Time to Head Computed Tomography Protocol in Traumatic Brain Injury: A Quality Improvement Metric

TAREQ KHEIRBEK, MD, ScM, FACS; ANDREW R. LUHRS, MD; JAYSON S. MARWAHA, MD; ANDREW H. STEPHEN, MD; CHARLES A. ADAMS, MD, FACS; STEPHANIE N LUECKEL, MD, ScM, FACS

ABSTRACT

BACKGROUND: Early identification of traumatic brain injury (TBI) with head CT HCT should expedite operative decision-making and improve outcome. We aimed to determine whether an early HCT protocol in TBI patients would improve outcome.

METHODS: A multidisciplinary protocol to obtain an HCT within 30 minutes from arrival for patients with GCS ≤ 13 was instituted on 1/1/2015. Our trauma registry was queried for patients evaluated between 3/2012 and 12/2015. Outcomes included compliance with protocol and in-hospital mortality.

RESULTS: 346 patients presented with GCS ≤ 13. Patients PRE- (n=264) and POST-protocol (n=82) were similar in demographic and physiologic characteristics. Time to HCT was lower (35 vs. 77 min; p<0.001). POST-protocol had lower odds of mortality (OR 0.65, 95% CI 0.43–0.99) adjusting for age, gender, ISS and GCS.

CONCLUSION: Implementing a protocol of early HCT for TBI optimized performance of the trauma team. Time to HCT could serve as a quality metric in TBI.

KEYWORDS: traumatic brain injury, head CT, time to CT, quality improvement

INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of death in individuals younger than 45 years old and many survivors are left with significant, life-long disabilities.[1,2] TBI accounts for nearly 1.4% of all emergency room visits, over 0.7% of U.S. hospitalizations, and contributes to over 30% of all injury-related deaths.[3]

Head computed tomography (HCT) is the preferred diagnostic imaging modality, and an expedited HCT should be a part of the initial workup in patients with suspected TBI.[4-7] Early identification of TBI by means of HCT could expedite operative decision making, lead to earlier interventions, and subsequently improve outcome. Some authors have found significantly higher odds of survival in patients undergoing early neurosurgical interventions in severe TBI, recommending early HCT and neurosurgical consultation.[8] To our knowledge there are no guidelines for time-sensitive HCT in patients with suspected TBI specifically, nor does data exist for its association with improved outcome. We hypothesized that the implementation of a protocol of early HCT in patients with moderate and severe TBI would be associated with improved outcomes.

METHODS

This is a retrospective cohort study of prospectively collected data following the initiation of a multidisciplinary quality improvement protocol at our level 1 trauma center. The protocol was initiated on January 1, 2015. It offered recommendations to transport patients to obtain HCT within 30 minutes of arrival to the emergency department (ED) for patients with suspected TBI and a Glasgow Coma Scale GCS of ≤ 13 (moderate and severe TBI). GCS was assessed at time of arrival to ED and re-assessed frequently. While GCS can be influenced by other factors, such as medical conditions or intoxication, patients with a traumatic mechanism and decreased GCS score were triaged as high-risk for traumatic brain injury.

Our ED is equipped with two CT scanners in close proximity to the trauma resuscitation rooms. The protocol included several educational sessions to ED staff and radiology technologists prior to and during the early phase of protocol implementation. Time to HCT was recorded in the registry in minutes from time of arrival to ED to time of first obtained image in CT. We elected to report time to first image of the CT scan to avoid variability among different scanning protocols. For patients with multiple injuries requiring more extensive CT imaging, the HCT was performed first and the start time of image capture was used to define time to HCT.

After constructing the study concept, we obtained an Institutional Review Board (IRB) approval prior to collecting the data. The trauma registry was queried for adult (≥18 years old) TBI patients with an Abbreviated Injury Scale (AIS) ≥ 3. AIS is coded by the trauma registrars based on severity of injury, from minor (AIS=1) to nonsurvivable (AIS=6), per the National Trauma Data Standards (NTDS) dictionary, (**See Appendix**). The AIS cutoff was chosen to evaluate the impact on severe injuries that are more likely to require an intervention in order to detect maximal improvement effect. Our exclusion criteria included those who had initial GCS>13, those with missing or incomplete data, and patients who were transferred from another facility. One patient was excluded because first head CT was obtained 24 hours after presentation due to new clinical findings suggestive of head injury. The time periods before (PRE) and after (POST) implementation of the protocol were compared. The PRE period included all patients captured in the trauma registry and extended from March 2012 until December 2014. The POST period extended from January 2015 until December 2015. Our primary outcome was compliance with protocol. Patients' outcomes that were evaluated included in-hospital mortality, the need for discharge from the hospital to a facility vs. home, and time to surgical interventions – external drainage device placement (EVD), craniectomy, or craniotomy – for those who required such an intervention within the first hospitalization day. These outcomes were evaluated as surrogates of quality of care and not as a direct response to the reduced time to HCT.

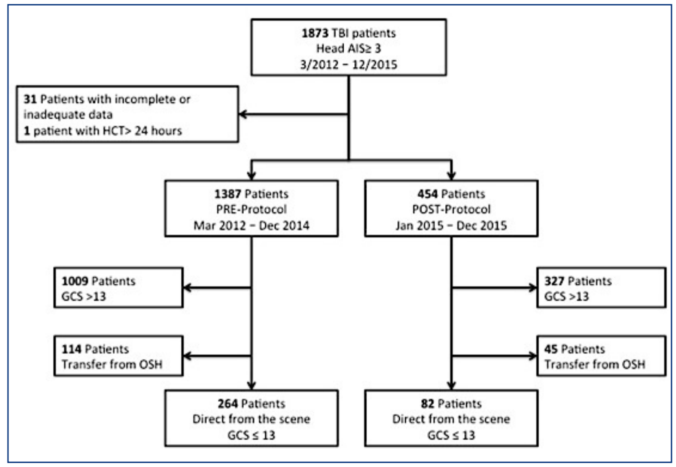
Categorical data were analyzed using Chi-square and reported as frequencies and percentages. Nonparametric continuous data were analyzed using Wilcoxon-Rank Sum test and nonparametric equality-of-medians test. These are presented as medians or averages with interquartile range (IQR) or percent as appropriate. Multiple regression analysis was used for predicting the odd ratios of mortality as a primary outcome. All statistical analyses were computed using a commercial statistical software (Stata/SE 14, StataCorp 2015, College Station, TX, USA) and were conducted with a significance level of 0.05.

RESULTS

Between March 2012 and December 2015, 1873 patients with TBI and a head AIS ≥ 3 were evaluated. After excluding patients based on above-mentioned criteria, our analytic sample included 346 patients. Two hundred and sixty-four patients (76.3%) were evaluated before the protocol was initiated PRE and 82 patients (23.7%) after the protocol POST. (**Figure 1**) There was no statistically significant difference between PRE and POST groups with respect to demographics, mechanism of injury, injury severity, or physiology. The number of procedures performed in the ED was similar in each group (median=1, p=0.34). (**Table 1**) Compared to the PRE group, the POST group was noted to have a significant difference in the percentage of patients who received HCT within 30 minutes (1.5% vs., 35.4%, p = <0.001), and the time to HCT (median: 77 minutes [58-95] PRE vs. 35 minutes [27-47] POST; p = <0.001, mean: 82 minutes PRE vs. 39 minutes POST). (**Figure 2**)

Post-protocol, EVD was placed more frequently (13.3% PRE vs. 25.6% POST, p = 0.01) and more rapidly (307 minutes [142-542] PRE vs. 159 minutes [129-195] POST, p = 0.01). Using multiple linear regression analysis to adjust for

Figure 1. Analytic sample selection process for traumatic brain injury patients who are evaluated in emergency department directly from the scene and who had GCS ≤13.



AIS: Abbreviated Injury Scale, HCT: Head Computed Tomography, GCS: Glasgow Coma Scale, OSH: Outside Hospital.

Table 1. Characteristics of patients in the PRE-protocol and POST-protocol groups. Data are presented as mean, median with range, or total number with percentage.

Characteristics	PRE-Protocol n=264	POST=Protocol n=82	p-value
Age, years	52 (18–101)	48 (18–96)	0.21
Gender, male	180 (68.2%)	62 (75.6%)	0.20
Race, white	227 (86%)	69 (85.2%	0.83
BMI	26 (13–44)	25.8 (15–40)	0.8
Mechanism, blunt	246 (93.2%)	77 (93.9%)	0.69
Fall	109 (41.3%)	34 (41.5%)	0.98
Pre–hospital anticoagulation	28 (10.6%) 28 (10.9)	8 (9.7%)	0.84
Injury severity score (ISS)	24.4 (9–59)	26.1 (9–75)	0.18
Head AIS (median)	4 (3–5)	5 (3–5)	0.08
AIS=3	73 (27.9%)	21 (25.6%)	0.19
AIS=4	83 (31.7%)	19 (23.2%)	
AIS=5	106 (40.5%)	42 (51.2%)	
Hypotension			
Pre–hospital	18 (8.6%)	4 (6.4%)	0.57
Emergency department (ED)	35 (13.2%)	17 (21.2%)	0.08
Number of ED procedures (median)	**1 (0–6)**	**1 (0–3)**	**0.34**
Tube thoracostomy	20 (7.6%)	3 (3.7%)	0.21
Central lines	34 (12.9%)	9 (11%)	0.65
Fracture reduction	9 (3.4%)	3 (3.6%)	0.91
Intubation	158 (59.8%)	53 (64.6%)	0.44

BMI: Body mass index, ISS: Injury Severity Score, AIS: Abbreviated Injury Scale, ED: Emergency Department.

age, gender, head AIS, and GCS, there was still significantly less time to EVD placement in the POST group compared to the PRE group (p=0.008). While there was no difference in the percentage of patients requiring surgical decompression on the first hospital day (38 [14.3%] PRE vs.7 [8.5%] POST, p = 0.26), the median time to surgical decompression, within the first twenty-four hours, was significantly shorter in the POST-protocol group (163 min [112-280] PRE vs.126 min [112-131] POST, p=0.04).

No significant differences were found in unadjusted mortality (38.1% vs. 32.9%, p=0.4), ED length of stay (median=291 min vs. 257 min, p=0.38), hospital length of stay (median= 6 vs. 9, p=0.30), or the need for discharge to a facility (73.8% vs. 78.2%, p=0.52). (**Table 2**) There were lower odds of mortality in the POST group compared to the PRE group when adjusting for age, gender, ISS, and GCS (OR 0.65, 95%CI 0.43 – 0.97). (**Table 3**)

Figure 2. Boxplot showing the distribution of time to head computed tomography (31) in the PRE-protocol and POST-protocol groups. The horizontal line is a reference line that represents the goal of time to HCT in the protocol (30 minutes).

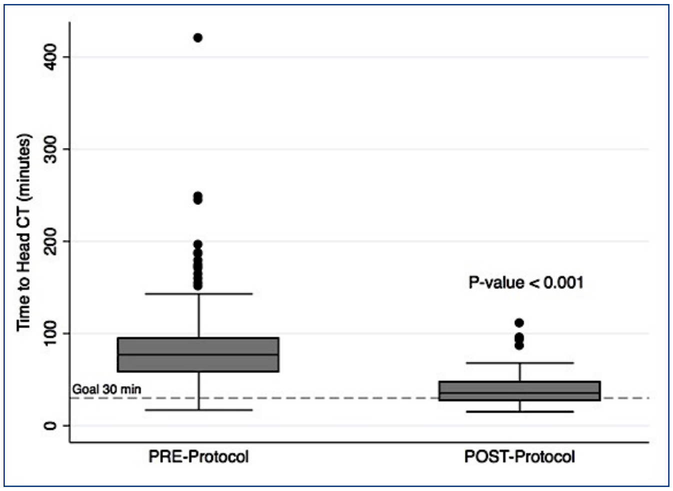


Table 2. Outcome differences between the PRE-protocol and the POST-protocol groups. Data presented as median with IQR or number of patients with percentage. Surgical decompression reflects number of craniectomy or craniotomy procedures performed on first hospital day (HD#1).

Outcome	PRE-Protocol n=264	POST=Protocol n=82	p-value
Death	101 (38.1)	27 (32.9)	0.4
Head CT scan within 30 minutes	4 (1.5) 29 (35.4)	29 (35.4)	<0.001
Time to head CT scan	77 (58–95)	35 (27–47)	<0.001
ED length of stay, minutes	291 (199–460)	257 (154–413)	0.38
Hospital length of stay, days	6 (2–18)	9 (3–22)	0.3
EVD placed on HD#1	35 (13.3)	21 (25.6)	0.01
Time to EVD, minutes*	307 (142–542)	159 (129–195)	0.01
Surgical decompression†	37 (14)	7 (8.5)	0.26
Time to decompression, minutes	163 (112–280)	126 (112–131)	0.04
Discharged to Facility	120 (73.6)	43 (78.2)	0.52

CT: Computed Tomography, ED: Emergency Department,
EVD: External Ventricular Drain.

* Time to EVD continued to be significantly less in the POST-protocol group when adjusted for age, gender, head AIS, and GCS in a multiple linear regression analysis (p=0.008)

† Rate of decompression if performed within 24 hours from admission.

Table 3. Multiple logistic regression analysis results showing crude and adjusted odds ratio (9) of mortality in POST-protocol group compared to PRE-protocol group adjusting to age, gender, ISS and GCS. Results expressed as odds ratios and 95% confidence intervals.

	Crude OR (95%CI)	Adjusted OR (95%CI)
POST-Protocol	0.78 (0.57–1.07)	0.65 (0.43–0.99)
Age	1.00 (0.99–1.01)	1.05 (1.04–1.06)
Gender, male	1.51 (1.14–2.01)	1.62 (1.10–2.38)
ISS	1.16 (1.14–1.18)	1.12 (1.10–1.15)
GCS	0.75 (0.73–0.78)	0.74 (0.71–0.78)

DISCUSSION

Severely injured patients, specifically those with moderate to severe traumatic brain injuries have improved outcomes when treated at a Level 1 trauma center.[9-12] This is due to improved access to appropriate diagnostic modalities, management by highly trained care teams, and rapid intervention when indicated.[13-15] Computed tomography has contributed to improved outcomes in trauma,[16] and many Level 1 trauma centers have implemented protocols that focus on expeditious image acquisition.[17-19] Delay in diagnosis of TBI is associated with increased mortality,[20] and the implementation of a decision support intervention to obtain early head CT resulted in higher rate of identification of intracranial hemorrhage that would have otherwise been missed, resulting in improved mortality.[21]

Ideal timing for first head CT in TBI patient is still unknown. Matsushima et al recommended faster times to CT scan in severe TBI patients in order to expedite neurosurgical interventions and subsequently to improve patients' outcomes.[8] In the aforementioned study of isolated severe trauma patients, the average time to HCT was 45 minutes. The Quality of Trauma in Adult Care (QTAC) program, based in the University of Calgary in Canada, uses time to HCT within 1 hour as a hospital quality indicator; however, the average time to HCT in one Canadian quality improvement study was 4 hours and 36 minutes.[22] The median time to HCT in a study by Easton and colleagues from the University of Newcastle in Australia was 66 minutes.[23] A recent analysis of the Trauma Quality Improvement Program database showed that earlier head CT within 1 hour from presentation was associated with earlier neurosurgical interventions.[24]

In an effort to improve the outcome of these patients, we implemented a quality improvement protocol in January 2015 to obtain head CT in moderate and severe TBI patients within 30 minutes from arrival. In our analysis immediately following the introducing the protocol, approximately one third of the patients POST-protocol met the desired goal time. Other investigators reported high compliance rates (>70%) after implementing similar CT protocols in acute stroke.[25, 26] The lower compliance rate we observed is likely multifactorial. Unlike stroke patients, moderate to severe TBI patients frequently present with an array of other injuries requiring immediate interventions during the initial resuscitation phase. Two thirds of the patients in our sample required intubation prior to obtaining diagnostic studies. These interventions, while unavoidable, cause significant delays in the workup of potential TBI. Future work is crucial to identify modifiable factors that could result in even further reduction in time to HCT. For example, in centers without immediate availability of CT scanners, the installation of these scanners in close proximity to trauma resuscitation rooms in the ED[18] or the utilization of portable CT scanners[27] has been shown to significantly reduce the time needed to obtain diagnostic imaging in trauma patients.

The time to critical neurosurgical intervention and in-hospital mortality are important quality metrics to consider when evaluating TBI-specific outcomes.[8] After implementing our protocol, more patients underwent EVD placement and received this intervention more rapidly, halving the median time from 309 minutes to 159 minutes. The increase in EVD placement can be attributed to two potential factors. The early diagnosis likely helped in identifying eligible patients who would benefit from early neurosurgical interventions. The improved awareness that was generated around the time of the protocol could have been led to earlier and more aggressive management decisions regarding invasive monitoring. Similarly, for those who required surgical decompression – craniotomy or craniectomy – the time to the operating room was shorter in the POST group than the PRE group by 34 minutes. Ultimately, there were lower odds (OR 0.65) of mortality in moderate to severe TBI patient after implementing the protocol, controlling for age, gender, ISS and initial GCS. We believe the observed improvement in these outcomes to be a surrogate to quality of care after implementing the protocol and not due to direct effect of the time to HCT. We attribute these findings to the increased awareness of the importance of rapid diagnosis and treatment of traumatic brain injury. Similarly, Techar et al found an association between delay in head CT scan and in-patient mortality. They attributed this association to delay in neurosurgical interventions as a result of delay in diagnosis. However, while the analysis by Schellenberg et al did show that earlier head CT was associated with earlier placemen of EVD and earlier surgical interventions when indicated, it did not find an association with reduced mortality.[24] Both the use of intracranial pressure monitoring[28] and the reduced time to surgical decompression have been suggested as interventions to improve outcomes in TBI patients.[13-15, 29, 30]

LIMITATIONS

There are several limitations to this study. First, this is a retrospective cohort study, and therefore, we cannot prove causality, nor can we account for unknown biases. Moreover, there are likely unmeasured confounders that we could not control for in our regression analysis. Complete adjustment of all confounders could have resulted in a weaker association. We acknowledge that unrecognized and immeasurable changes in the practice patterns might have occurred. Our analysis was limited by observational bias due to data collection and entry. This study design might impact its generalizability. In this current analysis, we compared pre- and post-protocol implementation, similar to an intention-to-treat analysis, to reflect the protocol impact as a whole. Alternatively, we strongly consider, and encourage, analyzing time to head CT specifically as an independent factor influencing TBI-specific outcomes. To avoid the possible confounding of the time of protocol implementation, such an analysis would include patients in the post-protocol time period only and compare those who did and did not get a head CT within 30 minutes. Second, the reported time to HCT did not account for potential delays within the radiology suite after arrival. Third, we were unable to report neurological outcomes at the time of discharge. Traumatic brain injury patients often have significant short-term and long-term functional deficits. Functional outcome scales, like Glasgow Outcome Scale, are not routinely obtained for our TBI population. Finally, due to the limited length of the POST period we could not identify a transition period after which we could possibly observe even stronger improvement in outcomes. Future evaluation of long-term effects of the protocol on times to interventions and outcomes would likely clarify this relationship and evaluate sustainable results for a longer duration. Further prospective investigations would be needed to demonstrate a direct effect on our primary and secondary outcomes.

CONCLUSION

In our experience, the application of a novel protocol to obtain early HCT for severe TBI optimized performance of the multi-disciplinary trauma team and improved outcomes.

We believe that our study provides preliminary evidence that time to HCT could be recommended as a quality metric in patients with moderate to severe TBI. Future evaluations, as well as a larger prospective study, are warranted to further validate its value. While our protocol focused on triaging suspected TBI based on GCS, we encourage extending this protocol to those with suspected mild TBI and focal neurological signs as it is imperial to identify these suspected injuries early.

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Authors

Tareq Kheirbek, MD, ScM, FACS, Alpert Medical School of Brown University, Providence, RI.

Andrew R. Luhrs, MD, Alpert Medical School of Brown University, Providence, RI.

Jayson S. Marwaha, MD, Alpert Medical School of Brown University, Providence, RI.

Andrew H. Stephen, MD, Alpert Medical School of Brown University, Providence, RI.

Charles A. Adams, MD, FACS, Alpert Medical School of Brown University, Providence, RI.

Stephanie N. Lueckel, MD, ScM, FACS, Alpert Medical School of Brown University, Providence, RI.

Disclosures

None of the authors have any conflict of interest to report.

Correspondence

Tareq Kheirbek, MD, ScM FACS
Trauma, Acute Care Surgery & Surgical Critical Care
Rhode Island Hospital, 593 Eddy Street, APC 435
Providence, RI 02903
401-444-6461
tareq_kheirbek@brown.edu