

Clinical significance of posttraumatic intracranial hemorrhage in clinically mild brain injury: a retrospective cohort study

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Abstract

Background: Much attention has been focused on management of severe traumatic brain injury (TBI); however, comparatively little is known about management of traumatic hemorrhage in clinically mild TBI. We aimed to clarify the role of clinical observation and repeat radiography for patients with mild TBI and abnormal findings on initial computed tomography (CT) of the head.

Methods: We queried the neurotrauma database of the Ontario Trauma Registry and the Sunnybrook institutional database to identify patients with CT findings of a traumatic hemorrhage or calvarial fracture between November 2014 and December 2016. Exclusionary criteria were age less than 16 years, Glasgow Coma Scale (GCS) score less than 13, anticoagulant use, bleeding diathesis and midline shift greater than 5 mm. The primary outcome was the need for neurosurgical intervention.

Results: A total of 607 patients were included. Most (374 [61.6%]) had a GCS score of 15; 185 (30.5%) and 48 (7.9%) had a GCS score of 14 and 13, respectively. Five patients (0.8%) required surgical intervention, all within the first 72 hours, owing to clinical deterioration with subsequently demonstrated radiographic evidence of expanding hemorrhage. Most patients (506 [83.4%]) had routine repeat imaging, without documented change in their neurologic status.

Interpretation: The majority of patients in our cohort had repeat imaging, which did not influence surgical management, at substantial cost to the health care system. The findings suggest the need to reevaluate repeat imaging protocols for this subset of patients with TBI.

The majority of patients arriving at the emergency department with head trauma have a clinically mild traumatic brain injury (TBI), defined as a Glasgow Coma Scale score of 13–15.^{1,2} Much attention has been directed toward identifying which patients with mild TBI should have computed tomography (CT) of the brain. Guidelines of this nature, such as the Canadian CT Head Rule, are helpful in selecting patients with mild TBI who are more likely to have an intracranial injury and to optimize resource use.³

Although there has been a substantial amount of research on mild TBI, most has been focused on concussion, which, by definition, excludes patients with an abnormal initial head CT scan.⁴ When imaging shows the presence of traumatic intracranial hemorrhage in patients with an otherwise minor head injury, the management becomes more complex. Comparatively less information is available to direct clinical management of these patients, who are without indication for surgical intervention. We hypothesized that 1) the majority of routine CT scans done in such patients in the absence of any clinical change likely do not show changes that will alter clinical management,

2) neurosurgical intervention in these cases is rare and 3) limiting these routine CT scans may help optimize hospital resources. The aim of the present investigation was to clarify the role of clinical observation and repeat radiographic imaging for patients with mild TBI who present with a CT scan of the brain showing traumatic intracranial hemorrhage.

Methods

Study design and sources of data

The study was a retrospective cohort database study. We obtained data from the Ontario Trauma Registry (www.ontario.ca/data/ontario-trauma-registry-otr), a database

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maintained prospectively by the government of Ontario with detailed data on major trauma and data on all deaths resulting from injury in Ontario, and the Sunnybrook institutional database, an institution-specific collection of patient data based on triaged cases of trauma and patients' electronic patient record. Information is collected for all cases (with or without TBI) in which the trauma team is activated as well as all cases with a mechanism of injury and Injury Severity Score of 12 or higher in which the trauma team is not activated. The Canadian Institute for Health Information ensures that the quality of information in their data holdings, including the Ontario Trauma Registry, is suited to its intended uses, and users are provided with accurate information about data quality; however, documentation of Ontario Trauma Registry data quality is currently unavailable.

Data collection and extraction

Three authors (C.D.W., J.Z.W. and N.S.) screened the Ontario Trauma Registry and the Sunnybrook institutional database using a coding form to identify patients who presented with TBI and a GCS score of 13 or higher between November 2014 and December 2016. Patients with mild TBI (GCS score at presentation \geq 13 and confirmed posttraumatic hemorrhage on noncontrast head CT) were included. From this list, patients were excluded from the analysis if they were less than 16 years of age, had an initial presenting GCS score less than 13, had a comorbid neurologic or psychological condition precluding a reliable neurologic examination, were documented as taking anticoagulation or antiplatelet medication, had previously diagnosed bleeding diathesis, had radiographic evidence of substantial mass effect (midline shift $>$ 5 mm), had a penetrating mechanism of injury, did not have sufficient clinical or radiographic information on their patient record, or otherwise had a clear, immediate neurosurgical indication based on their initial presentation and CT scan as determined by the admitting neurosurgical staff physician.

All patients were initially assessed in the trauma bay or emergency department. Initial imaging was ordered as deemed appropriate by the treating physician in the emergency department (emergency doctor or trauma team leader). Although there is no established protocol at our institution, repeat head CT after an initial scan shows positive findings is often ordered routinely after a specific period of time (usually 4–6 h after the initial scan) or for a specific indication such as neurologic deterioration. All CT scans were read by a staff radiologist and compared with the patient's previous scan(s).

We collected patient characteristics including age, gender, presenting GCS and alcohol use status. Trauma characteristics including mechanism of injury, concomitant other injuries identified with Abbreviated Injury Scale codes and total Injury Severity Score were also collected. In addition, we collected information on the patient's subsequent course including number of head CT scans, indication for repeat head CT, disposition after the emergency department, length of stay in hospital, length of stay in the intensive care unit (ICU) and need for neurosurgical intervention.

Outcomes of interest

The primary outcome of interest was the need for neurosurgical intervention, defined using *International Classification of Diseases and Related Health Problems* (ICD-10) procedure codes, including but not limited to insertion of an intracranial monitoring device or external ventricular drain, or decompression by craniotomy or craniectomy. Secondary outcomes included number of repeat CT scans, indication for repeat CT, ICU admission, length of stay in the ICU and total length of hospital stay.

Analysis

We conducted a descriptive data analysis on admission patterns, radiographic follow-up and the association of radiographic follow-up with our primary outcome of interest. Continuous variables are presented as medians with their respective interquartile range (IQR), and categorical variables are generally presented as frequencies and proportions. A basic cost analysis was also done.

Ethics approval

The study was approved by the Research Ethics Board at Sunnybrook Health Sciences Centre. Since all data were deidentified before collection, informed consent from the patients was not required.

Results

Patient information

From November 2014 to December 2016, 617 patients with mild TBI were identified and met the initial criteria for inclusion (mild TBI and posttraumatic hemorrhage). Ten patients were excluded: use of aspirin and clopidogrel (1), use of warfarin (1), severe frontal bone fracture with more than 2 cm of depression (1), discharged and re-presented 6 weeks later with a chronic subdural hematoma requiring evacuation (1), midline shift measuring 6 mm or more on initial head CT (3), documented GCS of 11 in trauma bay (1), no traumatic injuries based on Abbreviated Injury Scale codes (1) and insufficient chart information on presenting condition, hospital stay, intervention and follow-up (1). Our final study cohort thus consisted of 607 patients.

Patient demographic and trauma information is presented in Table 1. The majority of patients were male (415 [68.4%]), and the median age was 55 (IQR 37–70) years. Only 57 patients (9.4%) presented with an isolated intracranial injury. The most common system concurrently injured was the face and neck (281 [46.3%]). The most common mechanism of injury was a fall (234 [38.6%]). A minority of the falls (50 [21.4%]) were from standing height; all others were from elevations ranging from several steps to ladders and scaffolds. The second most common mechanism of injury was motor vehicle collision (138 [22.7%]).

Neuroimaging

Most patients (506 [83.4%]) received serial neuroimaging with repeat CT scans of the head. A total of 304 patients

Table 1: Baseline characteristics of patients with mild traumatic brain injury and computed tomography findings of intracranial hemorrhage

Characteristic	No. (%) of patients* n = 607
Median age, yr (IQR)	55 (37–70)
Male	415 (68.4)
Mechanism of injury	
Fall	234 (38.6)
Motor vehicle collision	138 (22.7)
Struck by motor vehicle as pedestrian	111 (18.3)
Struck by motor vehicle as cyclist	44 (7.2)
Assault (blunt trauma)	23 (3.8)
Motorcycle/all-terrain vehicle collision	23 (3.8)
Other†	34 (5.6)
Isolated head injury	57 (9.4)
Finding on initial head CT	
Traumatic subarachnoid hemorrhage	325 (53.5)
Subdural hematoma	280 (46.1)
Intracerebral hemorrhage	218 (35.9)
Skull fracture/pneumocephalus	124 (20.4)
Intraventricular hemorrhage	48 (7.9)
Epidural hematoma	36 (5.9)
Concomitant other injuries	
Face + neck	281 (46.3)
Thorax	240 (39.5)
Abdomen/pelvis	61 (10.0)
Spine	186 (30.6)
Upper extremity	212 (34.9)
Lower extremity	167 (27.5)
External/burns/other	19 (3.1)
Median Injury Severity Score (IQR)	17 (14–24)
Total Injury Severity Score	
1–15	197 (32.4)
16–25	274 (45.1)
> 25	133 (21.9)
Missing	3 (0.5)
Initial Glasgow Coma Scale score	
15	374 (61.6)
14	185 (30.5)
13	48 (7.9)
Alcohol consumption (n = 392)	
No	316 (80.6)
Yes, beyond legal limit	60 (15.3)
Yes, trace limit	16 (4.1)

Note: CT = computed tomography, IQR = interquartile range.
*Except where noted otherwise.
†Intentional self-harm, snowmobile accident, diving injury, watercraft-related injury.

(50.1%) had 1 repeat CT scan after their initial neuroimaging, 118 (19.4%) had 2 repeat scans, and 84 (13.8%) had 3 or more repeat scans. The most common indication (385/506 [76.1%]) for repeat CT was for “routine” surveillance and radiographic follow-up in the absence of any clinical change. Only 30/506 patients (5.9%) received repeat CT owing to documented neurologic deterioration, and only 5/607 patients (0.8%) subsequently required neurosurgical intervention. There was no difference in the median number of head CT scans done per patient based on the initial GCS. Three patients required a longer hospital stay for monitoring without the need for surgical intervention, owing to the development of increased pneumocephalus on the interval scan in 2 and enlargement of temporal contusions in 1. In 6 patients, anticoagulation therapy was started for a vascular dissection found on the second CT scan.

Disposition and duration of stay

The patients’ hospital course and imaging/interventions are presented in Table 2. After assessment in the trauma bay and emergency department, 282 patients (46.5%) were admitted to the dedicated hospital trauma/general surgery service, and 160 (26.4%) were admitted to the neurosurgical service. Only 29 patients (4.8%) were discharged directly from the emergency department after observation (back to their own home or home hospital in most cases); of the 29, 25 (86%) received at least 1 repeat head CT scan during this observation period, with 6/25 (24%) receiving more than 1 repeat CT scan.

The majority of patients (382 [62.9%]) were admitted to the ICU for at least a short period, with a median length of ICU stay of 3 days (IQR 1–6 d). The overall median length of stay in hospital was 7 days (IQR 3–13.25 d). Most patients (303/578 [52.4%]) stayed 1 week or less in hospital.

Neurosurgical intervention

Of the 607 patients, 5 (0.8%) required neurosurgical intervention (Appendix 1, available at www.cmajopen.ca/content/7/3/E511/suppl/DC1). All of these patients experienced neurologic deterioration within 72 hours of their presentation to the emergency department and subsequently received repeat CT, which showed worsening of their intracranial injury such as expansion of an intracranial hematoma and/or worsening mass effect that mandated operative intervention. The specific operation, findings on the initial plain head CT scan and indication for the operation for the 5 patients are described in detail in Appendix 1.

Cost analysis

The basic cost analysis is presented in Appendix 2 (available at www.cmajopen.ca/content/7/3/E511/suppl/DC1).

Interpretation

Our study showed that routine CT of the head is frequently repeated in patients without notable risk factors for progressive intracranial bleeding following a mild traumatic brain injury and hemorrhage. Computed tomography of the head done in

Table 2: Hospital course, imaging and interventions

Variable	No. (%) of patients*
No. of head CT scans, median (IQR)	2 (2–3)
No. of head CT scans	
1	101 (16.6)
2	304 (50.1)
3	118 (19.4)
≥ 4	84 (13.8)
Indication for repeat head CT (n = 506)	
Routine†	385 (76.1)
Neurologic deterioration	30 (5.9)
Rule out vascular injury	89 (17.6)
Other	2 (0.4)
Finding on repeat head CT altered medical management‡	7 (1.4)
Disposition after emergency department	
Trauma/general surgery	282 (46.5)
Neurosurgery	160 (26.4)
Medicine	78 (12.8)
Orthopedic surgery	51 (8.4)
Plastic surgery	7 (1.2)
Discharged	29 (4.8)
Length of stay, d, median (IQR)	7 (3–13.25)
Total length of stay, d	
≤ 7	317 (52.2)
8–14	156 (25.7)
> 14	134 (22.1)
Required ICU stay	382 (62.9)
Length of ICU stay, d, median (IQR)	3 (1–6)
Total length of ICU stay, d (n = 382)	
≤ 7	307 (80.4)
8–14	39 (10.2)
> 14	36 (9.4)
Required neurosurgical intervention§	5 (0.8)
Type of operation (n = 5)	
Decompressive craniectomy	3 (60)
Craniotomy	2 (40)

Note: CT = computed tomography, ICU = intensive care unit, IQR = interquartile range.
 *Except where noted otherwise.
 †Done in the absence of any documented neurologic change.
 ‡E.g., extended length of stay, administration of antiplatelets for vascular dissection.
 §Owing to clinical deterioration within 72 hours in all cases.

the context of an unchanged neurological examination, even in patients with concomitant injuries, rarely alters medical management and, in even rarer cases, prompts any surgical management. All patients in our study who required neurosurgical intervention showed clinical deterioration before repeat head

CT revealed interval progression of their hemorrhage. Therefore, judicious selection of which patients should undergo repeat CT, even in the context of positive findings on the initial CT scan, may benefit both patients and hospitals in resource-limited settings.

Anandalwar and colleagues⁵ in 2016 retrospectively assessed a cohort of 95 patients with an initial GCS score of 13–15 and positive findings on head CT who were followed without repeat CT. They compared this cohort to 47 patients treated at the same institution and randomly assigned to “standard management” (i.e., repeat head CT within 24 h). Of the 95 patients without routine repeat head CT, 8 (8%) subsequently had a scan because of the treating physician’s judgment or a documented change in mental status. Interestingly, none of the repeat CT scans led to an intervention (medical or surgical). Only 1 (2%) of the 47 patients in the control group required medical intervention (aggressive hydration for asymptomatic venous sinus thrombosis). In the United States, Joseph and colleagues⁶ developed the brain injury guidelines (BIG) following a retrospective cohort analysis of 1232 patients with abnormal findings on head CT. They categorized the patients based on GCS score, neurologic examination, intoxication, anticoagulation and radiographic findings as mild (BIG 1), moderate (BIG 2) or severe (BIG 3) according to their need for hospital admission, observation, routine CT or neurosurgery. All patients in the BIG 1 and BIG 2 groups had a GCS score of 15. None of the patients in the BIG 1 group had radiographic progression or neurologic deterioration, and only 2.6% of those in the BIG 2 group had radiographic progression; none of the patients in either group required neurosurgical intervention.

Other retrospective and prospective studies, most with a focus on older patients, have also shown that routine repeat CT in the absence of neurologic deterioration does not predict the need for neurosurgical intervention in mild TBI.^{7–10} Similarly, in our study, all patients who eventually required neurosurgical intervention first experienced neurologic deterioration, prompting repeat CT, which showed substantial progression of their initial hematoma. Conversely, patients with mild radiographic progression on routine repeat CT in the absence of neurologic worsening were observed without an operation, which suggests that it is safe to base management decisions on clinical condition. Although the risks of radiation exposure from plain CT are low, they are not negligible, particularly in younger patients.^{1,2,11–13} Smith-Bindman and colleagues¹⁴ calculated that the median adjusted lifetime attributable risk for a routine head CT scan was 0.23 (range 0.03–0.70) cancers per 1000 patients and that cancer due to plain head CT will develop in 1 in 8100 women aged 40.

Limitations

Our sample size of 607 patients is relatively small compared to a few larger studies in the US.^{5,6} The majority of the patients in our study had multisystem injuries ranging in severity. Although this reflects the type of patients with mild TBI who more commonly present to level I trauma centres, it confounded our ability to quantitatively and accurately assess ICU admission, ICU stay and total hospital length of stay,

since these may have been affected by injuries other than the head injury. However, previous studies have shown that ICU admission is generally unnecessary for isolated mild TBI and that a substantial subset of patients may be safely observed in the emergency department for 6–8 hours before discharge under home supervision if neurologically unchanged.^{15,16} Because only 5 patients met our primary outcome of interest — the need for neurosurgical intervention — we could not perform statistical analysis to assess for common factors that may have contributed to their neurologic deterioration.

Conclusion

Our study shows that routine repeat neurologic imaging in the absence of clinical change may be unnecessary for the majority of neurologically examinable patients with a mild head injury, even in the presence of posttraumatic hemorrhage, without risk factors for delayed hemorrhage (e.g., anticoagulation, coagulopathy) and has limited value for predicting the need for neurosurgical intervention, which is rare. Routine repeat CT may represent an opportunity to optimize the use of health care resources and decrease the burden of health care costs. Decreasing the number of head CT scans for mild TBI by only 10% may result in savings of greater than US\$10 million annually.^{17,18} A large prospective multicentre study is needed to better delineate the optimal care pathways in regard to serial clinical and radiographic monitoring of patients with mild TBI and associated intracranial hemorrhage and/or skull fracture.

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Contributors: Leodante da Costa and Christopher Witiw conceived and designed the study. Christopher Witiw, Noah Ditkofsky, Avery Nathens and Leodante da Costa collected the data. Christopher Witiw, Justin Wang and Nadia Scantlebury analyzed the data. Justin Wang interpreted the data. Justin Wang and Christopher Witiw drafted the manuscript. All of the authors critically revised the manuscript for important intellectual content, approved the final version to be published and agreed to act as guarantors of the work.

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