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Mild Traumatic Brain Injury: The Feasibility of Reducing Repetitive Head CT Scans in Stable Patients

THESIS

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in Biomedical and Translational Sciences

By

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ABSTRACT OF THE THESIS

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By

Geoffrey Christopher Darby

Master of Science in Biomedical and Translational Sciences

University of California, Irvine, 2015

Professor Sherry Kaplan, Chair

Introduction: Traumatic brain injuries (TBI) are a leading cause of mortality and morbidity. The Glasgow Coma Scale (GCS) is a clinical TBI severity grading system. CT scanning has also become a sensitive diagnostic tool in assessing TBIs. Currently, there is a widely varied practice in evaluation of patients with mild TBIs. We hypothesize that patients with an initially positive head CT and stable GCS (15) are less likely to have positive repeat CTs than patients who's GCS has dropped below 15.

Methods: A 5 year retrospective analysis was done (Jan 2007-Dec 2011). Data points included ISS, ICU LOS, Hospital LOS, initial GCS, first head CT scan, lowest GCS between scans, and treatment after 2nd CT. Positive CT findings were considered an increase in contusion, bleed, edema, midline shift, or a new bleed.

Results: In 369 patients, those with a stable GCS (15) were less likely to have a positive repeat CT scan than patients who whose GCS dropped (12.9% vs. 24.9%, p<.01). They also tended to require less Interventions (0.8% vs. 4.0% , p=0.09). Unchanged patients were more likely to have a lower ISS (14 vs. 17, p<.01), ICU LOS (2 vs. 3 days, P<.01), and Hospital LOS (4 vs. 6, P<.01).

Conclusion: CT scans are a rapid, non-invasive diagnostic tool that can accurately diagnose a patient’s intracranial status. Our study shows that most patients who have initially positive CT scans and maintain a stable GCS of 15 can still safely forego the cost and radiation exposure of repeated scans.

Chapter 1: Introduction

Traumatic brain injuries are major cause of mortality and morbidity in United States and worldwide. Traumatic brain injury (TBI)s account for over 1.4 million ER visits each year in United States.[1] For an already strained medical system, this medical problem costs the United States in both human life and resources. As of 2010, TBIs accounted for 715 ED visits and 92 hospitalizations per 100,000.[1] Over the last 10 years, the number of ED visits has risen despite a decrease in the number of TBI related deaths.[1] Traumatic brain injury hospitalizations continue to remain stable over the last 10 years.[1]

Traumatic brain injuries are defined as a head injury that disrupts normal function of the brain. This can be caused by a blow or penetration to the skull that directly or indirectly injuries the brain, but not all injuries to the head will cause a TBI. Most commonly, falls are the main cause of TBI's and account for around 40% of all TBIs in the US.[12] Falls occur more frequently in elderly and children accounting for more than 81% of TBIs among the former and 55% in the latter.[1,2] The next most common cause of TBI's are blunt trauma to the head accounting for approximately 15% of TBIs and motor vehicle accidents accounting for 14.4%.[1–3]

Traumatic brain injuries are typically graded as mild, moderate or severe. The Glasgow Coma Scale (GCS) was developed in 1974 and has been used to help clinicians assess a patient's mental status. Few other instruments are as effective and easy to use in clinical practice as the Glasgow coma scale.

In the late 1970's, x-ray computed tomography (CT) scan or CT scan changed the way that trauma and neurosurgeons managed traumatic brain injuries. As computer systems and programming continued to evolve, surgeons were able to use CT scans to more safely and quickly assess head trauma, replacing invasive monitoring. Head CT scans can be performed rapidly and can give clinicians accurate and safe information about damage to the brain without invasive monitoring. With this information, trauma and neurosurgeons can make the decision to place intracranial monitors or perform a decompressive craniotomy. Through the 1980's and into the 1990's, head CT scans became the standard management for any patients who came into the ER with a GCS score of less than 14 and evidence of head trauma.[4]

A substantial body of literature related to severe and moderate traumatic brain injuries suggests that patients who present to the emergency department with a Glasgow Coma Scale score of less than 13, a repeat head CT scan is warranted due to the high clinical suspicion of increased bleed size and increasingly inaccurate clinical instruments to assess the patient and need for neurosurgical intervention.[4–6] Moderate and severe TBI patients are more likely to be placed on mechanical ventilators due to their inability to breath on their own or due to other concurrent injuries. Repeat CT scans are used to determine whether a neurosurgical intervention is warranted. Among patients with a mild TBI, clinicians are able to interact with patients and therefore assess their mental and neurological status; whereas most patients with moderate or severe TBIs are unresponsive and intubated to protect their airway.

Anticoagulant drugs are used to prevent blood clot formation and more disastrous conditions such as stroke or myocardial infarction. When a patient comes to the ER on an anticoagulant and TBI, trauma and neurosurgeons become more concerned about an increased risk for intracranial bleeding and death. [7–9] Especially in head trauma, anticoagulant and antiplatelet therapy may cause larger and more problematic intracranial bleeding that may require aggressive therapy to prevent cerebral infarction or even brainstem herniation. Such patients require additional intervention such as the addition of fresh frozen plasma or even packed platelets. Patients on anticoagulant therapy who have traumatic brain injuries may represent a unique management challenge, however, little empirical evidence exists to identify the most effective management of mild TBI patients who are on anticoagulants and the time of injury.

Patients who have sustained a mild TBI with a GCS of 15 and no neurological symptoms continue to receive the same clinical management as patients who deteriorate. These otherwise normal patients may not need to be exposed to the radiation of a CT scan and the related costs of care when observation may be more appropriate management. Studying a subset of these patients, those on anticoagulant therapy who have mild TBI's and maintain a GCS of 15, would provide information about the need for additional scans.

This study will provide data to address the following research questions:

1. Do patients with mild TBIs and a GCS of 15 need to have repeat head CT scans?
2. Do patients who are on antiplatelet or anticoagulant therapy, mild TBI's and a GCS of 15 need to get repeat head CT scans?

This study has provided further evidence that repeat head CTs in patients with mild TBI's is not warrented, GCS of 15; and more evidence is needed to look at the need for additional radiologic imaging for the subgroups of those patients who in addition are taking anticoagulants at the time of the imaging.

Chapter 2: Background

In the 1970's, Computer x-ray tomography became known for its vital role in management of acute head trauma.[10,11] CT scans are a noninvasive way to look at intracranial lesions such as bleeding or edema and allows the clinician to use that information to make a more accurate decision to their management. Before CT scans were introduced, traumatic brain injuries were only visualized using skull x-rays.[11] The enhanced imaged provided by a CT scan lead to a shift away from inaccurate and unwieldy single frame x-rays to allow for a more comprehensive clinical picture. In Zimmerman et al.'s paper, CT scans led to improved outcomes for patients by identifying hemorrhagic lesions and cerebral swelling. They were able to reduce angiography by 84%, surgical intervention by 58%, in skull radiograph by 24%. In addition to decreased mortality, CT scans have been shown to reduce unnecessary angiographies, x-rays, and craniotomies.[12] As CT scans became a widely accepted and technology improved, the types of hemorrhage and edema were better classified according to position, size, and x-ray absorption. Head CT scans therefore became an integral part of traumatic brain injury management.

In Larson et al.'s study, the National Hospital Ambulatory Survey was used to evaluate the number of ED visits and associated CT usage from 1995 to 2007.[13]This study showed that from 1985 to 2007 there was a six-fold increase in CT usage. Among the results, head CT usage increased from 7 million scans to 16.2 million scans. Interestingly, the percentage of ED visits involving CT scan traumatic head injury according to chief complaints increased from 19.1% in 1995 to 40.7% in 2007. They also noted that there was no inflection point in CT usage, but there have been other subsequent studies with contradictory results. Shinagare et al. suggest that the rate the CT scans began to decline around 2008 has been decreasing ever since.[14]

The Glasgow coma scale (GCS) was created in 1974 as a clinical instrument to measure patients impaired consciousness or mental status. At that time, there was no clinical instrument that was reliable and easy-to-use. Any member of the clinical team, without specialized training, could use this instrument.[15] The GCS is made up of three parts: eye-opening, verbal response, and motor response. The three different sections are included in the table below (see Figure 1). The scores range from 3-15 with a higher GCS of 15 considered normal, and a score of 3 considered severely debilitated. The three different categories of traumatic brain injuries are severe between 3 and 8, moderate between 9 and 12, and mild between 13 and 15. The scale has been and continues to be an integral part of clinical diagnosis and management of patient management.

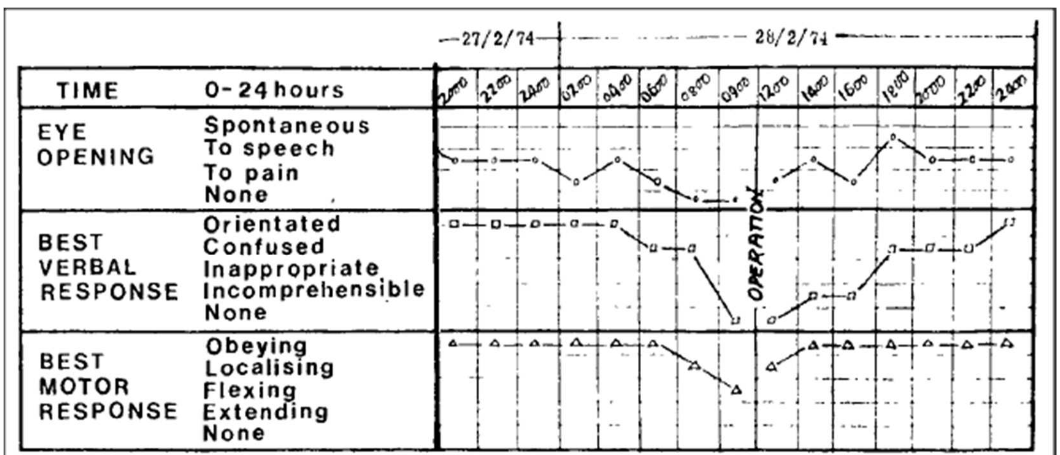

Chart for recording assessment of consciousness.

Fig. 2.1 - Glasgow Coma Scale broken down by three clinical components.

In 1996, Miller et al. studied patients with the GCS of 15 and the witnessed loss consciousness/amnesia in 1382 patients. They observed that several factors were indicative of an abnormal CT scan: severe headache, nausea, vomiting, signs of trauma, and skull depression.[16] In the second study in 1997, Miller et al. studied head trauma patients with a GCS of 15 and their clinical factors mentioned above to see if, using these clinical indicators, they were able to predict abnormal CT scans. Among patients with no risk factors, 3.7% of those patients had abnormal CT scans and among the patients with one or more risk factors, 11% of them had abnormal scans. Additionally, patient with no risk factors did not require neurosurgical intervention; whereas, 5 (0.6%) of patients with one or more risk factors required intervention. When they created guidelines using their clinical indicators, they found their sensitivity of these guidelines was 65% and specificity was 63%.[17]

The Canadian head CT rule is a set of guidelines created in 2001 by Stiell et al. They combined the same principles as the previous studies combining five high risk factors and two moderate risk factors to be used to determine whether the patient needed to have the head CT scan. From their patient population, 8% of those patients had clinically important brain injuries and 1% required neurological intervention. Following the guidelines, they were able to achieve close to 100% sensitivity for intervention. With all seven risk factors as a composite, the instrument was 98.4% sensitive and 49.6% specific. This clinical instrument could be used to reduce CT ordering by approximately 54%.[3]

The New Orleans CT rule made by Haydel et al. in 2000 and is another clinical guideline for standardizing clinical decision-making and providing ER physicians and trauma surgeons guidelines on appropriate physician CT ordering. Among patients with a GCS a 15, positive loss of consciousness, and no neurological deficits this group noted short-term memory deficits, drugs or alcohol intoxication, physical evidence of trauma above the clavicles, age greater than 60, seizure, headache, vomiting, and coagulopathy, as indications for patients to receive a head CT scan. The New Orleans CT rule had an 100% sensitivity for neurocranial trauma lesions but only 24% specificity.[18] Both the Canadian head CT rule and New Orleans have a 100% sensitivity to neurological interventions.

A study by Smits et al. compared the Canadian head CT rule and the New Orleans Head CT guidelines. They applied both rules in a multicenter study to compare the original results to their own prospective trial period. From their studies, Smits et al. found that both the Canadian Head CT tool and the New Orleans rule had 100% sensitivity for detecting lesions that require neurological intervention.[19] The New Orleans had a higher sensitivity (98.4% vs. 83.4%) but a lower specificity (3.2% vs. 39.4%) for detection of intracranial trauma. The number of excess CTs reduced by the New Orleans guideline was also lower (3.0% vs. 37.3%). These investigators concluded that while the Canadian Head CT rule had a moderately high sensitivity of 83.7%, it was not sufficiently accurate for clinicians to consider forgoing a head CT and therefore miss an important intracranial finding. The Canadian head CT rule does have a higher sensitivity and a greater number of excess CT eliminated from clinical management, representing a potential improvement over the New Orleans guideline for detecting patients with intracranial bleeds and reduction in inappropriate CT scans. Other studies have shown the same high level of sensitivity for detecting patients who required neurological intervention.[20,21]

The usefulness of initial CT scanning in patients who meet clinical risk factors has been well established and is considered the standard of care. Whether patients required further observation for a period of time to determine whether a repeat CT scan is needed to assess the progress of the bleed is controversial. Sifri et al. studied patients with mild traumatic brain injury to assess the value of this repeat scan. This study found that 151(75%) the patients had persistently normal mental status, while 51(25%) had worsening status. The repeat CT scans of the normal group showed progression of the bleed or contusion in around 15% of patients versus 35% in the abnormal. None of the normal patients were sent for a neurological intervention, whereas, 3% of the abnormal went for neurological invention (craniotomy, ICP Monitor, etc).

The authors conclusions were that routine repeat scanning of patients with mild traumatic brain injuries may not indicated.[22]

In 2004, Brown et al. did a prospective study looking at the value of routine repeated CT scans and change in clinical management. They found that 90% of patients with a positive CT scan got rescanned on routine basis without any neurological changes such as weakness, changes in mental status, etc. Rhee et al. found that the 3% of patients who did require neurological intervention had changes in neurologic status before the CT scan was scheduled. They concluded that routine repeat head CT scans for patients with TBI and no other findings were not supported.[23]

In 2014, Joseph et al. proposed the Brain Injury Guidelines (BIG). From these guidelines, they performed a prospective study looking at the effectiveness of their clinical instrument. A total of 1232 patients were categorized into BIG severity categories of 1, 2, or 3, see a description of the guidelines provided in the table below. They found that none of their patients categorized as BIG 1 had a worsening CT study or clinical deterioration that would indicate a need for repeat CT scans. In the BIG 2 category, 2.6% had worsening repeat scans but no patients needed clinical interventions. From their BIG 3 category, 21.6% had worsening head CT scans and 3% of those patients needed neurological intervention. They created a set of guidelines that could be easily used for emergency room physicians and trauma surgeons with an evidence-based foundation.[24]

	BIG 1 (n = 121)	BIG 2 (n = 313)	BIG 3 (n = 798)
Age, mean (SD), y	43.1 (22.3)	35.5 (25.1)	46.5 (26.4)
Male, %	57	66	68
Antiplatelets, %			
Aspirin	Nil	Nil	15
Clopidogrel	Nil	Nil	3.4
Ibuprofen	Nil	Nil	2.5
Anticoagulants	Nil	Nil	3.9
Intoxication	Nil	30	26
GCS score	15 (15–15)	15 (15–15)	15 (7–15)
Abnormal neurologic examination finding, %	Nil	Nil	23
Loss of consciousness, %	68	50	65
ISS	12 (10–18)	16 (10–18)	18 (14–25)
Head AIS score	2 (2–3)	3 (2–3)	3 (3–4)

Table 2.1 – Adapted from Joseph et al. (2014)[24]

Anticoagulation in Traumatic Brain Injuries

The mean age of the U.S. population on anticoagulation therapy continues to rise.[25] A number of studies have shown the benefits of anticoagulation for patients with myocardial infarction or stroke, but when trauma patients present to the hospital on anticoagulation, this therapy can represent a major problem.[26–29] Studies have shown major adverse outcomes for patients with severe traumatic brain injuries who are on anticoagulation or antiplatelet therapy than with severe traumatic brain injuries alone. Patients who are on anticoagulant therapy have a higher rate of brain death and mortality than those who are not on anticoagulant therapy.[26,30,31] Many of these studies have grouped traumatic brain injuries into one category instead of segregating them by severity.[26,27]

Garra et al. studied anticoagulated patients, patient who were taking anticoagulant therapy such as warfarin or antiplatelet therapy such as aspirin, who have sustained mild traumatic brain injuries, without loss of consciousness or neurological deterioration, and looked at the progression to clinically significant intracranial bleeds. Of the 65 patients included in their study, all 39 patients who received head CTs had negative results. They concluded that anticoagulated patients who sustained mild head trauma without loss of consciousness or neurological deterioration did not require CT scanning.

Many studies have investigated the different types of anticoagulation among patients with head trauma. The International normalized ratio(INR) is the laboratory test used to measure the degree of coagulation in a patient. The normal range of INR is from 1.0-2.0 and patients who are on the anticoagulant warfarin are normally kept between 2.0 – 3.0. Pierracei et al. studied patients who were on warfarin at therapeutic (INR $\geq$ 2.0) levels, subtherapeutic (INR $\leq$ 2.0) levels, and not on warfarin. They found that the therapeutic group had a significantly worse GCS scores, and an increased likelihood for mortality and morbidity.[32] Cohen et al. also studied the effects of warfarin among patients with GCS scores <8 and those with scores 13-15. They recommended that patients with GCS 13-14 on warfarin or GCS 15 with supratherapeutic doses of warfarin receive repeat head CT scans to follow the progression of these intracranial bleeds.[30]

Bellel et al. studied low dose aspirin as an indication to repeat head CT scans among patients with TBIs. When matching patients who were on low dose aspirin (LDA) vs. non-aspirin users, they found no differences in progression on routine head CT scans, changes in management as a results of the repeat scans, or mortality between the groups. Their recommendations based on these findings were that patients on LDA did not require repeat head CT scans.[33]

Moore et al. studied patients with a GCS of 13-15 and TBIs who needed neurosurgical intervention. They found that the majority of the patients were >65 years old (63.7%) and 55% of those patients were on anticoagulation. All of the deaths (n=10) were among patients on anticoagulation therapy. Overall, they found that patients age >65 who were on anticoagulation therapy had an increased likelihood of needing neurosurgical intervention, and the percent chance of needing neurosurgical intervention rose from 1.3% at baseline to 5.35% when those risk factors were taken into account. They recommended that patients >65 and on anticoagulation have repeat CT scans in order to follow the intracranial bleeds due to the increased need for neurological interventions.[34]

Wong et al. studied clopidogrel in elderly patients. They found that they were more likely to die or require discharge to a long-term care facility. They found that mortality among patients on ASA or warfarin were not different from rates of patients not on those medications. Joseph et al. also looked the effect of preinjury clopidogrel on TBIs. They found that patients on clopidogrel were more likely to have progression of intracranial trauma on routine repeat head CT scans, required a repeat scan as a result to clinical deterioration, and required neurological intervention. They recommended that patients on clopidogrel who sustained a traumatic brain injury undergo a routine repeat head CT scan to monitor the progression of the intracranial injury. For many institutions, the management includes reimaging all patients who are on anticoagulation; however, there are few studies to support this clinical decision.

Once a patient has sustained a traumatic brain injury, the goal of care is to monitor the patient with a combination of clinical instruments such as the Glasgow coma scale and clinical imaging such as x-ray computer tomography. At the UCI Medical Center, such patients are admitted to the ICU for neurologic status checks and a routine repeat head CT scan. The time interval between routine repeat scan varies from 4-16 hours and can be up to 24 hours. If a patient begins to deteriorate clinically before their schedule repeat CT scan, they are evaluated with a repeat CT scan to assess the status of the intracranial injury. After the scan is conducted, neurosurgery determines whether they would benefit from a neurological intervention such as intracranial pressure monitoring or possibly decompressive craniotomy. We investigated the possibility of reducing the number of repeat head CTs by performing them only among patients with a GCS of <15 or other signs of neurological deterioration.

In summary, data from multiple studies suggest that performance of a repeat CT scan for patients with mild TBI and no other risk factors for subsequent complications (ICP monitoring, shunt placement, or decompressive craniotomy may be unnecessary and may subject patients to additional risk from radiation exposure, extended hospital stays, and increased healthcare costs. This study will evaluate the effectiveness of repeat CT scans among low-risk patients with TBI, and among patients with an otherwise low risk neurological profile who are taking anticoagulants at the time of their injury.

Chapter 3: Methods

Description of the sample

This is a retrospective cohort study using the UCI Level 1 trauma registry between January 1,2007 to December 31, 2011to identify sufficient numbers of patients needed for the study. The trauma registry is a collection of all trauma patients that have been seen or admitted to the UCI Medical center between the above-mentioned dates and contains 8915 patients. Information that is stored in the registry includes a patient's name, Date of Birth, MRN, reason for admission, all procedures done, hospital length of stay, etc. The patients identified from the registry were initially screened for the presence of head CTs performed when they reached the UCI Emergency room. Those patients were screened for any evidence of epidural or subdural bleeding, intraparachymal bleeding, or skull fracture on their initial head CT. A sample of CT scans were initially reviewed by both the primary researcher and the trauma fellow, and the rest of the study population was reviewed only by the primary researcher. This patient population was then further screened to include only patients greater than 18 years of age or old, who had a Glasgow Coma scale between 13-15, and received two or more CT scans while at UCI Medical center. The IRB granted a waiver of consent for this study. Patients who were under 18 years of age, pregnant, and had penetrating mechanism of injury were excluded from this study.

Research Design

A cohort study design is appropriate because we are looking at practice differences for a specific diagnostic procedure; a prospective randomized trial was not appropriate at this stage of research in this area. With this retrospective design, we were able to obtain the required patient sample to satisfy power specification. Data abstracted from the medical records allowed for gathering of data needed to address the study hypotheses.

Patients were categorized into stable patients (those who entered the ER with an initial GCS of 15 at their first head CT and remained at a GCS score of 15 until their next head CT), and unstable patients (those with an initial GCS<15 or a GCS that dropped below 15 in between head CTs). There were 120 patients in the stable GCS group, and 249 patients in the unstable GCS group. Additionally, among the same 369 patients, 290 patients who did not experience any neurologic symptoms and 79 who did during the period between CT scans.

Key study measures

1. Repeat Head CT findings

Repeat head CT findings were evaluated for substantial indication that these repeat scans would be indicated. Repeat head CT scan reports, found in the results section of the charts, are normally reviewed alongside previous imaging, so each subsequent scan can be compared to its predecessor. For the majority of our study, we evaluated the first repeat CT scan performed after the patient was first assessed in the UCI Emergency Room. For all study patients, we abstracted data for every head CT scan that was recorded for that particular hospital visit. We classified a positive repeat head CT as any "increase" in contusion, bleed or edema area. This was found under the "Impressions" section of the head CT report. Negative CT scans were classified as any "stable, unchanged, or decreased" bleed, contusion, or edema area. If there was a simultaneous increase in one area but decrease in another, we based the classification on the report of the radiologist. We did not specify which areas were positive since any size increase in bleeds or edema might suggest that neurosurgical intervention was needed to relieve pressure on the brain.

We adopted this approach so as not to underestimate the need for a particular neurosurgical intervention to prevent brain damage.

2. Neurosurgical intervention

In the literature, less than 1% of patients with mild TBI's needed any kind of neurosurgical procedures such as Camino bolt placement or external ventricular drain.[6,35] We classified neurosurgical intervention as Camino bolt placement, extra ventricular drain, Burr hole, or decompressive craniotomy. This measure was used to compare our rates of neurosurgical intervention to other similar studies, and to look at the frequency of performed intervention. This measure also allowed us to look at the frequency that repeat head CT findings were positive, and compare the number of times that neurosurgery physicians deemed an intervention was required.

3. Time Interval between scans

At our institution, there are no set guidelines for the interval in which head CT scans should be repeated after the initial assessment or beyond. If a patient's mental status or GCS scores declines or there are new onset neurological deficits, then a repeat CT scan is warranted regardless of the elapsed time period. The nature for this repeat scan is to assess for any increase in bleed or edema that may be causing more pressure on parts of the brain or brainstem herniation. Appropriate time intervals when the patient's GCS or mental status is unchanged or even improved are uncertain. At our institution, neurosurgery physicians generally order repeat CT scans to be performed within 6-12 hours after the initial assessment to check for changes. During this time, the patients are normally in the Intensive Care Unit (ICU) undergoing hourly neurological checks by skilled ICU nurses. Inclusion of this measure allowed us to assess patients with stable GCS of 15 with no changes required hospital admission. If a safe interval could be identified for observation in the ED/Trauma Bays before sending patients home with recommendations to come back to the hospital if they get worse, without placing these patients at risk or unnecessarily exposing them to an expensive and potentially harmful workup.

4. Anticoagulant Status

Currently in the literature, anticoagulation status and the need to reimage patients with mild TBI's remains controversial. Anticoagulation therapy included taking aspirin, NSAIDs, Coumadin, Plavix, etc. The purpose of this study was to examine this subset of patients to determine whether anticoagulation and/or the specific type of anticoagulation affects the outcomes of these TBI patients. For example, a patient taking aspirin may be less likely to have an increased intracranial bleed than a patient taking digatroban. Therefore we specified the types of anticoagulant therapy for each study patient.

5. Glasgow Coma Scale

The Glasgow Coma Scale (GCS) has three components: Eye Opening, Verbal, and Motor. The score ranges from 3 to 15 with 3 being completely unresponsive and of poor prognosis and 15 being awake and responsive. Patients who are admitted to the hospital with a confirmed TBI are monitored by the nursing staff every hour for their GCS scores and any neurological deficits. The scores and their meanings are located in the chart in the Background section. GCS scores are then grouped into mild, moderate, and severe TBIs. A GCS score of 3-8 is a severe TBI, 9-12 moderate, and 13-15 mild TBI. Our study included only the patients who initially came to the ER with a GCS of 13-15.

6. Neurological symptoms

Neurological symptoms are well-established measures for monitoring traumatic brain injuries for additional complications and severity of the injury. Medical records were examined for neurological symptoms including: any new onset motor or sensory deficits, such as, paresthesia, paralysis, focal weakness, slurring of speech, amnesia, foggy thought process, word finding difficulties, personality changes, nausea and vomiting, and loss of consciousness. Some of these symptoms are not commonly documented in the charts, but are often observed by the primary and consulting teams progress notes. Nursing notes were examined for any indication that the patient had changes in strength, sensation, altered mental status, or other neurological deterioration. Primary and consulting team progress notes were then examined for any indication that the team was concerned for worsening neurological deterioration. If there was no mention of changes in neurological status, then "none" was marked in the data collection sheet.

Data Collection strategies/measure

From January 2007 to June 2010, only paper copies of the medical records were available for review. Medical record number and date of admission were used to verify each patient from our trauma registry. All of the patient's chart volume for the specific admission dates were ordered and reviewed. For each patient, the initial ER report, the documentation containing all initial management before hospital admission, was first assessed for any notes at the time of the patient's arrival or first recorded GCS. If the initial ER report's first recorded GCS was not 13-

15, the chart was excluded. The PACS system is an online record for medical imaging. Each CT scan was uploaded to the PACS system with a time stamp and this time stamp was used to mark the start of the time interval between CT scans. Between each head CT scan, the GCS scores noted on the ER and ICU flow sheets were scanned for any increases or decreases in GCS scores. The lowest score between scans was recorded independent of the amount of time that they remained at this score. All progress notes and operative dictations from the NCU, SICU, MICU and Neurosurgery were reviewed for possible indication for repeat scan. A change in GCS, new onset or continued neurological symptoms, etc were marked as indications for a repeat scan regardless of the specialty of the recommending provider. If there was no comment from the neurosurgical team and there was no change in GCS/new onset neurological symptoms, then "no indication" was recorded. The repeat head CT scan was deemed positive if the report read that there was an increase in bleed size, contusion, edema or new onset bleed/contusion/edema regardless of the size. If the bleed, contusion, or edema were noted as stable or unchanged from the previous scan, the CT scan was deemed negative. From June 2010 to December 2011, the charts were scanned onto the eCharts record system available online.

The UCI Trauma registry contained the variables for Injury Severity Score (a cumulative score of all of a patient's injuries), age, date of birth, admission date, race, gender, mechanism of injury, total number of head CT scans, ICU length of stay, Hospital length of stay, loss of consciousness, and final outcome (lived or died). These variables were provided on a secured Excel spreadsheet and sent to the primary researchers.

For the subset of patients on anticoagulation therapy, the specific medication was noted from recordings in the ED, initial patient admission forms, home reconciliation forms, or consults from other services (Aspirin, Naproxen or other NSAID, Aggrenox, Coumadin, Plavix, or Lovenox). If the doses were known, they were also recorded. Some patient's records did not contain the complete initial ER report with documentation of anticoagulant status and were excluded from analysis. If the patient's were treated for possibly being on anticoagulants, the treatment was recorded. The type of therapy was recorded including fresh frozen plasma, packed platelets, vitamin K, Novo seven, Desmopressin, DDAVP, Aminocaproic acid, and Prothrombin complex. Patient's initial INR was recorded if they were on antiplatelet therapy.

Table 3.1: Study Measures

Variables	Specific/Descriptions	Data Source
Repeat CT Findings	Unchanged or stable intracranial injury, worsening intracranial injury	Medical Record, Trauma Registry
Neurosurgical intervention	ICP monitor, decompressive craniotomy	Medical Record
Time interval between scans	Measured from initial scan to repeat scan	PAX medical imaging record
Anticoagulant status	ASA, clopidogrel, Warfarin	ER records, inpatient medical record
Glasgow Coma Scale		ER record, nursing record, Trauma Registry
Neurological symptoms	Paralysis, altered mental status, amnesia, nausea/vomiting	ER record, primary and consulting progress notes, nursing records

Statistical methods/analytic plan

The patient population was divided into two groups: stable and unstable patients. Stable patient group was noted as the set of patients who arrived in the ED with a GCS a 15 and stayed at a GCS a 15 throughout the entire interval to the repeat CT scan. The unstable patient group included patients who arrived in the ED with a GCS of 13 – 14 or who's GCS dropped below 15 in the interval period between their CT scans. For the descriptive statistics looking at the two patient populations, student t-test were used for continuous variables such as age and ISS. Chi-squared analysis was used for binary variables such as survival and loss of consciousness. Mann Whitney-U was used for variable such as ICU length of stay and hospital length of stay.

Multivariable logistic regression analysis was used to assess the contribution of GCS and neurological symptoms to detect worsening intracranial bleeds. The dependent variables were repeat head CT findings and neurosurgical intervention. The independent variables were patient age, ISS, ICU and hospital length of stay, anticoagulation status, unstable GCS, neurological symptoms, and a combination of unstable GCS or neurological symptoms. Odds ratios, confidence intervals, and p-values were reported.

Statistical analyses were performed, independently checked, and replicated using IBM SPSS Statistics, Version 22.0 (IBM Corp, Armonk, NY). Independent samples T test, Chi Squared test, and Mann Whitney U test were used to compare groups where appropriate. Missing data and the data entries associated will not be included in all analyses.

Chapter 4: Results

There were 8915 trauma patients admitted during the study period who had received a head CT scan. Evidence of TBI and an initial GCS of 13-15 were identified in 658 patients. Of those patients, 201 of them did not have a repeat CT scans and 88 had incomplete records, no CT scan reads, or were excluded for not meeting criteria. The remaining 369 cases make up the final dataset(see Figure 4.1).

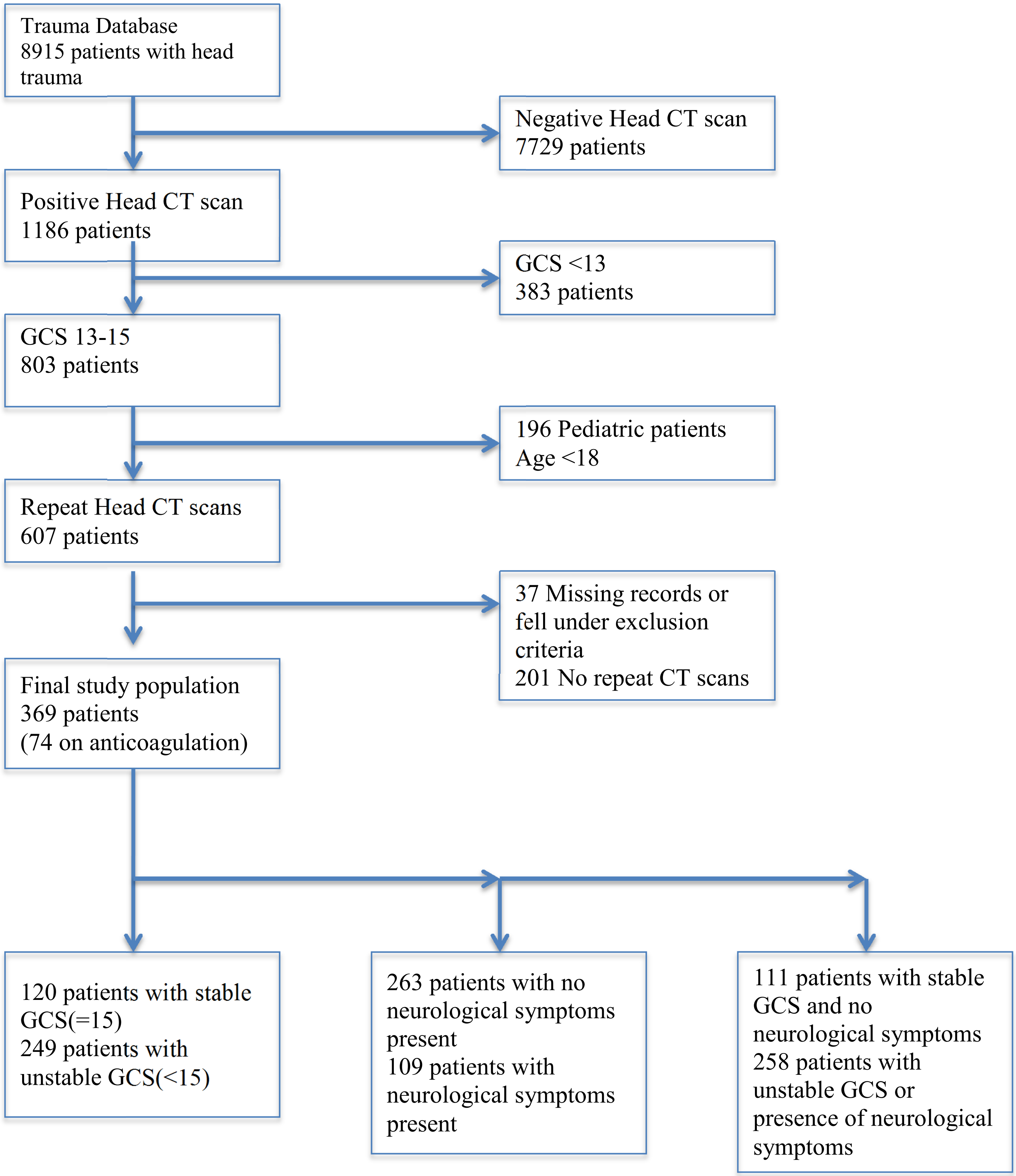

Fig. 4.1 – Conceptual model of the study design.

Table 4.1: Characteristics of patients who had a single positive CT vs. multiple/repeat CT scans (n=570)

	Single CT	**Multiple CT**	**p-value**
	n=201	n=369	
Age, y	**45.6+/- 20.1**	**52.8+/-22.0**	**p<0.01**
Age>65	**20.4%**	**32.0%**	**p=0.03**
Gender (male)	**78.6%**	**73.4%**	**p<0.01**
Injury Severity Score	**14.1+/-10.0**	**17.1+/-8.1**	**p<0.01**
Positive Loss of Consciousness	115 (68.0%)	214 (74.3%)	p=0.15
ICU Length of Stay, days	**2.2+/-2.0**	**4.2+/-4.0**	**p<0.01**
Hospital Length of Stay, days	**4.2+/-4.7**	**7.8+/-8.4**	**p<0.01**
Non displaced skull fracture	**15.4%**	**23.3%**	**p=0.02**
Displaced skull fracture	2.5%	3.8%	p=0.43
Mortality	2.5%	2.2%	p=0.77

There were 201 patients who had an initially positive head CT, GCS between 13-15 (See Table 1). There were 369 patients who had an initially positive head CT, GCS between 13-15, who also had a repeat head CT scan. The multiple CT scan group who were older (52.8 vs. 45.6, p<0.01), had fewer males (73.4% vs. 78.6%, p<0.01), had a higher ISS (17.1 vs. 14.1%, p<0.01), had a longer ICU LOS (4.2 vs. 2.2, p<0.01), had a longer hospital LOS (7.8 vs. 4.2, p<0.01), and more had a skull fracture (23.3% vs. 15.4%, p=0.02). There were no differences in patients who lost consciousness, sustained a displaced skull fracture, or died in the hospital.

Table 4.2: Characteristics of patients who had a GCS score equal to 15 or ≤15 (n=369)

	Stable (GCS=15)	**Unstable (GCS<15)**	**p-value**
	n=120	n=249	
Age, y	53.5+/-21.5	52.3+/-22.3	p=0.63
Age>65	31.7%	32.1%	p=0.93
Gender (male)	**64.2%**	**77.9%**	**p=0.05**
Injury Severity Score	**15.1+/-6.3**	**18.1+/-8.7**	**p<0.01**
Positive Loss of Consciousness	68 (68%)	146 (77.7%)	p=0.07
On Anticoagulation/antiplatelet	25.8%	17.7%	p=0.07
Non displaced skull fracture	17.5%	26.1%	p=0.09
Displaced skull fracture	2.5%	4.4%	p=0.56

Number of head CTs	**2.4+/-0.7**	**3.1+/-1.6**	**p<0.01**
Time Interval between scans (hours)	12.4+/-8.1	11.4+/-8.6	p=0.27
ICU Length of Stay, days	**2.8+/-1.8**	**4.9+/-4.5**	**p<0.01**
Hospital Length of Stay, days	**5.2+/-4.0**	**9.0+/-9.5**	**p<0.01**
Positive repeat head CT scan	**12.5%**	**24.9%**	**p<0.01**
Neurological intervention	0.8%	4.0%	p=0.11
Mortality	0.8%	2.8%	p=0.21

In Table 2, the patients were grouped by GCS. If they had a GCS equal to15 that did not change between scans, they were labeled as Stable GCS, but if at any point their GCS was less than 15, they were labeled as Unstable. More unstable patients were more males (77.9% vs. 64.2%, p=0.05), these patients had a higher ISS (18 vs. 15, p<0.01), had a higher number of CT scans (3.1 vs. 2.4, p<0.01), had a longer ICU LOS (3 vs. 2 days, p<0.01), had a longer hospital days (6.0 vs. 4.0 days, p<0.01), and had more positive repeat scans (24.9% vs. 12.5%, p<0.01) compared with stable patients. There were no differences in the number of patients who lost consciousness, had displaced or non-displaced skull fractures, needed neurological interventions, or died in the hospital.

Table 4.3: Characteristics of patients who had recorded neurological symptoms(n=369)

	No Neurological symptoms	**Neurological symptoms present**	**p-value**
	n=263	n=106	
Age, y	53.1+/-21.8	51.7+/-22.4	p=0.56
Age>65	31.1%	32.3%	p=0.82
Gender (male)	**70.0%**	**82.1%**	**p=0.02**
Injury Severity Score	**16.2+/-7.4**	**19.3+/-9.2**	**p=0.01**
Positive Loss of Consciousness	144 (71.3%)	70 (81.4%)	p=0.07
On Anticoagulation/antiplatelet	22.7%	14.7%	p=0.09
Non displaced skull fracture	17.5%	26.1%	p=0.09
Displaced skull fracture	2.7%	6.6%	p=0.13
Number of head CTs	**2.6+/-1.2**	**3.5+/-1.8**	**p<0.01**
Time Interval between scans (hours)	*12.2+/-8.4*	*10.4+/-8.5*	*p=0.06*
ICU Length of Stay, days	**3.5+/-3.2**	**5.9+/-5.0**	**p<0.01**
Hospital Length of Stay, days	**6.1+/-5.7**	**11.9+/-11.8**	**p<0.01**
Positive repeat head CT scan	**25.9%**	**49.1%**	**p<0.01**

Neurological intervention	**2 (0.4%)**	**10 (9.4%)**	**p<0.01**
Mortality	**0.8%**	**5.7%**	**p<0.01**

In Table 3, there were 263 patients who did not display any neurological symptoms between initial presentation and before their repeat scan and 106 who had such symptoms. More patients with neurological symptoms compared to those without symptoms were males (82.1 vs. 70.0%, p=0.02), had a higher ISS (19.3 vs. 16.2, p=0.01), had more CT scans (3.5 vs. 2.6, p<0.01), had a longer ICU LOS (5.9 vs. 3.5, p<0.01), had a longer hospital LOS (11.9 vs. 6.1, p<0.01), had more positive repeat CT scans (49.1% vs. 25.9%, p<0.01), had more neurosurgical interventions (9.4% vs. 0.4%, p<0.01) and they had a higher mortality rate (5.7% vs. 0.8%, p<0.01). There were no differences between patients with and without neurological symptoms in age, number of patients over 65 years old, on anticoagulation/antiplatelet therapy, or had sustained a displaced or non=displaced skull fracture.

Table 4.4: Characteristics of patients who had a GCS = 15 with no other neurological symptoms (n=369)

	Stable (GCS=15) and no Neurological symptoms	**Unstable (GCS<15) or Neurological symptoms present**	**p-value**
	n=111	n=258	
Age, y	52.6+/-22.3	53.2+/-21.3	p=0.81
Age>65	31.5%	32.2%	p=0.90
Gender (Male)	**64.0%**	**77.5%**	**p<0.01**
Injury Severity Score	**15.3+/-6.4**	**17.9+/-8.6**	**p<0.01**
Positive Loss of Consciousness	63 (68.5%)	151 (77.0%)	p=0.12
On Anticoagulation/antiplatelet	25.2%	18.3%	p=0.13
Non displaced skull fracture	17.1%	26.0%	p=0.07
Displaced skull fracture	2.7%	4.3%	p=0.47
Number of head CTs	**2.4+/-0.7**	**3.1+/-1.6**	**p<0.01**
Time Interval between scans (hours)	12.6+/-8.1	11.3+/-8.6	p=0.17
ICU Length of Stay, days	**2.8+/-1.9**	**4.8+/-4.4**	**p<0.01**
Hospital Length of Stay, days	**5.0+/-4.0**	**8.9+/-9.4**	**p<0.01**
Positive repeat head CT scan	**20.7%**	**37.6%**	**p<0.01**
Neurological intervention	**0 (0.0%)**	**11 (4.3%)**	**p=0.04**
Mortality	0.9%	2.7%	p=0.27

There were 111 patients whose neurologic status remained stable and 258 whose neurological status deteriorated or did not improve(see Table 4). Compared to unstable patients, patients whose GCS remained stable and unchanged had a lower Injury Severity Score (15.3 vs. 17.9, p<0.01), had fewer males (64.0% vs. 77.5%, p<0.01), had lower number of CT scans (2.4 vs. 3.1, p<0.01), had a shorter ICU LOS (2.8 vs. 4.8 days, p<0.01), had a shorter hospital LOS (5.0 vs. 8.9 days, p<0.01), fewer positive repeat scans (20.7% vs. 37.6%, p<0.01) and fewer needed neurosurgical intervention (0.0% vs. 9.4%,p=0.03). Between groups, there were no differences in age, number of patients who were >65 years old, on anticoagulation or antiplatelet therapy, sustained a non-displaced or displaced skull fracture, or who died in the hospital.

Table 4.5: Characteristics of patients with improved GCS 14 to 15 (n=369)

	Improved (GCS 14 -> 15)	**Stable (GCS=15)**	**p-value**
	n=19	n=120	
Age, y	*46.2+/-18.5*	*53.5+/-21.5*	*p=0.13*
Age>65	21.1%	31.7%	p=0.43
Gender (male)	78.9%	64.2%	p=0.30
Injury Severity Score	17.3+/-8.0	15.1+/-6.3	p=0.26
Positive Loss of Consciousness	*14 (87.5%)*	*68 (68.0%)*	*p=0.15*
On Anticoagulation/antiplatelet	21.1%	25.8%	p=0.78
Number of head CTs	2.4+/-0.7	2.5+/-0.7	p=0.87
Time interval between scans (hours)	12.6+/-9.7	12.4+/-8.1	p=0.91
ICU Length of Stay, days	3.1+/-1.2	2.8+/-1.8	p=0.46
Hospital Length of Stay, days	*4.3+/-2.0*	*5.1+/-4.0*	*p=0.20*
Non displaced skull fracture	10.5%	17.5%	p=0.74
Displaced skull fracture	0.0%	2.5%	p=1.00
Positive repeat head CT scan	31.6%	21.3%	p=0.38
Neurological intervention	0.0%	1 (0.8%)	p=1.00
Mortality	0 (0.0%)	1 (0.8%)	p=1.00

There were 19 patients whose GCS improved over the time interval between scans (see Table 5). Compared to stable GCS patients, there were no studied statistically significant differences in any of the characteristics. The improved patients were younger, fewer had a loss of consciousness, and they had a shorter hospital LOS compared to stable patients, although these differences did not reach statistical difference.

Table 4.6: Characteristics of patients with deteriorated GCS 15->14 (n=369)

	Deteriorated (GCS 15->14)	**Stable (GCS=15)**	**p-value**
	n=64	n=120	
Age, y	51.7+/-23.8	53.5+/-21.5	p=0.12
Age>65	34.4%	31.7%	p=0.71
Gender (Male)	68.8%	64.2%	p=0.63
Injury Severity Score	16.7+/-6.8	15.1+/-6.3	p=0.12
Positive Loss of Consciousness	36 (69.2%)	70 (68.0%)	p=0.88
On Anticoagulation/antiplatelet	12 (20.7%)	21 (25.8%)	p=0.45
Number of head CTs	2.5+/-1.0	2.5+/-0.7	p=0.51
Time interval between scans (hours)	11.9+/-6.7	12.4+/-8.1	p=0.71
ICU Length of Stay, days	3.4+/-2.7	2.8+/-1.8	p=0.35
Hospital Length of Stay, days	6.4+/-6.9	5.1+/-4.0	p=0.18
Non displaced skull fracture	20.3%	17.5%	p=0.69
Displaced skull fracture	3.1%	2.5%	p=1.00
Positive repeat head CT scan	26.6%	21.7%	p=0.46
Neurological intervention	2 (3.1%)	1 (0.8%)	p=0.28
Mortality	1 (1.6%)	1 (0.8%)	p=1.00

Patients who had an initial GCS of 15 but deteriorated to a GCS of 14 from the time they presented to the ER till the time they received a repeat head CT scan (n=64) were compared to a control of patients with a stable GCS of 15. There were no significant differences between the two patient groups.

Table 4.7: Characteristics of patients on anticoagulation or antiplatelet therapy (n=257)

	No AC/AP	**On AC/AP**	**p-value**
	n=284	n=73	
Age, y	**47.5+/-20.3**	**74.6+/-13.6**	**p<0.01**
Age>65	**20.4%**	**79.5%**	**p<0.01**
Gender (Male)	**75.7%**	**63.0%**	**p=0.04**
Injury Severity Score	16.8+/-7.8	18.2+/-8.8	p=0.22
Positive Loss of Consciousness	**174 (77.7%)**	**36 (64.3%)**	**p=0.04**
Number of head CTs	2.8+/-1.4	3.1+/-1.3	p=0.21
Time Interval between scans (hours)	11.5+/-8.7	12.4+/-7.8	p=0.38

ICU Length of Stay, days	4.1+/-3.8	4.4+/-4.0	p=0.11
Hospital Length of Stay, days	7.5+/-8.3	8.2+/-7.7	p=0.75
Non displaced skull fracture	**8.2%**	**26.8%**	**p<0.01**
Displaced skull fracture	4.9%	0%	p=0.08
Positive repeat head CT scan	32.4%	32.9%	p=0.94
Neurological intervention	3.2%	0%	p=0.21
Mortality	1.4%	2.7%	p=0.61

Of the 369 patients from the initial sample population, 73 were on anticoagulation or antiplatelet therapy (see table 8). These patients were older (74.6 vs. 47.5, p<0.01), more of them were >65 years old (79.5% vs. 20.4%, p<0.01), fewer were males (63.0% vs. 75.7%, p=0.04), they had a lower incidence of loss of consciousness (64.3 vs. 77.7%, p=0.04), and a higher incidence of non-displaced skull fracture (26.8% vs. 8.2%, p<0.01). There were no differences between the groups in the Injury Severity Score, number of head CT scans, ICU or hospital length of stay, displaced skull fractures, positive repeat scans, neurosurgical interventions or died in the hospital.

Multivariate Analysis

Table 4.8: The association of the presence of unstable (GCS <15) Group with other risk factors with subsequent positive repeat head CT finding (n=369)

Risk Factor	Unadjusted OR (95% CI)[1]	Adjusted OR (95% CI)[2]	p-value[3]
Unstable (GCS<15)	2.21 (1.33-3.68)	1.71 (1.00-2.91)	p=0.05
ISS	1.04 (1.01-1.07)	1.01 (0.99-1.05)	p=0.27
Age	1.01 (1.00-1.02)	1.01 (.99-1.02)	p=0.08
ICU LOS	1.15 (1.08-1.23)	1.09 (.99-1.20)	p=0.07
Hospital LOS	1.05 (1.03-1.08)	1.01 (0.97-1.06)	p=0.60
Anticoagulation	1.02 (0.59 – 1.77)	0.76 (0.40 – 1.47)	p=0.42

[1] Unadjusted OR are from separate univariate logistic regression models testing the association of each independent variable with the odds of a positive repeat head CT scan

[2] Adjusted OR are from a single multivariate logistic regression including all independent variables listed in the table

[3] p-values are from multivariate logistic regression

Unstable GCS (<15), ISS, age, ICU LOS, Hospital LOS, and anticoagulation were all significantly associated with positive repeat head CTs on univariate regression analysis (see Table 8). However, when adjusted for the other factors in a multivariate logistic regression only unstable GCS was associated with a positive repeat head CT. If a patient had an unstable GCS <15, they were more likely to have a positive repeat head CT than those whose GCS remained at 15. Age and ICU LOS were associated with a positive scan but did not reach statistical significance.

Table 4.9: The association of the presence of neurological symptoms with other risk factors with subsequent positive repeat head CT findings (n=369)

Risk Factor	Unadjusted OR (95% CI)[4]	Adjusted OR (95% CI)[5]	p-value[6]
Neurologic symptoms present	2.59 (1.61-4.19)	2.03 (1.21-3.41)	p<0.01
ISS	1.04 (1.01-1.07)	1.02 (0.99-1.05)	p=0.26
Age	1.01 (1.00-1.02)	1.01 (0.99-1.02)	p=0.06
ICU LOS	1.15 (1.08-1.23)	1.10 (.99-1.20)	p=0.053
Hospital LOS	1.05 (1.03-1.08)	1.00 (0.96-1.05)	p=0.84
Anticoagulation	1.02 (0.59 – 1.77)	0.77 (0.40 – 1.48)	p=0.43

[4] Unadjusted OR are from separate univariate logistic regression models testing the association of each independent variable with the odds of a positive repeat head CT scan

[5] Adjusted OR are from a single multivariate logistic regression including all independent variables listed in the table

[6] p-values are from multivariate logistic regression

Table 9 shows the results of a multivariate logistic regression model predicting positive repeat head CTs. Patients with neurological symptoms (excluding changes in GCS), ISS, age, ICU LOS, Hospital LOS, and anticoagulation were all associated with positive repeat head CTs on univariate regression analysis, but when adjusted for the other factors only neurological symptoms remained significantly associated with of a positive repeat head CT. If a patient had neurological symptoms between the initial CT and the repeat CT, they were more likely to have a positive repeat head CT than those who did not have symptoms.

Table 4.10: The association of the presence of unstable (GCS <15) and/or presence of neurological symptoms with other risk factors with subsequent positive repeat head CT findings (n=369)

Risk Factor	Unadjusted OR (95% CI)[7]	Adjusted OR (95% CI)[8]	p-value[9]
Unstable GCS or Neurological symptoms present	2.33 (1.37-3.94)	1.81 (1.05-3.14)	p=0.03
ISS	1.04 (1.01-1.07)	1.01 (0.99-1.05)	p=0.25
Age	1.01 (1.00-1.02)	1.01 (.99-1.02)	p=0.08
ICU LOS	1.15 (1.08-1.23)	1.09 (.99-1.20)	p=0.07
Hospital LOS	1.05 (1.03-1.08)	1.01 (0.97-1.06)	p=0.62
Anticoagulation	1.02 (0.59 – 1.77)	0.76 (0.40 – 1.47)	p=0.41

[7] Unadjusted OR are from separate univariate logistic regression models testing the association of each independent variable with the odds of a positive repeat head CT scan

[8] Adjusted OR are from a single multivariate logistic regression including all independent variables listed in the table

[9] p-values are from multivariate logistic regression

Table 10 shows the results of a multivariate logistic regression model for predicting positive repeat head CTs. When adjusted for the other factors, only unstable patients with a GCS < 15 and/or presented with other neurological symptoms were associated with a positive repeat head CT. If a patient had an unstable GCS <15 and/or other neurological symptoms, they were more likely to have a positive repeat head CT than those whose GCS remained at 15.

Table 4.11: The association of the presence of unstable (GCS<15) and other risk factors with subsequent neurosurgical intervention (n=369)

Risk Factor	Unadjusted OR (95% CI)[10]	Adjusted OR (95% CI)[11]	p-value[12]
Unstable (GCS<15)	4.16 (.51-33.63)	2.98 (0.35-25.18)	p=0.32
ISS	1.04 (1.01-1.07)	1.05 (0.99-1.12)	p=0.10
Age	1.01 (1.00-1.02)	1.01 (.98-1.04)	p=0.54
ICU LOS	1.15 (1.08-1.23)	1.11 (.96-1.28)	p=0.16
Hospital LOS	1.05 (1.03-1.08)	0.99(0.92-1.08)	p=0.82

[10] Unadjusted OR are from separate univariate logistic regression models testing the association of each independent variable with the odds of neurosurgical intervention

[11] Adjusted OR are from a single multivariate logistic regression including all independent variables listed in the table

[12] p-values are from multivariate logistic regression

None of the variables included in a multivariate logistic regression analysis predicting neurosurgical intervention were statistically significant after adjustment (see Table 11).

Table 4.12. The association of the presence of neurological symptoms and other risk factors with subsequent neurological intervention (n=369)

Risk Factor	Unadjusted OR (95% CI)[13]	Adjusted OR (95% CI)[14]	p-value[15]
Neurological symptoms present	21.62 (2.67-175.17)	21.01(2.57-171.53)	p<0.01
ISS	1.04 (1.01-1.07)	1.05 (0.99-1.12)	p=0.13
Age	1.01 (1.00-1.02)	1.01 (0.98-1.04)	p=0.52
ICU LOS	1.15 (1.08-1.23)	1.12 (.94-1.31)	p=0.22
Hospital LOS	1.05 (1.03-1.08)	0.97 (0.90-1.06)	p=0.54

[13] Unadjusted OR are from separate univariate logistic regression models testing the association of each independent variable with the odds of neurosurgical intervention

[14] Adjusted OR are from a single multivariate logistic regression including all independent variables listed in the table

[15] p-values are from multivariate logistic regression

Table 12 shows the results of a multivariable logistic regression model predicting clinical management requiring neurosurgical intervention. Presence of neurological symptoms (excluding changes in GCS) was associated with neurological intervention. After adjustment for the other factors, the odds a patient requiring neurological intervention were 21 times greater for patients without presenting with neurological symptoms than those presenting with no neurological symptoms between scans.

Chapter 5: Discussion

The current management of mild Traumatic Brain Injuries is highly variable.[2] As other studies have shown, the use of current clinical guidelines set out by the Canadian Head CT rule and the New Orleans Criteria have shown a 100% sensitivity for diagnosing Intracranial bleeds. [19] In addition, these criteria, if used properly, have been shown to reduce the number of additional CT scans.[19,36] Standard management of mild TBIs is to repeat the CT scan to diagnose potential worsening of the intracranial bleed or contusion.[37] Some investigators question the need for repeat Head CT scans in patients who do not have neurological symptoms.[23,24,35,38,39] Others believe that routine repeat scans are needed to monitor these patients for any changes.[40,41]

In our study, we found that patients who had mild TBIs and a GCS of 15 with no other neurological symptoms were less likely to have progression of the intracranial injury on their repeat CT scans and to require neurological intervention. From our study, patients who come into the ER with a stable GCS of 15 and an initially positive HCT scan have less than a 13% chance of progressive or worsening on repeat CT scan and less than a 1% chance of requiring neurosurgical intervention. Patients whose GCS decreased below 15 showed nearly a double (12.5 % vs. 24.9%) the number of worsening intracranial bleeds on repeat scans. Patients who had neurological deterioration also had nearly double (49.1% vs. 25.9%) the proportion of worsening intracranial bleeds or contusion on their repeat scans. There were no patients who had a GCS of 15 and had no neurological symptoms that required neurological intervention and is consistent with similar rates of neurosurgical intervention.[3,22,23,35,39,42] Using data from clinical exams, we were able to identify all patients that required neurosurgical intervention.

Data from the multivariable analysis illustrated the importance the GCS and neurological symptoms as indicators for a patient's current intracranial status. Neurological deterioration was the most important variable for predicting progression of the injury on repeat head CT and leading to the need for neurological interventions. A GCS <15 was associated with a progression on head CT but not for the neurosurgical intervention. The combination of an unstable GCS< 15 or having neurologically symptoms was associated with progression of injury on repeat head CT but not with neurological intervention. Our data suggests that presence of neurological symptoms is still an important clinical indicator for detecting the worsening of these life threating head injuries. Additional studies with higher samples sizes are required to examine the risk factors for declining neurological status.

Anticoagulation was not a risk factor for worsening of the intracranial injury on repeat CT scans or neurological intervention. Our study showed similar percentages of patients on anticoagulation as those reported by other studies.[39,43] Other researchers have proposed that aspirin may not be a risk factor for intracranial bleeds.[33] Warfarin also does appear to be a risk factor, however, in this study, there was insufficient patients to power this finding.[9,28,44] Future studies looking at the role of antiplatelet and anticoagulation medication as indicators for repeat head CTs are needed.

From our patient population, we observed one patient that had no change in GCS but needed neurosurgical intervention. This patient had a midline shift of 4-5mm on their initial CT scan and should have gone to the OR. This suggests that more attention should be paid to patients with a midline shift, even with a stable GCS. Additionally, we found that the ten patients who did have a drop in GCS or had other neurologic symptoms were found to have them within the first 7 hours.

Traumatic Brain Injuries are serious conditions that are treated with a thorough and conservative management. The most serious outcome from TBIs is brain death and death. In mild TBIs, the current mortality rate is between 1-4%.[23,39] As seen with other studies, almost all patients that require neurosurgical intervention display neurological deterioration.[23,35,39,42] With the incidence of needing neurological intervention in mild TBIs and no other neurological symptoms being <1%, our data suggest that there needs to be any change in clinical management. Current clinical bedside skills appear to be sufficiently sensitive to detect worsening injuries that require further diagnostic workup and intervention. [24,45–47]

Examining the post-hospital and long term outcomes of mild TBIs, Rimel et al. found that the most common complaint for mild TBI patients at 3 months was headaches (80%), memory problems (59%), and unemployment (34%).[48] Alves et al. reported in mild TBI patients at 6 months headaches were still the most common problem at 28%, but at 1 year, they found that less than 2.5% of patients were asymptomatic.[49] Another study by McMilliam et al. found that the death rates for mild TBIs to be much higher than the general population (14.8 vs. 2.2 per 1000).[28] Long term, comprehensive studies are needed to look at the long-term effects of mild TBIs.

From the current U.S. CDC data on TBIs, there are around 715 ER visits and 92 hospitalizations per 100 thousand people.[1] With the 2014 US population consensus at 318.9 million people, this comes out to around 2,280,000 ER visits and 293,000 hospitalizations per year. Assuming around 70% of those hospitalized get routine repeat scans at a Medicare reimbursement rate of $375 dollars per scan, the total cost of repeat scans is around $77 million dollars per year. While not a large percentage of the total Medicare budget, it is a large source of spending that may be avoided with different clinical management. Other studies have shown annual savings from adherence to clinical guidelines of up to $120 million.[50] Current studies have shown increasingly low yield of medical diagnostic exams. With the shift in medical policy towards evidence-based medicine, there is a desire to see a reduction in low yield imaging that does not endanger the patient. With the current state of the medical legal atmosphere pressuring physicians to protect themselves, evidence based clinical guidelines may provide more clinically safe and economically reasonable decisions. With more people coming under the coverage of Obamacare, hospitals need to consider the cost benefit analysis of these low yield exams. With more and more patients being admitted to the hospital for TBIs, policy changes to a more conservative management may be more appropriate.

In addition to the financial costs to the patients and hospitals, the increased exposure to repeated radiological scans is dangerous. The higher number of scans that a patient is exposed to the higher the risk for developing neoplasms.[51,52] Studies have shown that patients who receive multiple CT scans in the ER are more likely to develop cancer than the general population.[53]

With the addition of our study to the growing body of literature, the next step is to create a prospective study that either validates current guidelines or looks at our patient population of mild TBIs to create grade A evidence based guidelines. The BIG criteria are a set of guidelines from Joseph et al. that have the potential to separating out the subset of patients. Within the BIG criteria, our subset of patients would fall under BIG 1 and 2 categories. The authors of the study believes that the BIG 1 patients would not need to undergo repeat head CTs and instead may be observed in the ER for 6 hours.[24] While they admit that the patients from the BIG 2 category are more ambiguous, this set of guidelines holds potential for the future of TBI management.

The next step to creating good evidence based guidelines is a large, multi-institution study. The current literature has a small number of patients with mild TBIs that require neurosurgical intervention (<1%). To create a well-powered study, multiple institutions are needed to bring in the necessary patients. Another problem is that many of the current studies are retrospective studies. While retrospective cohort studies can be used to look at clinical management, a prospective, double blinded study would be ideal for determining the most important clinical indicators as well as the most appropriate clinical management.

One interesting issue for clinicians is whether patients need to be admitted to the hospital or can they simply be observed. While most of these patients are admitted to the ICU for other problems besides TBIs, isolated TBIs may be able to undergo simple observation for 6-12 hours with outpatient follow up, but this clinical decision is still controversial. The time period for observation is currently controversial.

There is currently controversy over what decrease in GCS is appropriate to rescan patients. Currently, any decrease in GCS below 15 is indication for a mild TBI patient to be reimaged. Many of these patients are trauma victims who have sustained multiple injuries and are normally on pain medications. We currently question the threshold for when patients need to be reimaged. Looking at our data, we found that patients who's GCS dropped from a 15 to a 14 were not statistically different from those who stayed at 15. Futures studies should look at the changes in GCS and their effect on detecting worsening Intracranial bleeds.

Current hospital policy is to admit all patients with positive TBIs and rescan based on the neurosurgeons recommendations. With the incidence of positive repeat head CTs being anywhere from 8-67%, but less than 1% of those needing any kind of medical or surgical interventions, guidelines for mild TBIs may save hospitals valuable resources and patients radiation exposure.[51–57] Currently, there is a huge amount of money used on clinical imaging. Inglehart et al. found that Medicare spending from 2000-2006 rose from 3.66 billion to 7.6 billion dollars.[58] While this is a significant amount of money, compared to the Medicare budget of 475 billion dollars, clinical imaging is not as much, but it is more highly scrutinized. The per beneficiary spending rose from $220 in 2000 to $419 in 2006. After Congressed passed a bill limiting reimbursements from $419 to $375, clinical imaging was reduced by 12.7%.[59]

Limitations of this study

Our study comes with the inherent limitations of a retrospective study. CT scans and radiologists were not blinded, and neurological exams were not standardized. There was a lack of standard timing for routine repeat scans. From our study, we did not examine specific types of lesions or their progression on repeat scans. For neurological interventions, we only had 11 patients who went for intervention, so our study was not powered well enough. Our patient population for antiplatelet and anticoagulation was not powered to detect a difference for any group other than the ASA population. Our study was generalized to all trauma patients and not just those with isolated mild TBIs, so there may have been other factors affecting their mental status such as hypovolemia or narcotic use.

Conclusion:

Our study shows that most patients who have initially positive CT scans and maintain a stable GCS of 15 can still safely forego the cost and radiation exposure of repeated scans. We hope to conduct a warranted, prospective, mutli-instutional study to prove our hypothesis is being formulated.

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