Prospective validation of the brain injury guidelines: Managing traumatic brain injury without neurosurgical consultation

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BACKGROUND: To optimize neurosurgical resources, guidelines were developed at our institution, allowing the acute care surgeons to independently manage traumatic intracranial hemorrhage less than or equal to 4 mm. The aim of our study was to evaluate our established Brain Injury Guidelines (BIG 1 category) for managing patients with traumatic brain injury (TBI) without neurosurgical consultation.

METHODS: We formulated the BIG based on a 4-year retrospective chart review of all TBI patients presenting at our Level 1 trauma center. We then prospectively implemented our BIG 1 category to identify TBI patients that were to be managed without neurosurgical consultation (No-NC). Propensity scoring matched patients with No-NC to a similar cohort of patients managed with NC before the implementation of our BIG in a 1:1 ratio for demographics, severity of injury, and type and size of intracranial hemorrhage. Primary outcome measure was need for neurosurgical intervention and 30-day readmission rates.

RESULTS: A total of 254 TBI patients (127 of NC and 127 of No-NC patients) were included in the analysis. The mean (SD) age was 40.8 (22.7) years, 63.4% (n = 161) were male, median Glasgow Coma Scale (GCS) score was 15 (range, 13–15), and median head Abbreviated Injury Scale (AIS) score was 2 (range, 2–3). There was no neurosurgical intervention or 30-day readmission in both the groups. In the No-NC group, 3.9% of the patients had postdischarge emergency department visits compared with 4.7% of the NC group ($p = 0.5$). All patients were discharged home from the emergency department.

CONCLUSION: We validated our BIG and demonstrated that acute care surgeons can effectively care for minimally injured TBI patients with good outcomes. A national multi-institutional prospective evaluation is warranted. (*J Trauma Acute Care Surg*. 2014;77: 984–988.

LEVEL OF EVIDENCE: Therapeutic/care management, level IV.

KEY WORDS: Management of traumatic brain injury; neurosurgical consultation; brain injury guidelines; neurosurgical intervention; acute care surgeons.

Traumatic brain injury (TBI) continues to burden the health care system of the United States, accounting for more than 1.4 million emergency department (ED) visits each year.[1] Approximately 75% of the patients who are seen in the ED have minor head injury not requiring immediate assessment by neurosurgical specialists.[2,3] The current standard of care for patients with traumatic intracranial hemorrhage (ICH) includes neurosurgical consultation (NC) and/or transfer to a trauma center where neurosurgical services are available.[4,5] However, in recent years, the management of these patients with TBI is evolving.

Several studies have emphasized the growing role of acute care surgeons in the care of patients with minor head injury.[4–10] In a previous study from our institution, we highlighted the management of patients with traumatic ICH without NC.[4] We found that there was no difference in patient outcomes among patients managed by acute care surgeons in comparison with a similar cohort of patients managed by neurosurgeons. However, there are no well-defined guidelines to define the management of these patients. As a result, we developed guidelines termed as *Brain Injury Guidelines* (BIG) in collaboration with neurosurgeons at our institution to formulate a therapeutic plan for management of these patients (Fig. 1).[6] Based on these guidelines, we suggested that mild TBI patients with miniscule findings on the initial computed tomography (CT) scan can be managed safely and effectively by acute care surgeons without NC.[6]

However, those guidelines were developed based on a retrospective review of patients and require prospective validation before widespread clinical implementation. The aim of our study was to validate our established BIG (BIG 1 category) for managing TBI patients without NC. We hypothesized that trauma surgeons can independently manage TBI patients without NC with the implementation of BIG (BIG 1 category).

METHODS

We performed a prospective cohort analysis of all patients with a TBI seen at our Level 1 trauma center from March 1, 2012, through December 31, 2013.

Inclusion and Exclusion Criteria

Patients with TBI with an ICH on initial head CT scan meeting BIG 1 criteria were enrolled in this study (Fig. 1).

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Brain Injury Guidelines			
Variables	**BIG 1**	**BIG 2**	**BIG 3**
LOC	Yes/No	Yes/No	Yes/No
Neurologic examination	Normal	Normal	Abnormal
Intoxication	No	No/Yes	No/Yes
CAMP	No	No	Yes
Skull Fracture	No	Non-displaced	Displaced
SDH	≤ 4mm	5 - 7 mm	≥ 8 mm
EDH	≤ 4mm	5 - 7 mm	≥ 8 mm
IPH	≤ 4mm, 1 location	5 - 7 mm, 2 locations	≥ 8 mm, multiple locations
SAH	Trace	Localized	Scattered
IVH	No	No	Yes
THERAPEUTIC PLAN			
Hospitalization	Observation (6hrs)	Yes	Yes
RHCT	No	No	Yes
NSC	No	No	Yes

Figure 1. Brain Injury Guidelines.

Patients who were categorized as BIG 1 were not on any antiplatelet or anticoagulation medications and had an ICH of 4 mm or less and no skull fracture on initial head CT scan. We excluded patients who had been transferred from other institutions, patients who were not examinable (e.g., altered mental status or intubated), patients with abnormal neurologic examination findings on presentation, and patients undergoing emergent neurosurgical intervention.

Study Protocol

1. We implemented the BIG in March 2012 for defining the management of TBI.
2. Patients with suspected TBI underwent an initial head CT scan; those with an intracranial injury were evaluated.
3. Patients categorized into BIG 1 category based on patient's history, neurologic examination, and initial head CT scan findings were included. Patients had to meet each criterion to be classified into this category.
4. Patients in the BIG 1 category were observed for 6 hours, without NC and no repeat head CT (RHCT).We defined abnormal neurologic examination finding as altered mental status, focal neurologic deficits, and an abnormal pupillary examination finding.
5. Neurologic examination was performed in a patient every 2 hours. Patients who had deterioration in clinical examination findings were upgraded to a higher category warranting an RHCT and NC.

Data Points

The following data points were prospectively recorded in each patient: patient demographics, which included age and sex; mechanism of injury; vital parameters on presentation, which included systolic blood pressure (SBP), heart rate (HR), temperature, and Glasgow Coma Scale (GCS) score; neurologic examination on presentation; intoxication (drug or alcohol); details regarding antiplatelet and anticoagulation therapy; intubation; loss of consciousness; initial head CT scan findings; reasons and findings of RHCT and NC; neurosurgical intervention details; hospital and intensive care unit (ICU) length of stay (LOS); discharge disposition; GCS score on discharge; and in-hospital mortality. The Injury Severity Score (ISS) and head Abbreviated Injury Scale (h-AIS) score were obtained from the trauma registry. Patients were followed up to 30 days after their initial discharge for any readmission, any RHCT requirement, and any symptoms of head injury (including headache, vomiting, and vision problems).

Study Population

Patients meeting BIG 1 criteria that were managed without NC (No-NC) were then matched to a similar cohort of patients managed with NC before implementation of BIG. The patients in the two groups, NC and No-NC groups, were matched using propensity score matching in a 1:1 ratio for age, sex, GCS score on presentation, neurologic examination, vital parameters on presentation (SBP and HR), size and type of ICH, type of skull fracture, and severity of head injury.

Outcome Measures

The primary outcome measure was the need for neurosurgical intervention. The secondary outcome measures were RHCT scan requirement, hospital and ICU admissions, in-hospital mortality, and 30-day readmission.

The initial CT and RHCT scan findings were reviewed by the attending radiologist and then reconfirmed by a single investigator for the type and size of ICH. Progression on RHCT was defined as an increase in the size of the initial hemorrhage or the development of a new hemorrhage. Neurosurgical intervention was defined as a craniotomy or craniectomy.

Data Analysis

Data are reported as mean (SD) for continuous descriptive variables, as median (range) for ordinal descriptive variables, and as proportion for categorical variables. We used Mann-Whitney U-test and the Student's t test to explore for differences in the two groups (NC and No-NC) for continuous variables. We used χ^2 test to identify differences in outcomes between the two groups for categorical variables. For our study, we considered $p \leq 0.05$ as statistically significant. All statistical analyses were performed using the SPSS (version 20, SPSS, Inc., Chicago, IL).

This study was approved by the institutional review board at the University of Arizona, College of Medicine.

RESULTS

A total of 148 patients meeting BIG 1 criteria were managed without NC after the implementation of BIG. In this study, we included a total of 254 TBI patients with ICH on initial head CT (NC before implementation of BIG, 127; No-NC after implementation of BIG, 127). The mean (SD) age was 40.8 (22.7) years, 63.4% (n = 161) were male, median GCS score was 15 (range, 13–15), and median h-AIS score was 2 (range, 2–3). There was no difference in age ($p = 0.71$), mechanism of injury ($p = 0.68$), GCS score on presentation ($p = 0.84$), and severity of head injury ($p = 0.94$) between patients in the NC and in the No-NC group. Table 1 demonstrates the demographic characteristics of the study population.

For both groups considered together, the two most common types of ICH were subarachnoid hemorrhage (36.6%)

TABLE 1. Demographics

Characteristics	No-NC (n = 127)	NC (n = 127)	*p*
Age, mean (SD), y	41.2 (21.6	39.4 (24.8	0.71
≥65 y, % (n)	22.8 (29)	24.4 (31)	0.76
Male, % (n)	64.6 (82)	62.2 (79)	0.69
GCS score, median (IQR)	15 (13–15)	15 (13–15)	0.84
ED SBP, mean (SD)	132.5 (28.1)	136.1 (22.4)	0.89
ED HR, mean (SD)	78.6 (24.5)	84.2 (21.8)	0.68
Mechanism of injury, % (n)			—
MVC	46.5 (59)	42.5 (54)	0.52
Fall	33.8 (43)	36.2 (46)	0.68
ISS, median (IQR)	14 (8–16)	14 (9–17)	0.91
h-AIS score, median (IQR)	2 (2–3)	2 (2–3)	0.94

MVC, motor vehicle collision.

and subdural hemorrhage (29.1%). We found no difference in the type ($p = 0.9$) or size of ICH ($p = 0.62$) between the two groups. Table 2 summarizes the initial head CT findings.

Of the patients, 30.3% (n = 77) underwent an RHCT scan. Patients in the NC group were more likely to receive an RHCT compared with patients in the No-NC group ($p = 0.001$). All RHCT scans were performed routinely, and no patient underwent deterioration in neurologic examination. Table 3 demonstrates the in-hospital outcomes of the study population.

Of the patients, 64.9% (n = 165) were admitted to the hospital. Patients in the NC group were more likely to be admitted to the hospital ($p = 0.02$) and ICU ($p = 0.01$) compared with patients in the No-NC group. No patient underwent a neurosurgical intervention, deteriorated clinically, or died in either group.

We found no difference in any 30-day outcome between the two groups. Of the 11 patients who visited the ED within 30 days, 5 had a headache and 4 had vomiting. Table 3 summarizes the in-hospital and 30-day outcomes.

Patients in the No-NC group had a shorter hospital stay than those in the NC group ($p = 0.04$). However, we found no difference in the ICU LOS between the two groups ($p = 0.85$). The overall hospital cost ($p = 0.02$) and hospital charges ($p = 0.04$) were lower in the No-NC group. Table 4 summarizes our LOS and cost analysis.

The compliance with the BIG was 84.3%. Of the patients, 15.7% (n = 20) deviated from the BIG 1 therapeutic plan.

TABLE 2. Initial Head CT Scan Findings

Characteristics	No-NC (n = 127)	NC (n = 127)	*p*
SDH, % (n)	28.3 (36)	30 (38)	0.76
Size, mean (SD), mm	3.1 (2.9)	3.3 (3)	0.62
EDH, % (n)	5.5 (7)	7.9 (10)	0.45
Size, mean (SD), mm	2.9 (2.5)	3.1 (2.8)	0.59
SAH, % (n)	37.8 (48)	35.4 (45)	0.69
IPH, % (n)	26.7 (34)	24.4 (31)	0.67
IVH, % (n)	7 (9)	9.4 (12)	0.48

EDH, epidural hemorrhage; IPH, intraparenchymal hemorrhage; IVH, Intraventricular hemorrhage; SAH, subarachnoid hemorrhage; SDH, subdural hemorrhage.

TABLE 3. Outcomes

Characteristics	No-NC (n = 127)	NC (n = 127)	*p*
In-hospital outcomes, % (n)			
RHCT	9.4 (12)	51.2 (65)	0.001
Progression on RHCT	1 (1)	2.3 (3)	0.64
Neurosurgical intervention	0	0	0.9
Hospital admission	56 (71)	74 (94)	0.02
ICU admission	6.3 (8)	25.2 (32)	0.01
30-d outcomes, % (n)			
30-d readmission	0	0	0.9
30-d ED visits	3.9 (5)	4.7 (6)	0.75
30-d RHCT	1.5 (2)	2.3 (3)	0.64
30-d mortality	0	0	0.9

Twelve patients had a routine RHCT, one of whom showed progression of ICH, while eight patients had an ICU admission. Figure 2 demonstrates the compliance to the BIG during the study period.

DISCUSSION

The current standard of care for patients with a minor intracranial injury is evolving. In this study, we prospectively implemented our developed BIG (BIG 1 category) for the management of patients with head injury without NC. In a matched cohort of patients, we found no difference in the need for neurosurgical intervention, the rate of progression on RHCT scan, and 30-day outcomes in patients managed by the acute care surgeons and patients managed by the neurosurgeons. In addition, the management of patients without NC was associated with a reduction in the use of RHCT scans and overall reduction in hospital costs.

Patients with minor head injury are routinely managed nonoperatively and have a low rate of neurosurgical intervention.[5,7–9,11,12] In our study, no patient had deteriorated clinically, and no patient underwent a neurosurgical intervention. Several authors have previously suggested that small intracranial bleeding can be managed independent of NC. Huynh et al.[7] demonstrated no neurosurgical intervention in patients with an ICH of 3 mm or less. Similarly, Rhodes et al.[8] in a retrospective review of assessing selective NC demonstrated no neurosurgical intervention in patients with minor head injury. In another recent analysis, Klein et al.[9] have suggested that solitary brain contusion of less than 1 cm in diameter, limited small subarachnoid hemorrhage, or subdural hematoma of less

TABLE 4. LOS and Cost Analysis

Characteristics	No-NC (n = 127)	NC (n = 127)	*p*
LOS			
Hospital LOS, mean (SD)	1.3 (1.1)	3 (2.8)	**0.041**
ICU LOS, mean (SD)	1 (0.9)	1.2 (1.1)	0.85
Cost			
Hospital cost, US dollars	11,615 (10,291)	16,238 (11,019)	**0.02**
Hospital charges, US dollars	41,528 (26,810)	48,780 (28,140)	**0.042**

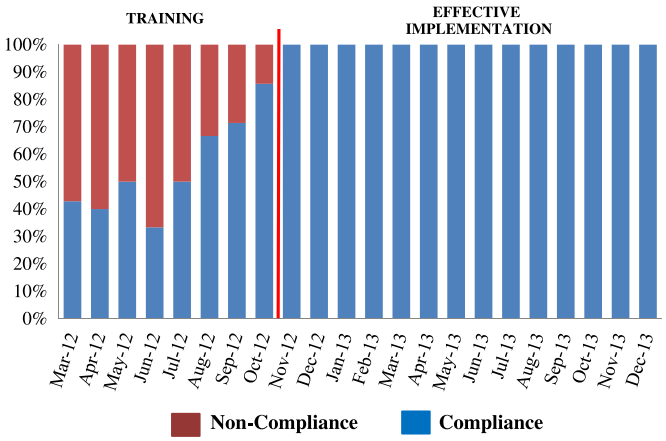

Figure 2. Implementation of BIG.

than 5 mm in maximal width and length can be safely managed without NC. Similarly, Borczuk et al.[5] showed that patients with isolated traumatic subarachnoid hemorrhage are at lower risk of clinical deterioration and can be managed independently by the acute care surgeons. However, all these studies have been retrospective in nature and have highlighted the need for a prospective analysis to assess this subject. Based on the findings of this study, we can safely conclude that an ICH of less than 4 mm can be safely and independently managed by the acute care surgeons without the need for NC.

In our study, 30.3% of the patients underwent an RHCT, of whom 5.2% had progression on RHCT and none required neurosurgical intervention. Brown et al.[13] in a prospective study demonstrated no change in management in patients based on findings on routine RHCT scan. Similarly, in another studies from our institution, we recommended the use of routine RHCT only in patients who were not examinable.[14,15] Furthermore, with the advancements in CT scan technology, the clinical importance of miniscule changes as recorded by the CT scanner is questionable. The findings of our current study validate our developed guidelines recommending no use of RHCT in examinable patients with an ICH of less than 4 mm.

Given the current national focus on minimizing health care costs while simultaneously improving quality of care and patient outcomes, our guidelines are of paramount importance. We demonstrated that care of patients with minor head injury by acute care surgeons is not only safe but also cost-effective. Patients cared for by acute care surgeons had a shorter hospital stay and also lower overall hospital costs than those cared for by neurosurgeons. The implementation of BIG may help to provide effective health care and a lower cost to patients with minor head injury.

The compliance rate for the implementation of our guidelines was 84.3%. In 20 patients, the therapeutic plan for the BIG 1 category was not followed: 12 of those patients underwent RHCT, and the remaining 8 required ICU admission. This deviation from the guidelines occurred in the early phase of our implementation, while our surgeons and residents were still becoming acclimated to this change in practice. The compliance rate was 100% in the later part of the study, which highlights the learning curve involved in the process of implementing our guidelines. It is important to note that the 19 patients who met BIG 1 criteria were excluded in the propensity score matching; all were compliant with the BIG 1 therapeutic management plan.

Our current study had several other limitations. First, our results were obtained at a single academic medical center and, therefore, may not be generalizable beyond similar patients. Second, we did not perform a robust cost analysis to assess the cost-effectiveness of the implementation of the guidelines. Third, we retrospectively matched the patients that were managed by the neurosurgeons before the implementation of our guidelines. Nevertheless, our study prospectively validates the developed BIG 1 and demonstrates that acute care surgeons can manage patients with traumatic ICH without NC.

CONCLUSION

We prospectively validated our developed BIG and demonstrated that implementation of the BIG allows acute care surgeons to independently care for patients with an ICH of less than 4 mm without the need for inpatient NC. In addition, we demonstrated that acute care surgeons can effectively care for minimally injured TBI patients with good outcomes. A national multicenter prospective evaluation to standardize the BIG is warranted.

AUTHORSHIP

B.J, N.K., T.K., R.S.F., M.G.L., and P.R. designed this study. B.J., H.A., V.P., N.K., A.T., R.S.F., and M.G.L. searched the literature. B.J., H.A., V.P., A.T., and D.J.G. collected the data. B.J., H.A., V.P., N.K., A.T., T.O., R.S.F., and M.L. analyzed the data. All other authors participated in the data interpretation and manuscript preparation.

DISCLOSURE

The authors declare no conflicts of interest.

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