular vision.
–Fixation disparities: Direction of the gaze so that the visual image of the object falls on the fovea centralis.
–Asthenopia survey: Subjective symptoms of ocular fatigue, discomfort, lacrimation, and headaches arising from use of the eyes.

It helps to identify persons who can benefit from the HTS iNet[7] program vision therapy device, which uses validated methods of behavior modification (operant conditioning), so that repeat testing over time identifies gains made in the various visuomotor skills.

(5) Balance testing

Patients undergo balance testing with the Balance Error Scoring System. The Balance Error Scoring System provides a feasible, cost-effective way to assess postural stability, and normative data have been published.[8] It consists of the patients standing to demonstrate single leg, double leg, and tandem stances on level ground as well as on a piece of foam. Because of the portability and ease of administration, this type of balance testing is feasible in the ED setting.

(6) Neuroimaging

Patients undergo noncontrast brain CT, based on treating clinician's assessment. If the treating clinicians assessed a need for CT, patients were given one. If there is concern for repeat head trauma or in cases where the neurological examination demonstrates deficits out of proportion to that noted on CT, then patients undergo a diffusion tensor magnetic resonance imaging in the ED. Table II summarizes the specific variables that are collected.

(7) In-hospital resource facilitation and coordination

All admitted patients see the trauma social worker who does an intake needs assessment, contacts caregivers, and jump-starts the reintegration into society process. This is accomplished by personal assistance with connecting the patient and their caregiver to resources, as well as assisting with necessary paperwork to make financial, legal, and vocational benefits streamlined and time efficient. In conjunction with trauma nursing, patients receive a comprehensive packet of information. Patients who do not require admission receive their educational materials, follow up information, and referral to community resources via the ED.

(8) Follow-up

Patients are followed up via telephone or clinic once between 3 and 15 days (1 "week" follow-up), then between 30 and 45 days (1 "month" follow-up). The purpose is to assess for persisting/newly developed symptoms that may indicate postconcussion syndrome, review new medications, ensure that patients understand any follow-up appointments

TABLE II. Imaging Variables on Noncontrast Brain CT[9]

Fracture
Calvarial
Displaced or Nondisplaced
Depressed or Nondepressed
Through Carotid Canal(s)
Through Foramen Magnum
Hemorrhage
Subarachnoid Hemorrhage (Maximum Thickness)
Intraventricular Hemorrhage
Epidural (Maximum Thickness)
Subdural (Maximum Thickness)
Parenchymal, i.e., Hemorrhagic Contusion (Maximum Diameter)
Diffuse Axonal Injury (Unilateral vs. Bilateral)
Mass Effect
Subfalcine Herniation (Millimeter Shift at Third Ventricle)
Uncal Herniation
Downward Transtentorial Herniation
Upward Transtentorial Herniation
Tonsilar Herniation
Ventricular Dilatation/Hydrocephalus
Obstructed Because of Blood Clot
Entrapped Because of Shift
Edema
Diffuse
Focal, (i.e., Nonhemorrhagic Contusion)

Additionally, information about extracranial soft tissue swelling and maxillofacial fractures including nasal bone fractures was also collected, as many head traumas are associated with facial trauma. Adapted from Maas AI, et al: Common data elements for traumatic brain injury: recommendations from the interagency working group on demographics and clinical assessment. Arch Phys Med Rehabil 2010; 91(11): 1641–9.

he or she has, and to check for development of any long-term complications associated with injury, particularly the development of postconcussive symptoms. It also provides an opportunity for our ED research team to determine how to improve our services both up front in the ED, as well as on the inpatient floor and after discharge.

RESULTS

A total of 816 patients have been through the TBI ADAPTER protocol to date. Table III summarizes the cohort's demographic characteristics, past medical, and neurological history. The majority of the cohort (94%) presented with a GCS of 15; 4% had a GCS of 14, and 2% GCS of 13. Most patients (79%) arrived via EMS, with 74% via ground ambulance and 5% via air transport. Nineteen percent arrived by car and 2% walked in. The most common mechanism of injury was motor vehicle collision (49%) followed by fall (43%), assault (5%), and being struck on the head (3%).

TABLE III. Cohort Demographics, Past Medical and Neurologic History

Demographics	
Age	Median 44, IQR 26–60, Range 18–102
Sex	51.5% Male
BMI	Median 26.1, IQR 22.7–30.7, Range 14.6–55.8
Race	75% White, 19% Black, 3% Hispanic, 3% Other
Smoker	31% Current Smokers
Past Medical History	
Hypertension	35.3%
Diabetes Mellitus	13.4%
Hyperlipidemia	15.6%
Atrial Fibrillation	4.7%
CAD/MI	9.2%
CHF	3%
Depression	14.8%
Substance Abuse Disorder	1.8%
Anxiety	12.2%
Other Psychological Disorder	4.4%
Bleeding Disorder	0.4%
Thyroid Disorder	6.6%
On An Antiplatelet Agent	18.1%
On An Anticoagulant Agent	5.4%
Past Neurologic History	
Headache/Migraine	16.3%
Dizziness or Fainting	7.3%
Seizure	7.2%
Brain Tumor	1%
Prior Head Injury/TBI	5.6%
Ischemic Stroke	2.4%
Hemorrhagic Stroke	0.6%
Neuropathy	1.8%
Memory Problems	6.7%
Alzheimer's Disease	0.2%
Parkinson's Disease	0.6%
Paresis/Weakness	5.8%
Loss of Balance	7.6%
Gait Abnormality	5.4%
Sensory Loss/Touch/Position Sense/Temperature	2.6%
Deafness	3.7%
Blindness	2.1%
Difficulty in Speaking	1%

BMI, body mass index; CAD, coronary artery disease; MI, myocardial infarction; CHF, congestive heart failure.

A total of 39% were admitted, with a median hospital length of stay of 3 days, interquartile range (IQR) 1 to 6, range 0 to 61. Patients admitted to the hospital were more likely to have a lower GCS ($p = 0.0003$), a lower MMSE score on ED examination ($p < 0.001$), have sustained multitrauma ($p < 0.0001$), or being older ($p < 0.0001$), and to arrive to ED through EMS ($p < .0001$). In multivariate models with and without age, the strongest predictors remained the occurrence of multitrauma and arrival to ED through EMS. Fourteen percent sustained multitrauma. Median MMSE scores were 28, IQR 26 to 29, range 10 to 30. Median ISS was 14, IQR 6.75 to 26.

The frequency of injury-related symptoms and signs and their associations with hospital admission are detailed in Table IV. Although post-head injury headache was most common, the occurrence of LOC ($p < 0.0001$), alteration of consciousness ($p = 0.002$), and post-traumatic amnesia ($p < 0.0001$) after head injury were significantly associated with hospital admission. Occurrence of vomiting or seizure after trauma was not associated with hospital admission.

Noncontrast brain CT was performed in 85% of the cohort, with 7.6% being abnormal. Table V describes abnormal findings on head CT scans and associated abnormalities on maxillofacial CT scan. Abnormal head CT scan was associated with significantly higher chances of hospital admission (74% vs. 40%, $p < 0.0001$) and also significantly higher chances of return ED visit within 72 hours of discharge (18.4% vs. 8.4%, $p = 0.039$).

The median Rivermead Post-Concussion Symptoms Questionnaire (RPCSQ) score was 12 with IQR of 5 to 25. The range was 0 to 61. RPCSQ score was not significantly associated with age, but was different between genders. Females (mean score = 18.6) had significantly higher scores than males (mean score = 13.2). As far as outcome variables are concerned, higher RPCSQ score was associated with hospital admission ($p = 0.004$, mean score of 21.5 for admitted vs. 13.7 for nonadmitted), though it was not associated with abnormal head CT scan. RPCSQ scores for all patients were then dichotomized in two groups (≤16 and >16). Subjects in the group with RPCSQ score >16 were significantly more likely to get admitted to hospital compared to those with RPCSQ score ≤16 (39.1% vs. 21.7%, $p = 0.04$). RPCSQ score of >16 were significantly associated with hospital admission ($p = 0.02$) even after controlling for gender and mode of arrival to ED.

The median GOAT score was 99, with IQR of 97.75 to 100 and a range of 84 to 100. There was no association between age and GOAT score, and contrary to RPCSQ score, there was no significant difference in mean GOAT scores for

TABLE IV. Frequency of Injury-Related Symptoms and Association With Hospital Admission

Symptom	Significantly Associated With Hospital Admission? Frequency in admitted patients (n = 318)	Frequency in not admitted patients (n = 498)	p-Value
LOC	50%	32.7%	0.0001
Feeling dazed	24.5%	24.1%	NS
Confusion	31.4%	21%	0.0008
Difficulty thinking	15.4%	13.3%	NS
Difficulty answering mental status questions	7.9%	5%	NS
Difficulty describing events surrounding trauma	30.2%	19.5%	0.0005
Disorientation	8.2%	7.6%	NS
Decreased level of consciousness	5%	2.8%	NS
PTA	46.8%	29.1%	< 0.0001
Vomiting	7.9%	8.6%	NS
Seizure after injury	2.2%	1%	NS
Headache	49%	59.4%	0.003

PTA, post traumatic amnesia. Neither anterograde nor retrograde PTA subtypes were individually significant.

females and males. A decreased GOAT score was significantly associated with outcome variables such as abnormal head CT scan (mean score 91.8 vs. mean score 97.5 for normal CT scans, p = 0.002) and admission to hospital (mean score 96.2 vs. mean score 98.1 for nonadmitted subjects, p = 0.017). All GOAT scores were also divided in two groups (≤97 and >97). Subjects with GOAT score ≤97 were significantly more likely to get admitted to hospital compared to those with GOAT score >97 (51.7% vs. 22.5%, p = 0.002). This remained true even after controlling for mode of arrival to ED (p = 0.003). Also, subjects with GOAT score ≤97 were significantly more likely to have abnormal head CT scan compared to those with GOAT score >97 (14.8% vs. 3%, p = 0.035). RPCSQ score of >16 were significantly associated with hospital admission (p = 0.02) even after controlling for gender and mode of arrival to ED.

Results of oculomotor testing are depicted in Table VI. Overall, the majority of patients failed the fusional ranges and accommodative facility subtests of the binocular vision assessment (BVA). Abnormal tests for saccadic eye movements (48% vs. 25%, p = 0.017), suppression (80% vs. 27%, p = 0.011), and pursuit (48% vs. 26%, p=0.041) were significantly associated with higher hospital admission rates, but none of the tests showed any significant association with abnormal CT scan findings.

TABLE V. Abnormal Findings on Brain CT Scans

Abnormal Findings on Brain CT Scans	Number of Subjects
Calvarial Fracture	11
Calvarial Fracture Through Carotid Canal	2
Calvarial Fracture Through Foramen Magnum	1
Epidural Hemorrhage	1
Subdural Hemorrhage	14
Subarachnoid Hemorrhage	18
Intraventricular Hemorrhage	2
Parenchymal Hemorrhage/Hemorrhagic Contusion	17
Diffuse Axonal Injury	1
Acute Brain Edema	6
Other Findings (Extracalvarial and Maxillofacial CT)	
Fracture of Maxillofacial Bones (Except Nasal)	48
Fracture of Nasal Bones	31
Extracalvarial Soft Tissue Swelling	131

DISCUSSION

A recent study in *Military Medicine* reports on a survey of mild TBI treatment in the ED.[10] The authors note that the evaluation of specific cognitive deficits is an area largely overlooked by providers. In our protocol, we specifically solicit deficits in the oculovestibulomotor system and assess for neurocognitive dysfunction. The study also notes that providers seldom assess for changes in sleep, energy level, and emotional or psychosocial factors. The current protocol attempts to address these with short term (3–15 days) and medium term (30–45 days) follow up, as well as specific scales to assess sleep and activity levels. Finally, the paper calls for increased emphasis on patient and family education,

TABLE VI. BVA Assessment Findings

Phoria	Pass: 92.5%, Fail: 7.5%
Phoria Type	ESO: 9.4%, EXO: 43.4%, Ortho: 47.2%
Fusional Ranges (Overall)	Pass: 9.4%, Fail: 90.6%
BI Break	Pass: 70.8%, Fail: 29.2%
BI Recovery	Pass: 47.9%, Fail: 52.1%
BO Break	Pass: 36.5%, Fail: 63.5%
BO Recovery	Pass: 13.5%, Fail: 86.5%
Accomodative Facility (Overall)	Pass: 12.1%, Fail: 87.9%
Right Correct	Pass: 78.8%, Fail: 21.2%
Left Correct	Pass: 70.7%, Fail: 29.3%
Average Cycles/min	Pass: 15.5%, Fail: 84.5%
Saccadic (Overall)	Pass: 74.8%, Fail: 25.2%
Saccadic Movement (Correct Response)	Pass: 99.1%, Fail: 0.9%
Saccadic Movement (Average Time Per Response)	Pass: 74.8%, Fail: 25.2%
Worth 4 Dot Test	Pass: 95.4%, Fail: 4.6%
Pursuit (Overall)	Pass: 78.1%, Fail: 21.9%
Pursuit (Correct Response)	Pass: 81.5%, Fail: 18.5%
Pursuit (Average Time Per Response)	Pass: 83.3%, Fail: 16.7%
Fixation Disparity	Pass: 57.5%, Fail: 42.5%

BI, base in; BO, base out; ESO, Esophoria; EXO, Exophoria.

which again, is incorporated in item 9, via in-hospital resource facilitation and coordination.

To our knowledge, this is the first ED-based multidisciplinary protocol for TBI. There have been various guidelines attempting to outline "rules" for when to neuroimage adults in TBI,[11–13] each with its own limitations. Similarly, the utility of neuroimaging in pediatric TBI has been reported,[14] again with the intent of reducing radiation exposure and keeping hospital charges low. However, these guidelines focus solely on who should get a head CT and do not address the various other parameters that are important after a head injury. As TBI is multimodal in etiology and mechanism, diagnosis and management is best achieved via a multimodal multidisciplinary approach, versus just relying on a single modality such as brain CT neuroimaging for example.

A study by Joseph et al[15] reports the feasibility of managing mild TBI without an inpatient neurosurgical consultation and found that mild TBI cases with intracranial hemorrhage managed with neurosurgical consultation did not have significantly different hospital or ICU lengths of stay and postdischarge return visits to ED. Those with neurosurgical consultations were significantly more likely to get repeat CT scan, have ICU admission, and thus increased hospital costs. The findings have led to change of practice at their institution with more efficient resource allocation. As TBI presentations to the hospitals continue to increase, studies such as these and the current study are important in that they help to outline different hospital strategies to manage these patients.

The current study describes a single center experience with an ED protocol to evaluate and risk stratify patients who present with a mild TBI. Although this type of integrated protocol is novel, the individual elements of the protocol have previously been conducted in EDs, including CT, neurocognitive and oculomotor testing, and short-term follow-up, which demonstrates portability of such a protocol. For example, a study by Wiebe et al[16] prospectively administered the neurocognitive test ImPACT (Immediate Postconcussion Assessment and Cognitive Testing) to children ages 11 to 17 in the ED and during hospitalization, with structured follow-up care. A similar study was conducted in adults with mild TBI presenting to the ED of an academic level I trauma center.[17] Vision screening for oculomotor dysfunction has been carried out in the sports field itself.[18]

CONCLUSION

In conclusion, based on our experience with the current protocol, we suggest that the implementation of an ED-based multidisciplinary protocol for mild TBI integrating practice, research, and education appears to be feasible. It is our hope that sharing the data we have collected using our protocol can help to inform the design of additional protocols and advance our field further toward the ultimate goal of having a rigorous, evidence-based methodology for the proper assessment and triage of TBI. Data obtained from such a protocol provides valuable information on local demographics and needs, helping to further refine clinical care protocols.

ACKNOWLEDGMENTS

The authors are grateful to the Toral Family Foundation, Davie, Florida, for their support and financial support of this work. http://toralfamilyfoundation.org. None of the authors have any conflicts of interest to disclose.

REFERENCES

1. Florida's Brain and Spinal Cord Injury Program: Central Registry Page. Available at http://www.floridahealth.gov/%5C/diseases-and-conditions/brain-and-spinal-cord-injuries/brain-and-spinal-cord-injury-program.html; accessed October 6, 2014.
2. Levin HS, O'Donnell VM, Grossman RG: The Galveston Orientation and Amnesia Test. A practical scale to assess cognition after head injury. J Nerv Ment Dis 1979; 167(11): 675–84.
3. 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(9): 587–92.
4. Johns MW: A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 1991; 14(6): 540–5.
5. McCrory P: Sport Concussion Assessment Tool 2. Scand J Med Sci Sports 2009; 19(3): 452.
6. Home Therapy Solutions: BVA Page. Available at http://www.visiontherapysolutions.net/bva.php; accessed September 2, 2014.
7. Home Therapy Solutions: HTS iNet Page. Available at http://www.visiontherapysolutions.net/hts.php; accessed September 2, 2014.
8. Iverson GL, Kaarto ML, Koehle MS: Normative data for the balance error scoring system: implications for brain injury evaluations. Brain Inj 2008; 22(2): 147–52.
9. Maas AI, Harrison-Felix CL, Menon D, et al: Common data elements for traumatic brain injury: recommendations from the interagency working group on demographics and clinical assessment. Arch Phys Med Rehabil 2010; 91(11): 1641–9.
10. Kennedy JE, Lumpkin RJ, Grissom JR: A survey of mild traumatic brain injury treatment in the emergency room and primary care medical clinics. Mil Med 2006; 171(6): 516–21.
11. Stiell IG, Wells GA, Vandemheen K, et al: The Canadian CT Head Rule for patients with minor head injury. Lancet 2001; 357(9266): 1391–6.
12. Haydel MJ, Preston CA, Mills TJ, Luber S, Blaudeau E, DeBlieux PM: Indications for computed tomography in patients with minor head injury. N Engl J Med 2000; 343(2): 100–5.
13. Jagoda AS, Bazarian JJ, Bruns JJ, et al: Clinical policy: neuroimaging and decision making in adult mild traumatic brain injury in the acute setting. Ann Emerg Med 2008; 52: 714–48.
14. Goldberg J, McClaine RJ, Cook B, et al: Use of a mild traumatic brain injury guideline to reduce inpatient hospital imaging and charges. J Pediatr Surg 2011; 46(9): 1777–83.
15. Joseph B, Aziz H, Sadoun M, et al: The acute care surgery model: managing traumatic brain injury without an inpatient neurosurgical consultation. J Trauma Acute Care Surg 2013; 75(1): 102–5.
16. Wiebe DJ, Collins MW, Nance ML: Identification and validation of prognostic criteria for persistence of mild traumatic brain injury-related impairment in the pediatric patient. Pediatr Emerg Care 2012 ; 28(6): 498–502.
17. Peterson SE1, Stull MJ, Collins MW, Wang HE: Neurocognitive function of emergency department patients with mild traumatic brain injury. Ann Emerg Med 2009; 53(6): 796–803.
18. Duenas MJ, Hsu SN, Jandial R: Visual screening test for rapid sideline determination of concussive and sub-concussive events. Neurosurgery 2013; 73(4): N17–8.