Distribution Agreement

An Underappreciated Diagnosis: A Prospective Cross-Sectional Study Examining the Documented Evaluation and Management of Patients with a Possible Mild Traumatic Brain Injury at an Urban Level 1 Emergency Department

By

Chet Christopher Zalesky
Master of Science

Clinical Research

____
David W. Wright MD, FACEP
Advisor

____
Mitch Klein PhD
Committee Member

____
Beau B. Bruce MD, PhD
Committee Member

Accepted:

____
Lisa A. Tedesco, PhD
Dean of the James T. Laney School of Graduate Studies

____
Date

An Under-Appreciated Diagnosis: A Prospective Cross-Sectional Study Examining the Documented Evaluation and Management of Patients with a Possible Mild Traumatic Brain Injury at an Urban Level 1 Emergency Department

By

Chet Christopher Zalesky
B.S., Wake Forest University, 2010

Advisor: David W. Wright MD, FACEP
Professor of Emergency Medicine & Interim Chair
Department of Emergency Medicine
Emory University School of Medicine

An abstract of
A thesis submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Master of Science
in Clinical Research
2019

Abstract

An Under-Appreciated Diagnosis: A Prospective Cross-Sectional Study Examining the Documented Evaluation and Management of Patients at High Risk for Mild Traumatic Brain Injury at an Academic Level 1 Emergency Department

By:
C. Christopher Zalesky

Background: Annually, 2.5 million Traumatic Brain Injuries (TBI) occur with nearly 75% classified as mild TBI (mTBI), also known as a concussion. Mild TBI can be subtle, and detection requires a high index of suspicion and a regimented evaluation process. This study was done to determine the proportion of patients, at high risk for an mTBI, who were evaluated for an mTBI at a high volume urban academic trauma center.

Methods: A prospective cohort of patients was identified using a 3-question screen at the time of triage: did an injury occur; was the mechanism consistent with mTBI; and was there a period of altered mental status. Patients who screened positive were thought to meet a minimum threshold for the evaluation of mTBI. Information about mTBI specific evaluation, management, and education was obtained from the patient's charts.

Results: 38,621 patients were screened over 16 weeks, of whom 441(1.14%) were identified as being high risk for having an mTBI and met inclusion criteria. The most significant findings revealed that recommended portions of an mTBI specific evaluation occurred in fewer than 50% of the study population. In total, 98 were diagnosed with mTBI, and 49 received mTBI discharge instructions. Logistic modeling, for a subgroup of patients who had documented criteria sufficient for diagnosis, estimated that having isolated head injury increased a patient's odds of having a documented diagnosis by 2.1 times (95% CI 1.3 – 3.4).

Conclusions: Many patients with a possible mTBI did not have significant portions of an mTBI evaluation documented and roughly half of patients with a documented mTBI diagnosis did not receive discharge education. Changes in Emergency Medicine providers' approach to mTBI must occur to increase the proportion of patients receiving an appropriate evaluation, management, and education.

An Under-Appreciated Diagnosis: A Prospective Cross-Sectional Study Examining the Documented Evaluation and Management of Patients at High Risk for Mild Traumatic Brain Injury at an Academic Level 1 Emergency Department

By

Chet Christopher Zalesky
B.S., Wake Forest University, 2010

Advisor: David W. Wright MD, FACEP
Professor of Emergency Medicine & Interim Chair
Department of Emergency Medicine
Emory University School of Medicine

A thesis submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Master of Science
in Clinical Research
2019

Acknowledgments

This thesis was supported in part by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR002378. Support also from UL1TR000424

Table of Contents

INTRODUCTION

Nearly three million Emergency Department (ED) visits were attributed to Traumatic Brain Injuries (TBI) in 2013 with nearly 75% classified as mild TBI (mTBI)(1). This type of injury has recently gained increased public awareness due to its association with collegiate and professional sports. However, the Centers for Disease Control (CDC) reports that the most common mechanisms, for mTBI, across all age groups are: falls, motor vehicle crashes, and assaults(2). The true epidemiology of mTBI is not well understood as most patients do not seek medical care after a minor mTBI and some are evaluated outside of the formal healthcare setting. Even within healthcare, reports describe low rates of mTBI identification. The reasons for the reportedly low identification rates are likely multifactorial, e.g., a historically ambiguous definition, the variability of clinical presentation, distracting injuries, and a lack of training on how to perform a proper mTBI evaluation. The lack of training has been revealed in multiple survey-based studies of medical students, residents, fellows, and attendings revealing gaps in knowledge or low confidence in how to manage mTBIs(3-5).

Beyond existing knowledge gaps, mTBI has had a vague history with various organizations seeking to define it(6). The CDC states an mTBI is a head injury, due to a blunt force or acceleration-deceleration mechanism, with at least one of the following associated conditions being observed or reported: (1) Any period of observed or self-reported transient confusion or impaired consciousness, (2) Any dysfunction of memory surrounding the time of injury, (3) Any neurologic or neuropsychological dysfunction, (4) Any period of loss of consciousness (LOC) lasting 30 minutes or less.

What is known about this kind of injury is that most adults will seek care at an ED for a suspected mTBI and ~30 - 50% of mTBIs presenting to the ED will not be diagnosed (7-9). The reason for remaining undiagnosed is not well known, but mTBI can be subtle, and detection requires a high index of suspicion and a regimented evaluation process. Identifying mTBI is crucial because, beyond the initial injury, ~30% of patients will experience persistent symptoms and are at a higher risk of worsened long-term neurologic outcomes (10, 11).

BACKGROUND

Generally, an mTBI is any injury to the brain that results in an acute episode of neurologic dysfunction that resolves within 30 minutes of the injury. Mild TBI fits on the spectrum of TBI between subclinical injuries and Moderate and Severe injuries. The levels of injury are differentiated based on the mental status of the patient as measured by the Glasgow Coma Scale (GCS). This scale ranges from 3 (completely unresponsive) to 15 (normal). Specifically, an mTBI is an injury to the head with neurologic dysfunction, a GCS of 13-15, and loss of consciousness, if present, for less than 30 minutes. A moderate TBI has no qualification for the length of loss of consciousness but must have a GCS between 9 and 11. Finally, a Severe TBI has a GCS less than or equal to 8 (6, 12, 13).

Mild traumatic brain injuries were first described in 900 A.D. by the Persian physician Rhazes, and the desire to understand Traumatic Brain Injuries has continued throughout medical history. In modern days, the classic sequelae of traumatic brain injuries were first seen among boxers. Fighters displaying a style which caused them to absorb more punches from their opponents were noted to develop dysarthric, ataxic, or parkinsonian characteristics. The term “punch drunk” was coined for this constellation of findings, and it was later conferred the more clinical name Dementia Pugilistica (14). More recently TBI, with mTBI being the most common, became the “signature wound” of the American military deployments in Iraq and Afghanistan with 17% of troops satisfying the diagnostic criteria for TBI during their tours of duty (15, 16). In addition to the interest the Department of Defense has brought to mTBIs, widespread public awareness has occurred due to the growing research link covered in the media about professional football and associated mTBIs and the chronic sequela of TBI (17, 18).

Mild TBI's significance can be misleading to the public and physicians, even with growing awareness, due to its initial transient symptoms. An inciting injury to the head resulting in any alteration of brain function is often sufficient to meet the diagnostic criteria developed by the CDC. While a patient's mental status must return to baseline within 30 minutes of the injury, the sequelae do not resolve at that time. Headaches, nausea, vomiting, balance disruptions, and reduced higher order mental capabilities are common after sustaining an mTBI(19). Longer term sequala, such as cognitive, emotional, and sleep disturbances, will occur for nearly 50% of patients and 22% of patients report being below their baseline functional status at one year (20, 21). The initial resolution of acute symptoms followed by a persistent constellation of physical, cognitive, emotional, and sleep disturbances causes a plethora of diversity among patients' presentations with an mTBI.

Fifty million mTBIs are thought to occur annually throughout the world with 90% being classified as mTBI (13). The rates of mTBI are increasing worldwide, and the evidence revealing higher rates of dementia, neurodegenerative disease, and mortality has emerged to support worsened long-term functional outcomes after mTBI has also increased (11, 22-25). The leading causes of mTBI shift between falls, accidents, violence, or motor vehicle crashes depending on patients age and the country being investigated. As alluded to before, this phenotypic diversity has complicated epidemiologic and interventional studies as broad definitions seeking to capture all patients can lead to a dilution of effect for possible interventions (13). The best evidence to date shows that educational interventions can improve outcomes, but this evidence is far from robust (26).

Within the United States, the vast majority of adult patients with an mTBI will seek care at an emergency department, accounting for 2.5 million visits in 2013 (1, 8). These visits were primarily due to falls, being struck by an object, and motor vehicle crashes. Within the emergency department, the evaluation for mTBIs has not been standardized. Currently, guidelines from the American College of Emergency Physicians (ACEP) and the CDC, focus on imaging guidelines for which patients should receive a head CT scan (27). There are no CDC or ACEP guidelines currently for the evaluation of an adult ED patient beyond imaging. Symptom and history based clinical evaluation tools do exist to track and quantify mTBIs, but their length or lack of validation in adult populations limit their usefulness in the acute setting (28). The pediatric mTBI population does not suffer from the same lack of guidelines and has best practice recommendations for the evaluation, prognostication, management, education and follow up of patients with an mTBI (29).

The disparity between adult and pediatric guidelines parallels the state of consensus in those realms of mTBI research. To date, the most robust research efforts have occurred in children, athletes, and veterans. Advances among these populations have generated enough of a consensus to create best practice guidelines in the given environments, but provider confidence in various specialties, including pediatrics, neurology, neurosurgery, primary care, and emergency medicine, is still far from robust (3-5, 30). It is not difficult to infer that much of this lack of confidence stems from a lack of exposure to mTBI care in education and clinical training.

Within the emergency depart previous studies have shown that 16-56% of patients who met criteria for an mTBI were not diagnosed (7, 9). These rates of underdiagnoses are important because not receiving a timely diagnosis puts patients at risk for repeat injuries, limits their ability to get appropriate follow up care and to be properly educated about their injury. Educating patients about their expected course is the current best practice for an mTBI injury, but more evidence is needed to confirm this practice (26). This simple intervention is impossible if the patient is never appropriately diagnosed. Educating patients with mTBIs about their injuries is also a way to reduce their rate of return visits to the ED as persistent mTBI symptoms are the most commonly cited reason for these patients to return to the ED (31).

The current state of adult mTBI research shows that mTBIs are a serious injury with both immediate and long-term sequelae. This significant injury has historically suffered from limited acknowledgment and treatment as physicians have not been trained on it sufficiently to feel comfortable with its evaluation and management. This evidence-practice gap creates an environment where many patients are not being properly evaluated, which can harm patients and lead to unnecessary repeat ED visits. Ultimately, we must understand why physicians are not evaluating patients at risk for an mTBI so that interventions can be designed to improve patient care. Beyond just caring for patients, improved rates of evaluation and, when appropriate, diagnosis are needed to strengthen the current ED mTBI research environment. If the current state of mTBI underdiagnoses persists, future studies will not reflect actual practice, in an effort to capture all mTBI patients, or, studies will miss a segment of the mTBI population not currently being evaluated.

Importance

Patients that are high risk for an mTBI should be identified, evaluated, and managed according to best practice guidelines. Failing to do so increases their risk for premature return to work/activity thereby predisposing them to more severe repeat injuries and prolonged recovery (32). These risks can be mitigated by following recommended evaluation and management guidelines from the CDC, and specialty organizations including Department of Defense, Sports Medicine, and Emergency Medicine (27, 33-36). ED provider decision making must include proper identification, evaluation, management, and education in line with published practice guidelines. Improving clinician knowledge and raising suspicion regarding mTBIs is an area in great need of innovative solutions to ensure every patient receives appropriate care.

In this study we sought to describe the proportion of patients with a documented mTBI evaluation consisting of 34 specific mTBI exam components. Documentation was based on physician chart documentation. The 34 exam components were also examined with a goal to better understand which affected a patient's odds of receiving a documented mTBI diagnosis.

METHODS

Specific Aims

This study sought to better understand the current state of mTBI evaluation, management, and provider decision-making documented to have been delivered to patients with a possible mTBI at an academic level 1 trauma and emergency care center. The primary goals of this investigation were describing the evaluation conducted for patients at high risk for mTBI and to understand the patient characteristics affecting their likelihood of a documented diagnosis. Secondarily, we sought to define the proportion of patients receiving a documented mTBI diagnosis and discharge instructions.

Specific Aim 1: Calculate the proportion of patients, identified as high risk for a mild Traumatic Brain Injury (mTBI), that had an mTBI evaluation documented by an Emergency Medicine clinician. Identification occurred during triage and was based upon questions satisfying the CDC criteria for an mTBI Diagnosis. All included patients should have a documented mTBI evaluation consisting of 34 separately documented components which encompass patient signs, symptoms, cognition, and physical exam.

Brief Summary of Patient Characteristics in Aim 1

Patients must:

1. Be at high risk for an mTBI by answering two nursing triage questions in the affirmative

    a. These questions are specific to mTBI and if answered in the affirmative would indicate patients are at high risk necessitating an mTBI evaluation
2. Be seen by an Emergency Medicine Clinician (Attending, Resident/Attending Team, Nurse Practitioner)
3. Have a clinical encounter documented by an Emergency Medicine Clinician
    a. Documentation could include documentation related to mTBI (34 possible components) or no documentation related to mTBI
    b. Each of the 34 components of an mTBI evaluation could be 1) documented as yes, 2) documented as no, or 3) not documented
4. Leave the Emergency Department
    a. Patients could be admitted to the hospital or discharged
5. Have their charts reviewed to understand the kind documentation completed by the clinician

<u>Specific Aim 2</u>*:* Using the CDC criteria for an mTBI diagnosis, a subgroup will be created of those who have clinician documentation that is sufficient for a diagnosis yet who may or may not have received a documented diagnosis. Meeting CDC criteria required having at least

one of sixteen possible mTBI exam components documented as being positive (Appendix 2). This subgroup, who meet criteria and may or may not be diagnosed, will be used describe the proportion of documented mTBI diagnosis among all patients who should have received a mTBI diagnosis based upon physician documentation. Ideally, all patients would be diagnosed by the provider. In other words, the goal is to estimate the sensitivity of a correct documented diagnosis by the clinician.

Brief Summary of Patient Characteristics in Aim 2

Patients must:

1. Meet all characteristics outlined in Aim 1
2. Have a documented “yes” (also known as positive or abnormal) for any one of 16 components of the (of the 34 mTBI evaluation components).
    a. Anyone of these components would fulfill the CDC criteria for an mTBI diagnosis in the setting of a head injury
    b. Having anyone of these components documented as a “yes” would be mean the patient has documentation sufficient for an mTBI.
    c. Having documentation sufficient for a diagnosis does not mean the patient received a clinician documented mTBI diagnosis

<u>Specific Aim 3</u>: Estimate which demographic characteristics and exam components (the 34 components of the mTBI evaluation) affect a patient's odds of receiving a documented mTBI diagnosis. Odds will be estimated for the subgroup of patients (Aim 2) and for all patients included in the study (Aim 1).

<u>Brief Summary of Patient Characteristics in Aim 1</u>

Patients must:

1. Meet criteria outlined for their respective groups (i.e. Aim 1 or Aim 2)

Study Design and Setting

This study was a prospective cross-sectional study of an adult ED population who were identified as being high risk for an mTBI. The study occurred in an ED of an urban academic level 1 trauma center that sees over 140,000 patients annually and houses a dedicated trauma center. Over a 16-week period during the fall and winter of 2016-2017 all patients who presented to the ED were asked mTBI identification questions as a part of their nursing intake triage. Patients who bypassed standard triage due to trauma severity were questioned by nurses upon arrival to their room. Providers were blinded to the results of the questions and unaware of the study's activities. If the patient answered the mTBI identification questions in the affirmative, it was considered sufficient to establish a high risk of mTBI that warranted further evaluation. Data, encompassing predetermined parts of the patient's evaluation and management, was abstracted from patient charts. A study diagram can be seen in Figure 1. This study was approved by the University's Internal Review Board and granted a waiver of patient consent.

Selection of participants

The study population was an exclusively adult cohort (18 years and older) identified by mTBI triage identification status. The identification questions were created for this study and included three items derived from the CDC criteria for mTBI. The questions consisted of: (1) did an injury occur? (2) was there a blunt force injury to the head and/or did the head move back and forward with a lot of force, and (3) was there a change in mental status or level of consciousness as a result of the event? An affirmative answer was needed to all three questions to be considered for inclusion in the study. Patients were excluded if they were <18 years old, did not have care documented by an emergency medicine clinician, left care against medical advice, had injuries which limited provider documentation (i.e., non-responsive, proceeded to the operating room, or died during treatment) or there was no injury, of any kind, reported. A graph of exclusion criteria can be seen in Appendix 3.

Measurements

Patients were prospectively identified, and data was collected from chart abstraction for all patients who met inclusion and exclusion criteria.

Four trained non-blinded reviewers were used to abstract the data independently from separate charts. A standardized protocol, including pre-defined criteria for all variables, was used. Variables collected were chosen to understand patient characteristics and to evaluate providers' approach to patient care, with providers blinded to the patient's screening status. Collected data points were specific to the cause of the patient's initial presentation, injury mechanism, injury history, subjective symptoms, objective signs, physical exam, management decisions, possible diagnosis, and discharge education. These data elements are consistent with the National Institute of Neurological Disorders and Stroke Common Data Elements for mTBI. Symptom documentation was recorded, however, blanket statements such as "systems reviewed and otherwise negative," were not considered when trying to identify mTBI specific criteria.

Practice guidelines from the CDC, Department of Defense/Veterans Affairs, Sports Concussion Assessment and Tool 5th Ed, American Academy of Family Physicians, and the Ontario Neurotrauma Trauma Foundation were used as a comparator for the evaluation of patients (27, 34-37). These guidelines were chosen due to their scope, organizational impact and methodology used for their development. Mild TBI was considered present if documented in the list of final diagnoses by the treating clinician. All recorded signs and symptoms were coded as "positive," "negative," or "not documented" while physical exam findings were coded "abnormal," "normal," and “not documented,” Glasgow Coma Scale (GCS) was reported as "documented" or "not documented" as well as the numeric value when documented. Items recorded as “not documented” were not treated as missing data, as the lack of documentation was considered a purposeful decision by clinicians. Isolated head injury was recorded as “yes” if all documented injuries were above the clavicles and “no” if other injuries, of any kind, were documented below the clavicles. Provider type was determined by the author or coauthor of the final ED provider note. If a patient was cared for by multiple provider types, the primary author (and if relevant, cosigner) of the note was counted as the provider. The triage screening rate for each level of the emergency severity index (ESI) was tracked over time to ensure universal identification over the course of the study (Figure 2). ESI is a measure of each patient’s medical status ranging from 1 (requiring Immediate clinician intervention) to 5 (requiring non-urgent clinician attention) A complete list of variables is presented in Appendix 1. All data points were entered into a REDCap database by study personnel at the time of chart review.

Specific Aim 3 was evaluated by creating a subgroup of patients who had at least one of the CDC criteria for diagnosis documented in their chart. Having one of these criteria documented in the setting of a head injury is significant as this would be sufficient for an mTBI diagnosis. These patients may or may not have been diagnosed with an mTBI. This subgroup represents a sample of patients who have clinician documentation sufficient for a diagnosis, but they may or may not have received a diagnosis. The variables used to construct this subgroup can be seen mapped to the CDC criteria for diagnosis in Appendix 2.

Outcomes

The primary outcome, patients receiving an mTBI evaluation, was examined through comparing the frequency of documented portions of an mTBI evaluation to the recommended mTBI evaluation from the CDC, Department of Defense/Veterans Affairs, Sports Concussion Assessment and Tool 5th Ed, American Academy of Family Physicians, and the Ontario Neurotrauma Foundation. All data was obtained through chart review in order to avoid direct observation of clinicians, which could bias clinician decision-making. mTBI was recorded as considered in the providers differential diagnosis if it was discussed in the medical decision-making portion of the note, or if mTBI was given as a reason for testing by the documenting provider. Diagnosis of mTBI was defined as a documented mTBI diagnosis in the final list of discharge diagnoses. Secondary outcomes sought to use the documented evaluation and injury characteristics to understand elements which affected the odds of receiving an mTBI diagnosis.

Analysis

Continuous variables were reported with means and standard deviations. Categorical variables were reported as a percent with confidence intervals estimated using the Agresti–Coull method. Missing data was imputed using multiple imputation. Variables were initially screened, to be included in logistic modeling, by univariate analysis using student t test, chi-squared, or Fisher's exact test when appropriate. Candidate variables were then evaluated using a forwards and backwards stepwise selection process. Two-way interaction for all final variables was evaluated. The only interaction term of significance was found to be colinear and excluded. Logistic regression modeling was used to estimate odds ratios. Effect coding was used with "not-documented" being the reference level for all variables. Sample size was initially estimated for a one-way ANOVA showing a 10% difference in exam component documentation between those with and without a documented mTBI assuming an alpha of 0.05 and a power of 0.8. This calculation shows a sample size of 394 patients was needed and a graph of this calculation can be seen in Appendix 4. Analyses were conducted with RStudio 1.1.414 and R Version 3.4.2.

<u>Analysis for Specific Aim 1:</u> Compare the proportion of documented evaluations, expressed as a percent of the sample with 95% confidence intervals, to the recommended evaluations from the CDC, Department of Defense/Veterans Affairs, Sports Concussion Assessment and Tool 5th Ed, American Academy of Family Physicians, and the Ontario Neurotrauma Foundation. The evaluation

consists of 34 separate components encompassing signs, symptoms, cognition, and physical exam. It would be expected that all patients would receive a documented evaluation.

Analysis for Specific Aim 2: Using percentiles and 95% confidence intervals describe the proportion of patients meeting CDC criteria for an mTBI diagnosis who received a documented mTBI diagnosis. It would be expected that all patients in the subgroup would have a documented diagnosis.

Analysis for Specific Aim 3: Construct a logistic regression model to estimate the odds of a documented mTBI diagnosis and the effects of selected candidate variables. Modeling was done for the subgroup of patients who have documentation sufficient for diagnosis and for the entire study sample. Within the subgroup it is thought that all patients should receive a diagnosis as they would meet CDC criteria for diagnosis in the setting of a head injury.

RESULTS

Characteristics of patients

38,621 patients presented to the ED over 16 weeks. Of these patients, 441(1.1%) were identified as high risk for having an mTBI and met inclusion criteria. The final cohort of patients was 65.8% male and had an average age of 39 ± 16.3. Further information about the cohort's demographic and injury characteristics can be seen in Table 1.

Aim 1

Almost all recommended portions of an mTBI specific evaluation occurred in fewer than 50% of the study population. This comparison, to guideline recommendations, can be seen in Table 2. Symptoms documented most commonly included loss of consciousness (78.9, 74.9-82.5), headache (61.2%, 56.6 - 65.7), nausea (73.0%, 68.7 – 77.0) and vomiting (77.3%, 73.2 - 81.2). Memory loss and confusion were documented in 14.97% (11.9 - 18.6), 16.55% (13.08 - 20.32) of patients, respectively. mTBI specific physical exam components (vestibular-ocular motor testing, coordination, balance, gait, or cognition) were documented in fewer than 30% of the identified patients. Beyond the limited documentation of an mTBI evaluation, 96 (21.8% 18.2-25.9) of the 441 patients determined to be high risk for an mTBI received a documented diagnosed with mTBI. Even with 96 patients receiving a diagnosis, only 57 (12.9%,10.1-16.4) patients in the study had documented mTBI-specific discharge instructions.

Aim 2

A subgroup of patients (n = 272, 96 with a documented mTBI diagnosis and 176 without one) who had at least one documented CDC criteria for mTBI were examined to understand their frequency of diagnosis and determine what factors in this group affected the odds of diagnosis. The characteristics of this group did not vary significantly from the total study sample (Table 4). A documented diagnosis was seen in 35.3% (29.4 – 41.1) of the subgroup.

Aim 3

Within the subgroup from Aim 2, age, documentation of patients denying symptoms of numbness, and having an isolated head injury affected the odds of a documented mTBI diagnosis (Table 5). Experiencing an isolated head injury had the largest effect size for a documented mTBI diagnosis with an odds ratio of 2.09 (1.28 - 3.43). The increased odds 2.3 (1.3-4.4) of a documented mTBI diagnosis in the presence of an isolated head injury held when the same analysis was applied to the entire study population (Aim 1). Age was also found to have an odds ratio of .98 (.96 - .99) showing that with decreasing years of age there is an increased odd of diagnosis.

Identification

29,781 of the 38,621 [78.05% (76.38 - 79.85)] patients who presented to the ED were asked mTBI identification questions. Performance of the questions over time, as well as by answers to the identification questions is presented in Figure

2. Of the 8,840 subjects who were not screened, 2,294 did not receive a triage Emergency Severity Index (ESI) score likely indicating they did not complete triage. Also, a more substantial proportion of patients triaged as ESI 1, when compared to lower ESI scores, did not have an mTBI screen completed representing 488 of the total unscreened patients (~21% of those unscreened).

Physical Exam and Management

The majority of patients had a Glasgow Coma Scale value, pupillary exam, ocular movements, general motor exam, and general sensory exam documented (Table 6). Few patients had an mTBI-specific ocular exam documented: 0.91% (95% CI 0.27-2.4) had a saccade exam; 0.9% (95% CI 0.27-2.4) had a smooth pursuit exam, and 0.5% (95% CI 0.01-1.75) had a convergence exam. Additional portions of an mTBI exam had similar rates of documentation, showing 2.04 % (1.02-3.89) had a balance exam, 12.02% (9.29-15.4) had a gait exam, and .45% (0.13 – 1.75) had a cognitive exam.

DISCUSSION

Strengths and Limitations

This study is limited due to its identification of patients based on a triage screen, and the reliance on chart documentation as a surrogate for clinician thinking. It is understood that providers consider many conditions that may not be included in documentation; however, it is also reasonable to assume that significant management decisions made by the provider (i.e., pertinent history questions, physical exam maneuvers, or relevant differential diagnoses) would be documented. The identification tool that was used was not meant to be the gold standard for mTBI diagnosis but was assumed to be a reasonable gold standard for the identification of patients warranting an mTBI evaluation. The sensitivity and specificity of the identification questions have not been addressed and it is possible that false positives occurred. This is why the prediction of a documented mTBI diagnosis was only completed within the subgroup of patients with clinician documentation fulfilling the CDC criteria. We would not expect all patients in this study to be diagnosed with an mTBI but certainly all patients in the subgroup of patients with documentation fulfilling the diagnostic criteria for the disease should have been diagnosed. Yet, we note that patient identification questions used in triage were created verbatim from the CDC diagnostic criteria for mTBI. Patients included in this study were clustered within providers meaning that patients seen by the same provider were non-independent observations. We were unable to account for this clustering because there were few patients per provider (e.g. many providers saw only a single study participant). Because of this the confidence intervals are likely artificially narrow. Also, there are not agreed upon interventions, with high quality evidence, to improve outcomes in mTBI but current best practice guidelines, built upon the available evidence, were used as a standard for the comparison of the documented evaluation.

The primary strength of this study is that it represents to our knowledge the first Emergency Department investigation of mTBI evaluation practices where clinicians were unaware of the study. Additionally, previous studies have not compared the documented evaluation to best practice guidelines from various organizations to reveal the current evidence practice gaps.

Conclusion

We aimed to describe the documented evaluation and management for patients who were identified to be “at risk” for mTBI based on a simple 2 question screen at a level 1 trauma and emergency care center. Based on previous literature there is good reason to believe that mTBIs are being under-evaluated, under-diagnosed, and under-educated in Emergency Departments.(7, 9, 38). Our study confirms these findings by showing that very few patients received a documented mTBI specific evaluation. Among patients with documentation sufficient for diagnosis, only 35.3% were appropriately diagnosed with an mTBI. Additionally, we appeared to identify an injury complex isolated to the head as a key driver of diagnosis that doubled the odds of mTBI diagnosis. We believe this is likely because this presentation drew focus to the evaluation of the consequences of head injury and permitted a more targeted evaluation undistracted by additional injuries.

These findings reveal critical areas for possible intervention and improvement in the care of patients at high risk for mTBI. An appropriate evaluation and diagnosis allows patients to be informed of their recovery trajectory and understand the risk of future injuries. This trajectory includes post-mTBI symptoms, which have been a debated topic, but recent ED-based studies show that 33% of patients with an mTBI are below full functional status at 3 months and 22% at 1 year (21) .These results seem to contradict the "mild" moniker given to this subset of injuries. Patients also often return to the ED after an mTBI due to persistent symptoms (31, 39). Each patient with an mTBI needs to be given discharge education and receive appropriate follow up care to improve their long-term outcomes.

A documented mTBI occurred in the study sample less frequently than previous studies which we believe is attributable to two factors unique to this work (7, 9). First, previous studies have used direct observation of providers in the ED which can alter provider behavior and has in fact been shown to do so in the ED (40). This is why the design of this study was built upon blinding providers to the study's activities. Secondly, this study took place at a high-volume urban level 1 ED with a high level of acuity, time constraints, and resource limitations.

The relatively low rate of documented mTBI diagnoses also impacted certain portions of patient documentation and their interpretation. This is especially true in the subgroup, which had documentation sufficient for diagnosis, where a negative finding for numbness (the patients reports not having numbness) was found to be predictive of a documented mTBI diagnosis. This could either be a false positive result or the “negative" finding could be significant due to the low occurrence of positive findings combined with a low diagnosis rate. With the negative responses making almost all of the documented responses they would be more likely to have a larger proportion of mTBI diagnoses and as such be predictive.

Another important consideration was to not include the physical exam and management decisions in statistical model analyses. These portions of the documented care would be confounded by the provider initially considering mTBI. If the signs and symptoms of the patient did not cause the provider to consider an mTBI then an mTBI specific exam and management decision would not occur. Even though this data was not used for regression analysis, understanding the descriptive statistics of the evaluation that occurred is helpful in appreciating how providers approach these patients. Primarily, this is seen to be only the ruling out of serious injuries without a subsequent evaluation for mTBI.

Much of the documented physical exams are consistent with an Advanced Trauma Life Support Primary and Secondary survey and not any kind of mTBI specific physical exam. The comparison of the evaluations performed in this study to mTBI guidelines from various organizations, seen in Table 2, shows few patients received a specific mTBI evaluation. Components such as the Vestibulo-ocular Motor screening (VOMs), coordination, balance, or cognition were usually not documented. These portions of the exam are considered specific to a TBI evaluation but are not common assessments in a general trauma exam. Completing these exams is vital because of their ability to predict the patient's recovery trajectory and determine a post-injury baseline exam (41).

Inconsistencies in the type of evaluation patients received shines a light on the evidence-practice gap concerning mTBI care in emergency medicine, and likely most primary care settings as well (42). This study has shown that patients evaluations were primarily, and correctly, to rule out emergent intracranial injuries, yet it did not continue to non-urgent injuries. It is not difficult to picture this in real practice where a provider rules out the possibility of intracranial injury, with imaging or a decision rule, then the work-up for head injury stops and attention is then focused on other injuries. Subgroup analysis supports this view as patients with documented criteria sufficient for an mTBI diagnosis had an odds ratio of 2.1 for diagnosis if there was no other injury to evaluate. If patients did not have another injury to manage, then providers were more likely to diagnose the patients mTBI. We suggest that mTBI needs to be considered much more frequently, especially in patients with multiple injuries, so patients can be educated on their injury and have expectations set for their recovery.

This kind of emergent evaluation being downgraded to non-urgent care often occurs in the ED. A typical example would be the evaluation of an injury that could be an unstable ankle fracture which is found to be an ankle sprain. The management of the patient continues beyond ruling out a serious fracture to inform the patient of their likely recovery from a sprain. This approach with orthopedic injuries has the benefit of indoctrinated mantras of evaluation. Every patient will be examined to ensure they are neurovascularly intact; they will be splinted, told to be weight bearing as tolerated, and given follow up. Similar mantras of evaluation are needed in the evaluation of traumatic head injuries. Patient must have intracranial injuries ruled out, have an mTBI evaluation to set recovery expectations, be educated, including being told to advance their cognitive load as tolerated, warned of the dangers of re-exposure prior to healing, and be given follow up as needed. All of these components of patient care are needed to ensure appropriate care and improve patient outcomes.

Standardizing this evaluation would ensure patients with a possible mTBI, especially those without isolated head injuries, are appropriately managed. Sports medicine already has a highly standardized approach to possible mTBIs in the form of the SCAT-5 instrument, as do pediatric emergency departments using the ED-ACE tool (34, 37). Adult Emergency care would be greatly aided by the adoption of standardized tools for the care of patients with mTBI.

In conclusion, we have shown that few patients, who were identified as being high risk for mTBI, received any specific evaluation for mTBI. Additionally, having an isolated head injury was associated with an odds ratio of 2.06 for receiving a documented diagnosis. This demonstrates that there is a need for increased education on the criteria for diagnosis and highlights the need for interventions that will facilitate standardized mTBI care in the ED. A paradigm shift is needed in how mTBIs are thought about in the ED. Rosen's Emergency Medicine text (2018) noted that an mTBI may not be detected in the ED setting when the patient presents with more prominent injuries.(43) This idea that an injury, that can affect patient outcomes, would go undiagnosed in the ED is something that would not be tolerated in most areas of emergency medicine. There is no principled reason to treat mTBIs differently. As our understanding of mTBI advances, clinical practice must also advance to close the evidence-practice gap. Future research needs to examine ways to improve clinician knowledge of the mTBI evaluation, create ways to unobtrusively alert clinicians when patients are high risk for an mTBI, and seek to develop a pragmatic standardized adult Emergency Department mTBI evaluation.

REFERENCES

1. Taylor CA, Bell JM, Breiding MJ, et al. Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths - United States, 2007 and 2013. *MMWR Surveill Summ* 2017;66(9):1-16.
2. Control CfD. National Hospital Discharge Survey (Hospitalizations). 2001-2010.
3. Boggild M, Tator CH. Concussion knowledge among medical students and neurology/neurosurgery residents. *Can J Neurol Sci* 2012;39(3):361-8.
4. Mann A, Tator CH, Carson JD. Concussion diagnosis and management: Knowledge and attitudes of family medicine residents. *Can Fam Physician* 2017;63(6):460-6.
5. Zonfrillo MR, Master CL, Grady MF, et al. Pediatric providers' self-reported knowledge, practices, and attitudes about concussion. *Pediatrics* 2012;130(6):1120-5.
6. Carroll LJ, Cassidy JD, Holm L, et al. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med* 2004(43 Suppl):113-25.
7. Powell JM, Ferraro JV, Dikmen SS, et al. Accuracy of mild traumatic brain injury diagnosis. *Arch Phys Med Rehabil* 2008;89(8):1550-5.
8. Korley FK, Kelen GD, Jones CM, et al. Emergency Department Evaluation of Traumatic Brain Injury in the United States, 2009-2010. *J Head Trauma Rehabil* 2016;31(6):379-87.
9. Rowe BH, Eliyahu L, Lowes J, et al. Concussion diagnoses among adults presenting to three Canadian emergency departments: Missed opportunities. *Am J Emerg Med* 2018.
10. Evans RW. Persistent post-traumatic headache, postconcussion syndrome, and whiplash injuries: the evidence for a non-traumatic basis with an historical review. *Headache* 2010;50(4):716-24.
11. Wilson L, Stewart W, Dams-O'Connor K, et al. The chronic and evolving neurological consequences of traumatic brain injury. *Lancet Neurol* 2017;16(10):813-25.
12. Mayer AR, Quinn DK, Master CL. The spectrum of mild traumatic brain injury: A review. *Neurology* 2017;89(6):623-32.
13. Maas AIR, Menon DK, Adelson PD, et al. Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. *The Lancet Neurology* 2017;16(12):987-1048.
14. Castellani RJ, Perry G. Dementia Pugilistica Revisited. *J Alzheimers Dis* 2017;60(4):1209-21.
15. McKee AC, Robinson ME. Military-related traumatic brain injury and neurodegeneration. *Alzheimers Dement* 2014;10(3 Suppl):S242-53.
16. Lindquist LK, Love HC, Elbogen EB. Traumatic Brain Injury in Iraq and Afghanistan Veterans: New Results From a National Random Sample Study. *J Neuropsychiatry Clin Neurosci* 2017;29(3):254-9.
17. Ward J. N.F.L Brains [electronic article]. *New York Times.*

18. Omalu BI, DeKosky ST, Minster RL, et al. Chronic traumatic encephalopathy in a National Football League player. *Neurosurgery* 2005;57(1):128-34; discussion -34.
19. Kelly PJ, Rosenberg HJ. Diagnosis and management of concussion in sports. *Neurology* 1997;48(3):575-80.
20. Bazarian JJ, Atabaki S. Predicting postconcussion syndrome after minor traumatic brain injury. *Acad Emerg Med* 2001;8(8):788-95.
21. McMahon P, Hricik A, Yue JK, et al. Symptomatology and functional outcome in mild traumatic brain injury: results from the prospective TRACK-TBI study. *J Neurotrauma* 2014;31(1):26-33.
22. Quaglio G, Gallucci M, Brand H, et al. Traumatic brain injury: a priority for public health policy. *Lancet Neurol* 2017;16(12):951-2.
23. Dams-O'Connor K, Gibbons LE, Bowen JD, et al. Risk for late-life re-injury, dementia and death among individuals with traumatic brain injury: a population-based study. *J Neurol Neurosurg Psychiatry* 2013;84(2):177-82.
24. Gardner RC, Burke JF, Nettiksimmons J, et al. Dementia risk after traumatic brain injury vs nonbrain trauma: the role of age and severity. *JAMA Neurol* 2014;71(12):1490-7.
25. Gardner RC, Yaffe K. Epidemiology of mild traumatic brain injury and neurodegenerative disease. *Molecular and Cellular Neuroscience* 2015;66:75-80.
26. Comper P, Bisschop SM, Carnide N, et al. A systematic review of treatments for mild traumatic brain injury. *Brain Inj* 2005;19(11):863-80.
27. Jagoda AS, Bazarian JJ, Bruns JJ, Jr., et al. Clinical policy: neuroimaging and decisionmaking in adult mild traumatic brain injury in the acute setting. *Annals of Emergency Medicine* 2009;35(2):e5-40.
28. Committee on Sports-Related Concussions in Youth; Board on Children Y, and Families; Institute of Medicine; National Research Council; Graham R, Rivara FP, Ford MA, et al., editors. Sports-related concussions in youth: improving the science, changing the culture. *Mil Med* 2015;180(2):123-5.
29. Lumba-Brown A, Yeates KO, Sarmiento K, et al. Diagnosis and Management of Mild Traumatic Brain Injury in Children: A Systematic Review. *JAMA Pediatr* 2018;172(11):e182847.
30. Patrick SP, Gaudet LA, Krebs LD, et al. Emergency Physician Training on Mild Traumatic Brain Injury: A Systematic Review. *AEM Educ Train* 2017;1(4):346-56.
31. Ganti L, Conroy LM, Bodhit A, et al. Understanding Why Patients Return to the Emergency Department after Mild Traumatic Brain Injury within 72 Hours. *West J Emerg Med* 2015;16(3):481-5.
32. Terwilliger VK, Pratson L, Vaughan CG, et al. Additional Post-Concussion Impact Exposure May Affect Recovery in Adolescent Athletes. *J Neurotrauma* 2016;33(8):761-5.
33. West TA, Marion DW. Current recommendations for the diagnosis and treatment of concussion in sport: a comparison of three new guidelines. *J Neurotrauma* 2014;31(2):159-68.

34. Zuckerbraun NS, Atabaki S, Collins MW, et al. Use of modified acute concussion evaluation tools in the emergency department. *Pediatrics* 2014;133(4):635-42.
35. Group TMoC-mTBIW. VA/DoD Clinical Practice Guidelines for the managment of Concussion-Mild Traumatic Brain Injury. 2016, (Affairs DoV
36. Team MGD. GUIDELINE FOR CONCUSSION/MILD TRAUMATIC BRAIN INJURY & PERSISTENT SYMPTOMS 3rd Edition. *Ontario Neurotrauma Foundation* 2018.
37. Sport concussion assessment tool - 5th edition. *Br J Sports Med* 2017.
38. Bazarian JJ, McClung J, Cheng YT, et al. Emergency department management of mild traumatic brain injury in the USA. *Emergency Medicine Journal* 2005;22(7):473.
39. Baron Shahaf D, Bar S, Leiba R, et al. Unscheduled adolescents return to the emergency department following acute concussion. *Brain Inj* 2018;32(3):331-4.
40. Zinman R, Bethune P, Camfield C, et al. An observational asthma study alters emergency department use: the Hawthorne effect. *Pediatric emergency care* 1996;12(2):78.
41. Anzalone AJ, Blueitt D, Case T, et al. A Positive Vestibular/Ocular Motor Screening (VOMS) Is Associated With Increased Recovery Time After Sports-Related Concussion in Youth and Adolescent Athletes. *Am J Sports Med* 2017;45(2):474-9.
42. Patrick SP, Gaudet LA, Krebs LD, et al. Emergency Physician Training on Mild Traumatic Brain Injury: A Systematic Review. *AEM Education and Training* 2017;1(4):346-56.
43. Walls RM, Hockberger RS, Gausche-Hill M. Rosen's emergency medicine : concepts and clinical practice. *Emergency medicine*. Philadelphia, PA: Philadelphia, PA : Elsevier, 2018.

TABLES AND FIGURES

Table 1. Demographics and Injury Information

Total	441
Sex (%)	
Female	151 (34.2)
Male	290 (65.8)
Age (CI)	38.3 +/- 15.4
Race (%)	
Black	291 (66.0)
Caucasian	91 (20.6)
Hispanic	29 (6.6)
Other	10 (2.3)
Missing	20 (4.5)
Means of Arrival (%)	
Ambulance services	293 (66.4)
Walk-in	101 (22.9)
Police	23 (5.2)
Other	21 (4.8)
Unknown/Missing	3 (0.7)
Mechanism of Injury (%)	
Motor Vehicle Crash	151 (34.5)
Assault	123 (27.9)
Fall	99 (22.4)
Other	39 (8.8)
Pedestrian Struck by Car	18 (4.1)
Blunt object	6 (1.4)
Sports injury	5 (1.1)
Glasgow Coma Scale (%)	
< 12	5 (2.4)
13	9 (2.8)
14	26 (8.2)
15	271 (86.5)
Not Documented	128 (29.0)
Isolated Head Injury (%)	
Yes	140 (31.8)
No	301 (68.2)
Loss of Consciousness	
Yes	189 (42.9)
No	159 (36.1)
Not Documented	93 (21.1)
mTBI Diagnosis	
Yes	96 (21.8)
No	345 (78.2)
Provider Type (%)	
Attending Only	34 (7.7)
Attending & Resident	318 (72.1)
Advance Practice Provider	89 (20.2)

Table 2. Documented mTBI Specific Evaluation Components Compared to Various Clinical Practice Guidelines

			Evaluation Recommendations from Clinical Practice Guidelines*				
Exam Component	**%**	**CI**	AAFP	DOD/VA	CDC-ACEs	SCAT-5	ONTF
Dazed/Stunned	7.10	4.97 - 9.83	■		■		■
Confused	16.55	13.08 - 20.32	■		■		■
Repeats Questions	2.27	1.17 - 4.18	■		■		■
Answers Slowly	1.36	0.55 - 3.01			■		■
Loss of Consciousness	78.91	74.85 - 82.46	■	■	■	■	■
Seizures at Time of Injury	9.29	6.90 - 12.39	■	■	■	■	■
Memory Loss Before/After Event	14.97	11.93 - 18.61	■	■	■	■	■
Headache	61.22	56.59 - 65.67	■	■	■	■	■
Nausea	73.02	68.69 - 76.95	■	■	■	■	■
Vomiting	77.32	73.18 - 81.23	■	■	■	■	■
Balance Problems	27.21	15.11 - 47.47		■	■	■	■
Fatigue	16.78	13.57 - 20.56	■	■	■	■	■
Sensitivity to Light	36.73	32.66 - 41.33	■	■	■	■	■
Sensitivity to Noise	0.45	.01 - 1.75	■	■	■	■	■
Numbness Tingling	60.09	55.45 - 64.56	■	■	■	■	■
Drowsiness	25.62	21.76 - 29.90	■		■	■	■
Sleeping More than Usual	0.68	.13 - 2.08	■	■	■	■	■
Difficulty Falling Asleep	1.50	.70 - 3.31	■	■	■	■	■
Dizziness	32.42	28.22 - 36.93	■		■	■	■
Blurry Double Vision	70.07	65.63 - 74.15	■	■	■	■	■
Feeling Mentally Foggy	2.94	1.68 - 5.03	■	■	■	■	■
Feeling Slowed Down	0.23	0 - 1.41	■	■	■	■	■
Difficulty Thinking Clearly	5.22	3.47 - 7.74	■	■	■	■	■
Difficulty Concentrating	2.04	1.02 - 3.89	■	■	■	■	■
Difficulty Remembering	3.85	2.38 - 6.13	■	■	■	■	■
Cranial Nerves	29.02	24.98 - 33.43	■				■
Ocular Alignment	0.68	.13 - 2.08					
Saccade	0.91	.27 - 2.40				■	
Smooth Pursuit	0.91	.27 - 2.40					
Convergence	0.45	.01 -1.75					
Finger-Nose-Finger	9.30	6.9 - 12.34	■			■	
Dynamic Balance	2.04	1.02 -3.89	■			■	■
Gait	12.02	9.29 - 15.4	■			■	■
Cognitive Exam	0.45	.13 - 1.75	■			■	■

*AAFP = American Academy of Family Physicians, DOD/VA = Department of Defense and Veteran Affairs, CDC-ACE = CDC Acute Concussion Evaluation ED, SCAT-5 = Sports Concussion Assessment Tool 5th Ed , Ontario Neurotrauma Foundation

Table 3. Logistic model for the odds of a documented mTBI diagnosis among the entire study sample

	n	Coefficients Estimate	Std. Error	Z Value	Pr(>|z|)	Odds Ratio	95% CI
(Intercept)		-1.95	0.62	-3.12	0.00	0.14	(0.05-0.38)
Isolated Head Injury							
No	301	-	-	-	-	-	-
Yes	140	0.91	0.27	3.32	0.00	2.48	(1.58-3.90)
Provider							
Attending Alone	34	-	-	-	-	-	-
NP/PA + Attending	89	-0.64	0.56	-1.14	0.26	0.53	(0.21-1.36)
Resident + Attending	318	-0.55	0.50	-1.11	0.27	0.57	(0.26-1.36)
Age	441	-0.02	0.01	-2.42	0.02	0.98	(0.96-0.99)
Sex							
Female	151	-	-	-	-	-	-
Male	290	-0.11	0.27	-0.39	0.69	0.90	(0.58-1.41)
Symptomatic Nausea							
Not Documented	119	-	-	-	-	-	-
Negative	299	0.50	0.40	1.26	0.21	1.65	(0.87-3.22)
Positive	23	0.85	0.60	1.41	0.16	2.33	(0.86-6.21)
Symptomatic Headache							
Not Documented	171	-	-	-	-	-	-
Negative	130	-0.21	0.35	-0.59	0.56	0.81	(0.45-1.45)
Positive	140	0.59	0.32	1.84	0.07	1.80	(1.07-3.06)
Symptomatic Numbness							
Not Documented	119	-	-	-	-	-	-
Negative	299	0.57	0.32	1.78	0.07	1.78	(1.05-3.05)
Positive	23	0.49	0.84	0.58	0.56	1.63	(0.33-5.86)
Confusion							
Not Documented	368	-	-	-	-	-	-
Negative	41	-0.35	0.46	-0.76	0.45	0.70	(0.32-1.47)
Positive	32	1.05	0.45	2.31	0.02	2.85	(1.34-6.00)
Loss of Consciousness							
Not Documented	93	-	-	-	-	-	-
Negative	159	-0.19	0.41	-0.46	0.65	0.83	(0.42-1.65)
Positive	189	0.84	0.37	2.23	0.03	2.31	(1.27-4.36)

Table 4. Demographics and Injury Information of Study Population and Subgroup

	Total Sample	Subgroup	p-value*
Total	441	272	
Sex (%)			
Female	151 (34.2)	83(30.5)	0.34
Male	290 (65.8)	189(69.5)	
Age	39.5 +/- 16.3	38.47 +/- 15.51	0.41
Race (%)			
Black	291 (66.0)	180(66.2)	
Caucasian	91 (20.6)	54(19.8)	
Hispanic	29 (6.6)	17(6.3)	0.85
Other	10 (2.3)	10(3.7)	
Missing	20 (4.5)	11(4.0)	
Means of Arrival (%)			
Ambulance services	293 (66.4)	192(70.6)	
Walk-in	101 (22.9)	56(20.6)	
Police	23 (5.2)	13(4.8)	0.62
Other	21 (4.8)	8(2.9)	
Unknown/Missing	3 (0.7)	3(1.1)	
Mechanism of Injury (%)			
Motor Vehicle Crash	151 (34.2)	77(28.3)	
Assault	123 (27.9)	81(29.8)	
Fall	99 (22.4)	64 (23.5)	
Other	39 (8.8)	30(11.0)	0.76
Pedestrian Struck by Car	18 (4.1)	11(4.0)	
Blunt object	6 (1.4)	5(1.8)	
Sports injury	5 (1.1)	4(1.5)	
Glasgow Coma Scale (%)			
< 12	7 (1.6)	4(1.5)	
13	9 (2.0)	8(2.9)	
14	26 (5.9)	23 (8.5)	0.80
15	271 (61.5)	164(60.3)	
Not Documented	128 (29.0)	73(26.8)	
Isolated Head Injury (%)			
Yes	140 (31.8)	103(37.9)	0.11
No	301 (68.2)	169(62.1)	
Loss of Consciousness			
Yes	189 (42.9)	189(69.5)	
No	159 (36.1)	43(15.8)	<.001
Not Documented	93 (21.1)	40(14.7)	
mTBI Diagnosis			
Yes	96 (21.8)	96(35.3)	<.001
No	345 (78.2)	176(64.7)	
Provider Type (%)			
Attending Only	34 (7.7)	13(4.8)	
Attending & Resident	318 (72.1)	206(75.7)	0.29
Advance Practice Provider	89 (20.2)	53(19.5)	

* Student T-test,fisher exact test or Chi squared

Table 5. Logistic model for the odds of a documented mTBI diagnosis among a subgroup which has at least 1 criteria for an mTBI diagnosis documented

	n	Coefficients Estimate	Std. Error	Z Value	Pr(>|z|)	Odds Ratio	95% CI
(Intercept)	272	0.16	0.88	0.19	0.85	1.18	(0.28-5.16)
Isolated Head Injury (n)							
No	169	-	-	-	-	-	-
Yes	103	0.74	0.30	2.47	0.01	2.09	(1.28 - 3.43)
Provider							
Attending Alone	13	-	-	-	-	-	-
NP/PA + Attending	53	-1.12	0.70	-1.59	0.11	0.32	(0.10-1.03)
Resident + Attending	206	-0.87	0.64	-1.35	0.18	0.42	(0.14-1.21)
Age	272	-0.02	0.01	-2.32	0.02	0.98	(0.96-0.99)
Sex							
Female	83	-	-	-	-	-	-
Male	189	-0.13	0.30	-0.45	0.65	0.87	(0.53-1.42)
Symptomatic Nausea							
Not Documented	60	-	-	-	-	-	-
Negative	193	0.23	0.43	0.54	0.59	1.26	(0.63-2.58)
Positive	19	0.24	0.62	0.38	0.70	1.27	(0.45-3.53)
Symptomatic Headache							
Not Documented	95	-	-	-	-	-	-
Negative	74	-0.26	0.39	-0.67	0.51	0.77	(0.41-1.45)
Positive	103	0.37	0.36	1.04	0.30	1.45	(0.81-2.61)
Symptomatic Numbness							
Not Documented	102	-	-	-	-	-	-
Negative	160	0.71	0.34	2.08	0.04	2.03	(1.167-3.585)
Positive	10	-0.37	0.90	-0.41	0.68	0.69	(0.131-2.720))
Confusion							
Not Documented	216	-	-	-	-	-	-
Negative	24	-0.31	0.50	-0.62	0.53	0.73	(0.311-1.640)
Positive	32	0.49	0.44	1.12	0.26	1.64	(0.789-3.365)
Loss of Consciousness							
Not Documented	40	-	-	-	-	-	-
Negative	43	0.63	0.51	1.24	0.22	1.88	(1.187-7.413)
Positive	189	-0.15	0.42	-0.36	0.72	0.86	(0.433-1.732)

Table 6. Physical Exam Documentation and Management Decisions

Component	n	percent
GCS	313	71% (66.6-75)
Pupil Symmetry	390	88.4% (85.1-91.1)
Pupil Responsiveness	386	87.5% (84.1-90.3)
Extraocular Movements	372	84.4% (80.7-87.5)
Ocular Alignment	3	0.7% (0.1-2.1)
Saccade	4	0.9% (0.3-2.4)
Smooth Pursuit	4	0.9% (0.3-2.4)
Convergence	2	0.5% (0-1.7)
Motor	332	75.3% (71-79.1)
Sensory	282	63.9% (59.4-68.3)
Cranial Nerves	128	29% (25-33.4)
Reflex	19	4.3% (2.7-6.7)
Reaction Time	1	0.2% (0-1.4)
Finger-Nose-Finger	41	9.3% (6.9-12.4)
Dynamic Balance	9	2% (1-3.9)
Gait	53	12% (9.3-15.4)
Patient Ambulatory	280	63.5% (58.9-67.9)
Cognitive Exam	2	0.5% (0-1.7)
Head CT Ordered	293	66.4% (61.9-70.7)
mTBI Listed in Differential Diagnosis	123	27.9% (23.9-32.3)
mTBI Listed in Final Diagnosis	96	21.8% (18.2-25.9)
mTBI Discharge Instructions Given	57	12.9% (10.1-16.4)
Disposition		
Admitted	85	19.3% (15.9-23.2)
Discharged, Ambulatory	343	77.8% (73.7-81.4)
Discharged, Not Ambulatory	8	1.8% (0.9-3.6)

Figure 1. Study Diagram

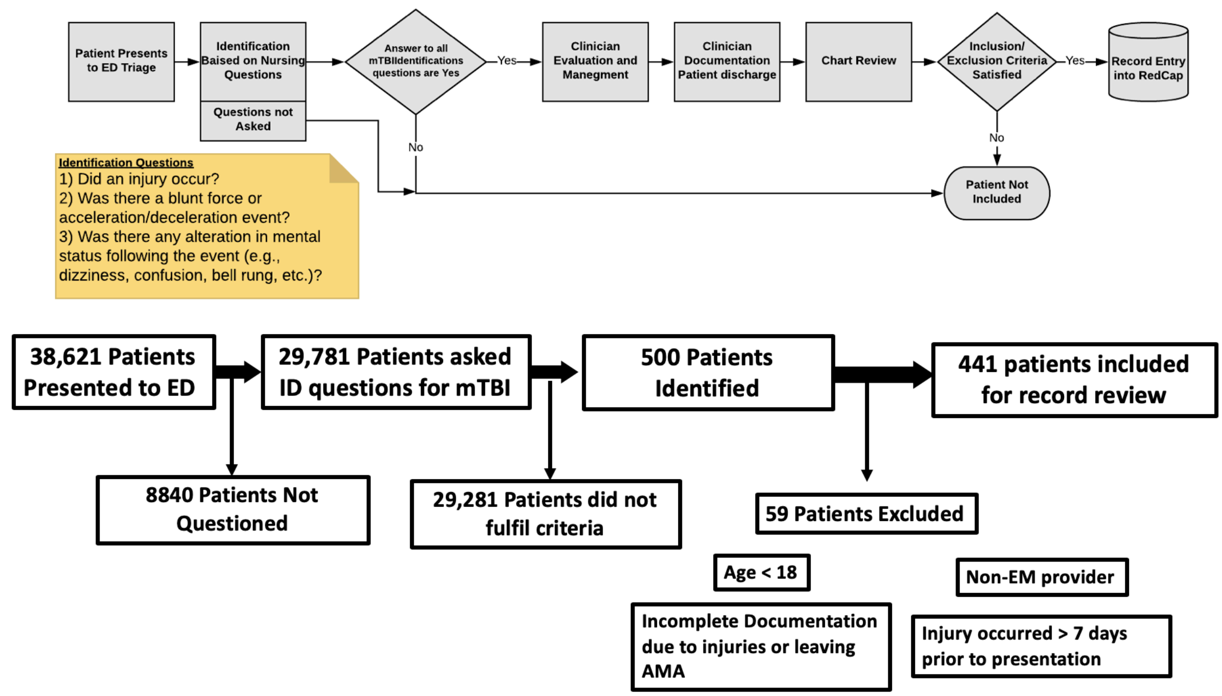
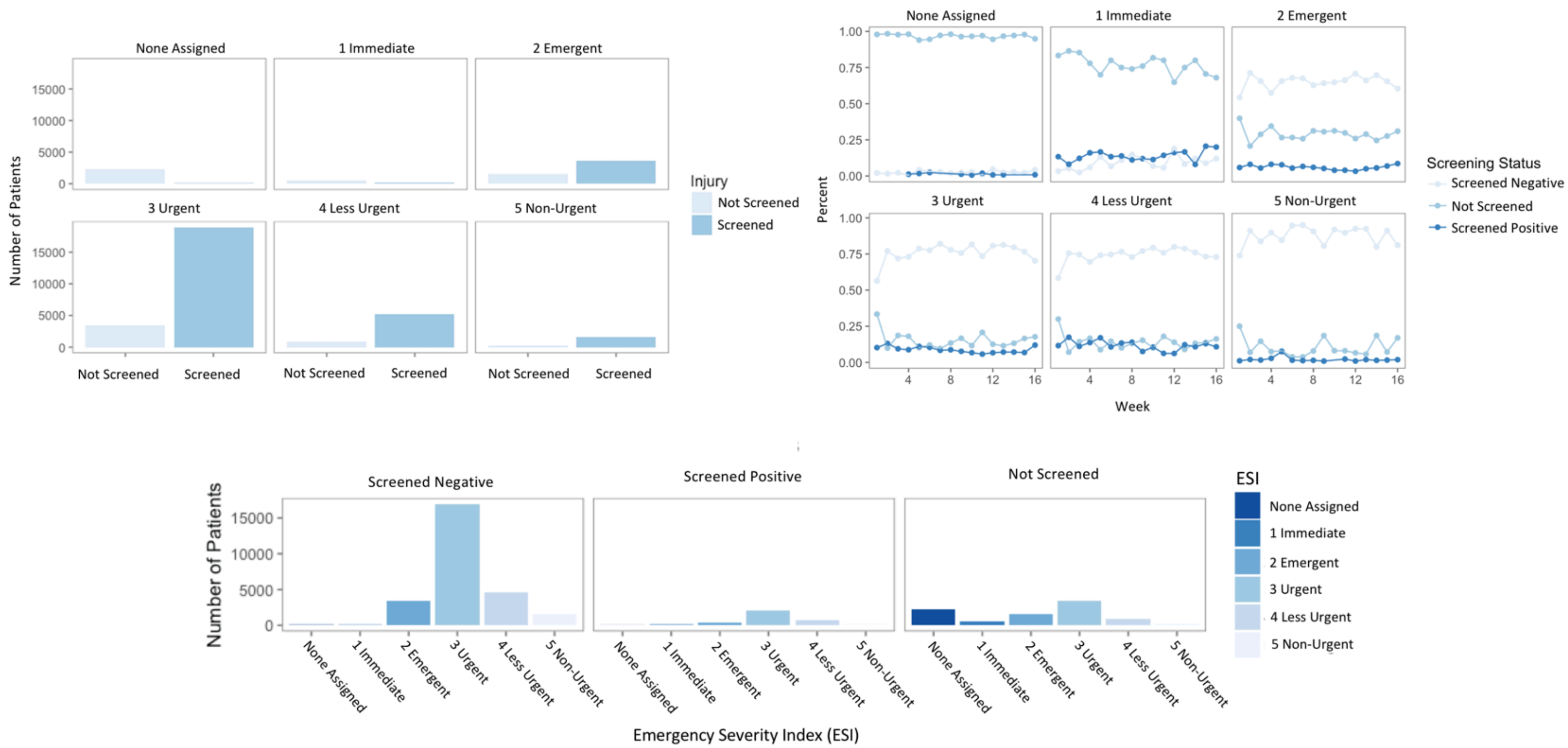
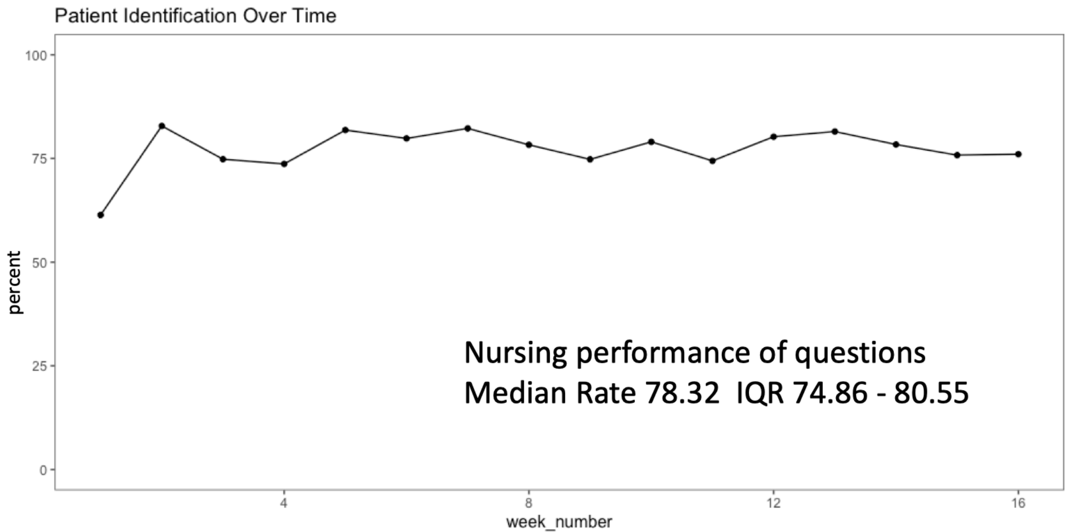
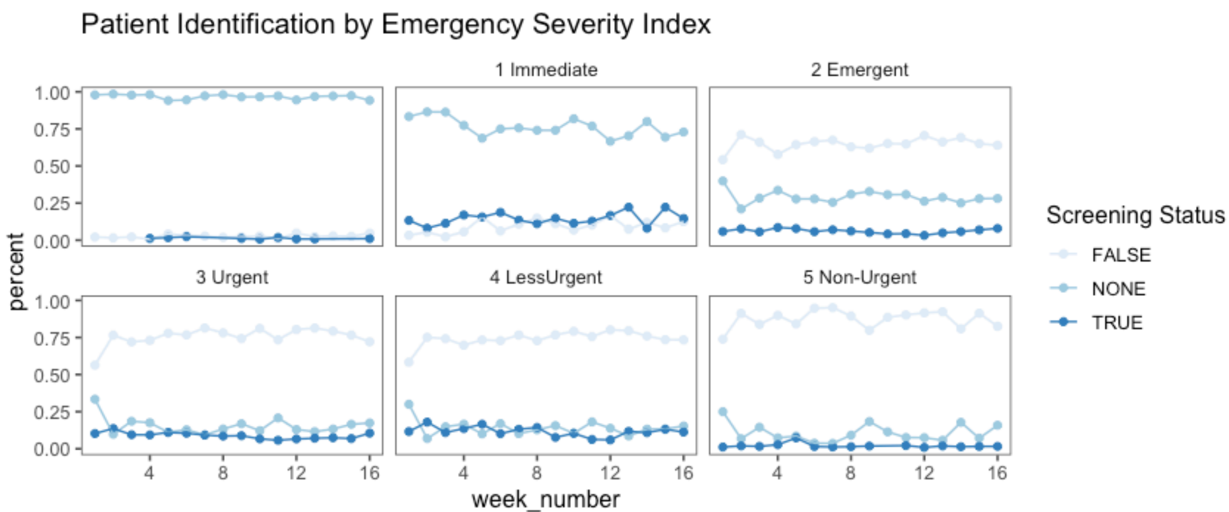
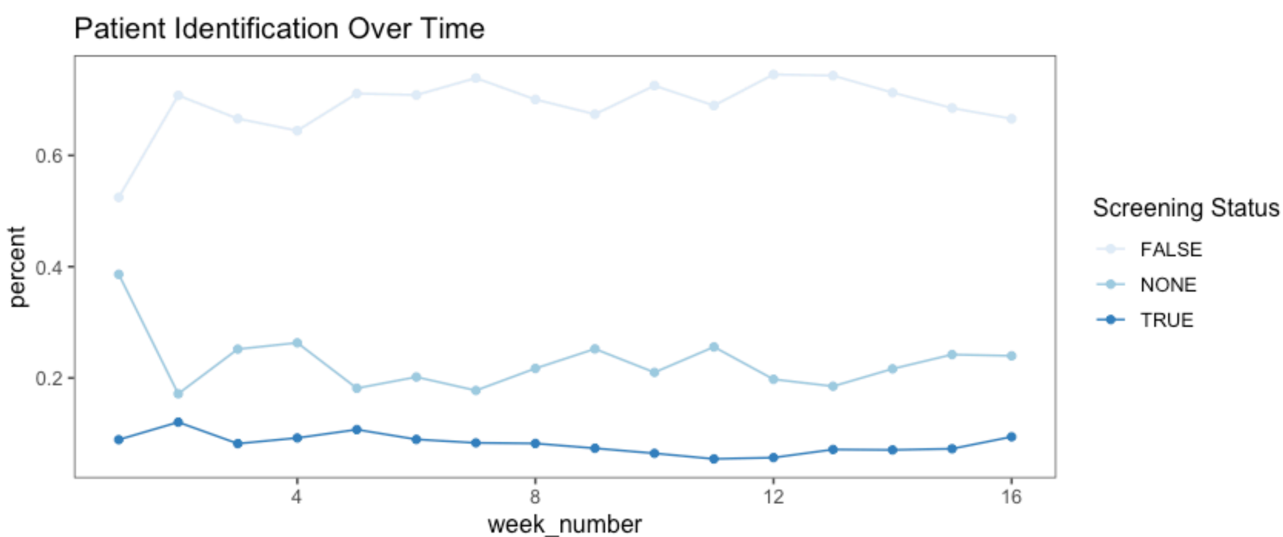


Figure 2. Performance of Screening Questions stratified by by Emergency Severity Index Value and Over Time




Patient Identification Over Time
100
75
50
25
0
percent
4
8
12
16
week_number
Nursing performance of questions
Median Rate 78.32 IQR 74.86 - 80.55


Patient Identification by Emergency Severity Index
1 Immediate
2 Emergent
3 Urgent
4 LessUrgent
5 Non-Urgent
1.00
0.75
0.50
0.25
0.00
percent
4
8
12
16
week_number
Screening Status
FALSE
NONE
TRUE


Patient Identification Over Time
0.6
0.4
0.2
percent
4
8
12
16
week_number
Screening Status
FALSE
NONE
TRUE

APPENDIX

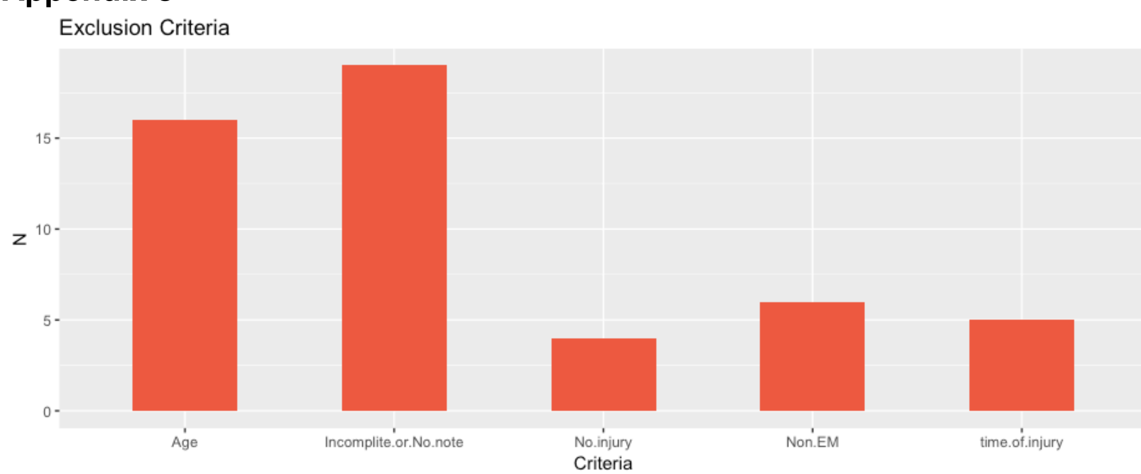
Appendix 1

General Encounter Information	**Evaluation**			**Management and Disposition**
Provider type	***Symptoms***	***Signs***	***Physical Exam***	ETOH level
Arrival date	Headache	Dazed/Stunned	GCS	UDS screen
Arrival time	Nausea	Confused	Pupil Symmetry	Pain medication given
Means of arrival	Vomiting	Repeats question	Pupil Responsiveness	Head CT ordered
Trauma level	Balance Problems	Answers slowly	Extra-Ocular movements	mTBI in Differential
Stat Pack indication	Fatigue	Loss of consciousness	Ocular alignment	mTBI as a Diagnosis
Age	Sensitivity to Light	Seizure at the time of injury	Saccades	mTBI ICD-10 code
Sex	Sensitivity to Noise	Memory Loss	Smooth Pursuits	mTBI discharge instructions
Race	Numbness/Tingling		Convergence	Disposition
Screening Questions	Drowsiness		Motor Exam	
Mechanism	Sleeping more than Usual		Sensory Exam	
Isolated head injury	Sleeping Less than usual		Cranial Nerves	
	Difficulty falling asleep		Reflex	
	Dizziness		Reaction Time	
	Blurry/double vision		Finger-nose finger	
	Ringing in Ears/Tinnitus		Dynamic Balance	
	Feeling Foggy		Gait	
	Feeling Slowed down		Gait with Turning	
	Difficulty thinking		Patient Ambulatory	
	Difficulty concentrating		Cognitive exam	
	Difficulty remembering			
	Irritability			
	Sadness			
	More Emotional			
	Nervousness			

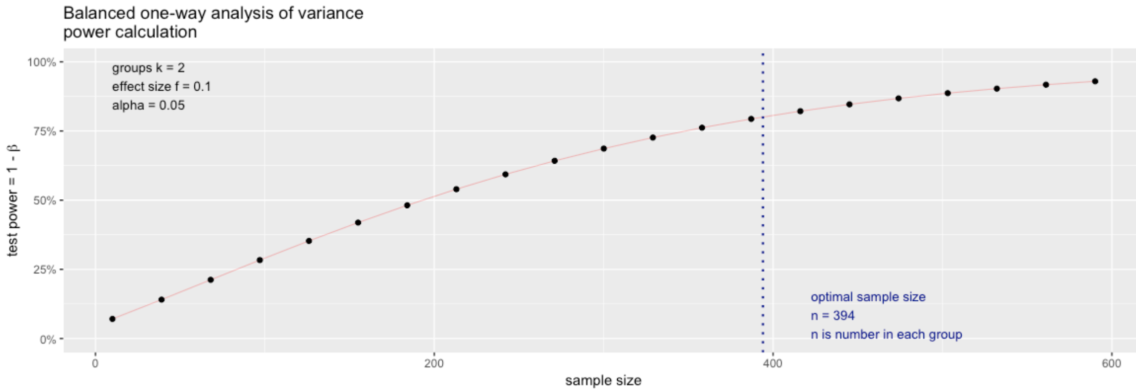
Appendix 2. Mapping the variables used to create the subgroup of patients which had documentation satisfying the CDC Criteria for an mTBI Diagnosis

Criteria 1: Any period of observed or self-reported transient confusion, disorientation, or impaired consciousness
Feeling dazed
Confusion
Repeating themselves
Being slow to respond to questions
Having difficulty thinking
Feeling foggy
Criteria 2: Any period of observed or self-reported dysfunction of memory (amnesia) around the time of injury
Memory dysfunction
Feeling like they cannot remember the injury
Criteria 3: Observed signs of other neurologic or neuropsychological dysfunction
Numbness
Double vision
Tinnitus
Dizziness
Sensitivity to light
Sensitivity to noise
Balance dysfunction
Criteria 4: Any period of observed or self-reported loss of consciousness lasting 30 minutes or less.
Loss of consciousness

Appendix 3



Appendix 4.


Balanced one-way analysis of variance
power calculation
groups k = 2
effect size f = 0.1
alpha = 0.05
optimal sample size
n = 394
n is number in each group
test power = 1 - β
sample size
100%
75%
50%
25%
0%
0
200
400
600