Follow-up CT Imaging in Patients With Traumatic Brain Injury in Zimbabwe

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Purpose To assess the type and degree of neurological complications in patients with traumatic brain injury (TBI) who presented with an initial typical baseline computed tomography (CT) brain scan and to assess the time in which neurological complications developed.

Methods A retrospective cross-sectional quantitative research design was conducted in which CT radiology reports of 85 adult patients with TBI and typical baseline CT scans were analyzed during a 2-year period. The evolution of different types of neurological pathology diagnosed on follow-up CT brain imaging in these patients was recorded and analyzed.

Results The results showed that 36% of patients (n = 31) presented with atypical neuroradiological findings on follow-up CT imaging. Subdural hematoma was diagnosed in 19% (n = 16), intracerebral hematoma in 8% (n = 7), subarachnoid hematoma in 6% (n = 5), pneumocephalus in 2% (n = 2), and epidural hematoma in 1% (n = 1). The average times elapsed between the traumatic event and acquisition of the baseline CT brain scan and follow-up CT were 8 and 18 hours, respectively.

Discussion The most common causal mechanism of trauma in this study was motor vehicle collisions; an increase in motor vehicle collisions might have resulted in many vulnerable road users on poor road infrastructure and communities living in the vicinity of such roads. The severity of neurological status of patients might be associated with a higher likelihood of detecting intracranial pathology on follow-up CT brain imaging. Follow-up CT brain imaging findings have a role in confirming or excluding late neurological complications preceded by a typical baseline CT brain scan.

Conclusion Follow-up CT brain imaging performed at 10 hours after the typical baseline CT scan was of value in detecting the evolution of intracranial neurological pathology and resulted in a change in neurological management in one-third of patients.

Keywords *traumatic brain injury, follow-up CT brain imaging, neurological complications, atypical radiological findings, intracranial hemorrhage*

Globally, traumatic brain injury (TBI) is a substantial public health burden, often associated with increased mortality and morbidity.[1] TBI might be referred to as *an alteration in brain function* or *any signs or symptoms of brain pathology due to external impact*.[2] TBI might result in admission to a hospital, neurological surgery, or death.[3] Complications related to TBI include lifelong disabilities and impaired cognitive function.[3] Computed tomography (CT) brain imaging can accurately demonstrate primary and secondary brain injuries caused by trauma.[4,5] As such, CT brain imaging is an essential part of the follow-up in patients who present with TBI.

Currently there is disagreement whether follow-up CT brain imaging in patients with TBI who present with a healthy baseline scan is beneficial.[6] The incidence of brain pathology that develops after a typical first baseline CT brain scan ranges from 1% to 52%.[7] A comprehensive meta-analysis of 41 studies on patients with mild TBI indicated that follow-up CT brain imaging and a typical first baseline CT brain scan caused a change in neurological treatment in a minority of patients (2.3%

and 3.9% for prospective and retrospective studies, respectively).[3] Thus, follow-up CT brain imaging might substantially affect some patients who have no decline in clinical status and as such, repeat imaging studies are important.[8] Conversely, early follow-up CT brain imaging in cases of head trauma is not routinely indicated.[9] The findings of a study conducted among 75 patients with TBI who all underwent follow-up CT brain imaging suggested that, where no surgical intervention was indicated, no alteration in neurological treatment was necessary.[10] Some experts suggest that there is a low risk of developing brain pathology after the first baseline CT brain scan.[11] Thus, it is argued that follow-up CT brain imaging leads to unwarranted health care expenditures and exposes patients to unnecessary radiation.[10] An assessment based on the severity of radiological findings on the first baseline CT brain scan and consecutive clinical examinations should act as a guide for the need for follow-up CT brain imaging in TBI.[9]

According to current practice at the authors' research site, when first baseline CT brain scan demonstrates no intracranial injury and patients seem stable after trauma to the brain, they are discharged without further observation. However, anecdotal observation suggests that a portion of these patients might develop neurological concerns in 48 hours after discharge, such as:

- confusion
- dizziness
- headaches
- memory loss
- nausea
- posttraumatic seizures
- vomiting

The objectives of this study were to assess the type of late neurological complications observed in patients with TBI who had a typical first baseline CT brain scan, the causal mechanisms of the trauma, and the average time in which follow-up CT brain imaging was performed.

Methods

A retrospective cross-sectional quantitative research design was employed for this research study. Data were collected from medical records of patients who were treated for TBI during a 2-year period at a university teaching hospital in Harare, Zimbabwe. Permission to conduct the research study was granted by the Research Ethics Committee of the Cape Peninsula University of Technology (reference CPUT/HW-REC 2107/H21) and the Medical Research Council of Zimbabwe (reference MRCZ/B/1341). Medical records of men and women between the ages of 18 and 75 years with TBI who had a typical first baseline CT brain scan were analyzed in this study. Medical records were excluded if patients presented with existent intracranial injury on the first baseline CT brain scan, experienced trauma to the brain more than once during the follow-up period, or presented with nontrauma related intracranial pathology.

All patients underwent routine nonenhanced CT brain imaging using a 16-slice Aquilion multislice CT scanner (Toshiba). Radiology reports of all patients with TBI and a typical first baseline CT brain scan and who also underwent a follow-up CT brain imaging, were recorded to assess whether any neurological complications occurred after acquisition of the first baseline CT brain scan. The Glasgow Coma Scale (GCS) classifications were used to determine the severity of TBI at the time of injury (mild, 13-15; moderate, 9-12; or severe, ≤ 8).[12] A maximum of 3 observations in 48 hours of the admission period were performed by the medical personnel to assess patients' clinical progression or regression. Radiological findings on the follow-up CT brain imaging of patients with late-stage neurological changes were categorized as per routine neurological classification, which included typical (healthy), subdural hematoma, subarachnoid hemorrhage, epidural hematoma, intracerebral hemorrhage, and pneumocephalus. Final analysis assessed the type of neurological complications patients developed in 48 hours after admission and the average time in which such complications developed.

Data Validity and Reliability

To minimize errors in data collection, inaccurately or incompletely captured variables were excluded. Radiological reports were completed by the on-duty radiologist and further analyzed by the neurosurgeon to avoid missing pathology and enhance consistency in the diagnostic value of radiological findings. To enhance validity of this research study, a literature review revealed research designs that allowed the researchers

to identify knowledge gaps in the role of follow-up CT brain imaging in patients with TBI.

Statistical Analysis

Data were entered into Excel (Microsoft) and imported into SPSS Statistics version 24 (IBM) for statistical analysis. Variables were reported as numbers with proportions in percentages and central tendency measures. Measures of dispersion in the form of standard deviation, range, and percentiles were used. Kurtosis was used as a preliminary indicator for peakedness of the age distribution. The Fisher exact test was performed at a 95% level of significance. An analysis of cross-tabulations, correlation analysis using Pearson correlation coefficient, and the logistic regression model were used to predict relationships between variables ($P \leq .05$ was considered statistically significant).

Results

A total of 85 patients met the inclusion criteria for this study, with men and women forming 53% (n = 45) and 47% (n = 40) of the sample, respectively. Of the 85 patients, 36% (n = 31) presented with atypical neuroradiological findings on follow-up CT brain images. The most common neurological pathology diagnosed in this sample was subdural hematoma, diagnosed in 19% (n = 16) of patients, followed by 8% (n = 7) with intracerebral hematoma, 6% (n = 5) with subarachnoid hematomas, 2% (n = 2) with pneumocephalus, and 1% (n = 1) with an epidural hematoma (see **Figure 1**).

This study showed that neurological status, GCS, mechanism of trauma, men, and stage 2 hypertension (ie, ≥ 140/90 mm Hg) had a significant relationship with follow-up CT brain imaging findings (see **Table 1**). There was a weak positive relationship ($r = 0.23$) between the time the patient was under observation and the time elapsed before the first baseline CT brain scan was performed. The odds of a man presenting with pathology on follow-up CT brain imaging were 5.77 times higher than for a woman in this sample. The odds of a patient with stage 2 hypertension presenting with pathology on follow-up CT brain imaging was 45 times higher than for other classes of hypertension.

The age distribution of the sample population was analyzed. The highest number of patients with TBI was

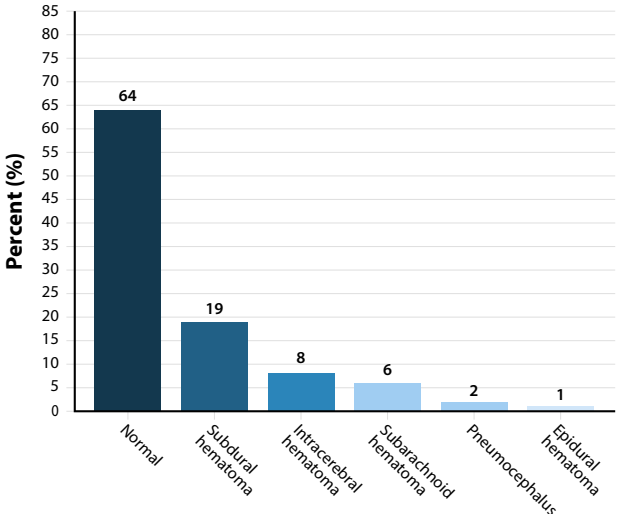

Figure 1. *Distribution of follow-up computed tomography brain imaging findings (N = 85). Graph courtesy of the authors.*

observed in the age groups 26 to 30 years and 31 to 35 years (27% and 20%, respectively). Thus, TBI in the younger age group of 26 to 35 years was 47% (n = 40) in total. The mean age of this group, as shown by the positive kurtosis, was 34 years, at which age it was considered that there was a high incidence of TBI in this sample. The age group 65 to 75 years had the least number of patients with TBI, at 6% (n = 5) (see **Figure 2**).

The neurological status of patients with TBI after follow-up CT brain imaging radiological findings was determined for this sample population. The distribution of patients who had an improved neurological status compared with their status at the time of admission was as follows: 44% (n = 37) were discharged, 20% (n =17) still underwent hospital treatment, while 2% (n = 2) died. It was unclear why 2 patients died, but it was suspected to have been caused by undiagnosed or delayed evolution of neurological lesions after trauma.

Among the patients who had worsened neurological status, 18% (n = 15) were receiving hospital treatment while 7% (n = 6) died. It might be argued that the aforementioned patients could have had evolution of neurological lesions after trauma. None of the patients who had worsened neurological status during the hospital observation period were discharged during the study period. In the range of patients who had an unchanged

Table 1

Relationship Between CTBS1, FCTBI, and Other Clinical Variables in 85 patients With TBI

Statistical analysis	Variables tested	Statistical value	*P* value[a]
Fisher exact cross-tabulation[b]	Neurological status	35.176	0.000
	Glasgow Coma Scale	24.004	0.002
	Mechanism of trauma	23.365	0.014
	Anticoagulants	7.00	0.178
	Body temperature	12.195	0.161
	Heart rate	7.423	1.000
Chi-square logistic regression[b]	Men	46.595	0.011
	Stage 2 hypertension	46.595	0.025
Pearson correlation	Hospital observation and time that elapsed before CTBS1	+0.226	0.037
	Hospital observation and time that elapsed before FCTBI scan	+0.005	0.966
	Time that elapsed before CTBS1 and FCTBI	+0.056	0.608

[a] *P* ≤ .05 indicate variables that had a significant relationship.

[b] *Statistical test was conducted with follow-up CT brain imaging findings.*

Abbreviations: computed tomography, CT; CTBS1, first baseline CT brain scan; FCTBI, follow-up CT brain imaging; TBI, traumatic brain injury.

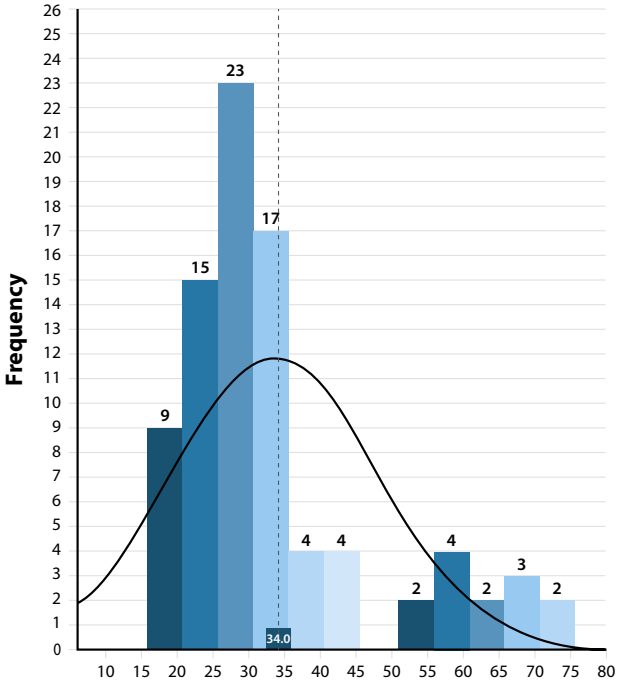

Figure 2. *Age distribution of the sample population (N = 85). The dotted line represents the mean age of the positive kurtosis. Graph courtesy of the authors.*

neurological status, 7% (n = 6) received hospital treatment, while 2% (n = 2) were discharged. This also might suggest that the former patients might have had a moderate to severe neurological status, whereas the latter had a mild neurological status on admission. None of the patients in this category died (see **Table 2**).

This study also explored the causal mechanism of injury for the patients enrolled. Mechanisms of injury were defined as the casual methods by which trauma to the brain occurred. The mechanism of trauma with the highest occurrence recorded was motor vehicle collisions (58%, n = 49), followed by assault (22%, n = 19), fall (12%, n = 10), and struck on the head by an object (8%, n = 7).

The average time of the patient's hospital observation, and time elapsed between acquisition of the first baseline CT brain scan and follow-up CT brain imaging were calculated. This study showed the mean time that patients spent under hospital observation was 20 hours, with the mean and mode times being 18 hours each. The mean time that elapsed between acquisition of the first baseline CT brain scan and follow-up CT brain imaging was 10 hours. The mean time that elapsed between time of trauma occurrence and acquisition of

Table 2

Distribution of Neurological Status in Patients With TBI

	Patient care			
Neurological status	Hospital treatment n (%)	Discharged n (%)	Deceased n (%)	Total n (%)
Improved	17 (20)	37 (44)	2 (2)	56 (66)
Worsened	15 (18)	0 (0)	6 (7)	21 (25)
Unchanged	6 (7)	2 (2)	0 (0)	8 (9)
Total	38 (45)	39 (46)	8 (9)	85 (100)

the first baseline CT brain scan and follow-up CT brain imaging was approximately 8 and 18 hours, respectively. This indicates that most first baseline CT brain scans and follow-up CT brain imaging were performed in the patients' observation period (see **Table 3**).

Discussion

CT brain imaging in the context of this study showed that significant late neurological findings were found among 36% of patients who underwent follow-up CT brain imaging. An observation from another study showed that most first baseline CT brain scans obtained in patients with mild TBI recorded typical radiological results, although intracranial injury might yet be progressing.[13] Some authors reiterated that if atypical changes in the brain are missed on first baseline CT brain scans, the patient could deteriorate after being discharged, which might be fatal.[11] Thus, follow-up CT brain imaging findings have a role in confirming or excluding late neurological complications preceded by a typical baseline CT brain scan. Similarly, an author recommended that follow-up CT brain imaging should be carried out after trauma to detect any developing hematoma, regardless of the patient's clinical examination.[14] Follow-up CT brain imaging thus might assist with patient management and can inform neurosurgeons when it is appropriate to discharge patients.

In this study, subdural hematoma was the most common atypical radiological finding on follow-up CT brain imaging. Subdural hematoma often occurs as a result of a sudden impact to the head from various mechanisms that rupture blood vessels along the brain's surface. In older people, brain atrophy leads to enlargement of the subdural space, which then further expands the bridging veins, making subdural hematoma common after TBI.[15] Epidural hematoma and subarachnoid hemorrhages usually occur as a result of tearing of the middle meningeal artery after head injury, causing arterial bleeding into the potential epidural space or intracranial cavity.[16] Traumatic subarachnoid hemorrhage is associated with a 2-fold increase in mortality, while intracerebral hemorrhage has up to 80% positive predictive value for poor functional outcome, with worsening prognosis accompanying an increase in hematoma size.[5] Fractures involving the skull base, sinuses, and mastoids often lead to air penetrating the intracranial cavity, resulting in pneumocephalus.[17]

The most common causal mechanism of trauma in this study was motor vehicle collisions. A study carried out in Zimbabwe revealed that 78% of patients with TBI experienced head injuries as a result of motor vehicle collisions, which was the leading mechanism of trauma.[18] In addition, based on the Global Burden of Disease classification of 2016, Zimbabwe had the highest rate of premature deaths (1275 per 100 000 people) because of motor vehicle collisions compared with countries such as Bangladesh, Ghana, Nigeria.[19] Thus, an increase in motor vehicle collisions might have resulted in many vulnerable road users on poor road infrastructure (eg, potholes on roads) and communities living in the vicinity of such roads. There has been a notable increase in the number of light-duty vehicles, by approximately 100%, from about 500 000 in 2005 to 1 000 000 in 2016 in Zimbabwe[20]; this increase in traffic by 100% resulted in increases in the numbers of motor vehicle collisions and fatalities by approximately 80% and 25%, respectively.[21]

Table 3

Distribution of the Times of Hospital Observation Period, CTBS1, and FCTBI Performance After the Time the Trauma Occurred

	Hospital observation (mins)	Time elapsed before acquisition of CTBS1 after trauma (min)	Time elapsed before acquisition of FCTBI after trauma (min)	Time elapsed between acquisition of CTBS1 and FCTBI (min)
Mean	1223	471	1063	591
Median	1080	430	1039	544
Mode	1080	187	821	592
Standard deviation	530	251	386	322

As shown in this study, the severity of neurological status of patients might be associated with a higher likelihood of detecting intracranial pathology on follow-up CT brain imaging, which might result in death. Likewise, of patients who deteriorated neurologically after TBI, 67%, had worse findings on follow-up CT brain imaging.[22] A similar trend of worsening radiological findings was associated with the severity of the GCS score. Furthermore, the GCS score cannot solely be used to determine the severity of TBI. In this study, 1 of the patients who died was involved in a motor vehicle collision, but had a recorded GCS score of 15, with a neurological status that declined from mild to moderate. The patient died approximately 5 hours after follow-up CT brain imaging, which resulted in a diagnosis of subdural hematoma. Thus, a typical GCS score does not negate the evolution of new lesions detected by follow-up CT brain imaging in patients with TBI. It is possible that patients might regress or die after what presents as clinically mild TBI. Hence, these patients might be considered suitable candidates to undergo a period of hospital observation before being discharged. This underscores the importance of follow-up CT brain imaging in patients with TBI and an altered or atypical GCS score, neurological status, or both.

In this study, men with TBI had a higher risk of presenting with atypical radiological findings on follow-up CT brain imaging. Men's neurons are more prone to pharmacological insults that trigger brain injury (eg, glutamate).[23] Hence, men's cells cannot retain intracellular glutathione levels after TBI, leading to evolution of brain pathology.[23] However, the comparable proportions of men and women with TBI in this study can be attributed to the economic and social environment of Zimbabwe. Currently, men and women commute for work and can be frequent road users involved in motor vehicle collisions, unlike in the past when women were less likely to work outside the home. In addition, men and women are prone to occupational hazards that might lead to TBI.

In previous studies, the effects of age on patients with TBI indicated that young people were at higher risk.[24-26] As this age group is active and economically productive, they might be more commonly exposed to occupational and social risks than are the other age groups screened. Risk-taking and lack of proper driving skills could be highlighted as a primary problem in the young age group (26-35 years old). Thus, this particular age cohort of the sample might be more vulnerable to motor vehicle collisions and violent disputes. Furthermore, it is possible that younger participants fall more during running and sporting activities, thus increasing TBI risk.[27] TBI in the older age group (60-75 years old), is caused mainly by falling because of changes in balance, proprioception, muscle tone, attention, and impaired vision, which makes it difficult to discern environmental hazards.[25]

Patients with stage 2 hypertension had a higher frequency of atypical radiological findings on follow-up CT brain imaging in this study. The set cut-off systolic blood pressure of lower than 90 mm Hg, which has been noted by some experts to result in secondary brain injury after trauma, might need to be revised.[28] A standardized hospital observation period of 20 hours could provide clinicians sufficient time to check for signs and symptoms of deterioration in patients with TBI

before discharge. Epidural hematoma might increase in volume when detected within 6 hours after TBI.[14] Therefore, performance of follow-up CT brain imaging at 10 hours after the first baseline CT brain scan and within 18 hours after trauma occurrence (which was during the observation period of the sample in this study) might allow enough time for lesions to evolve regardless of the patient's clinical status. One study showed that progressive intracranial lesions between the first baseline CT brain scan and follow-up CT brain imaging were noted in 40.5% of patients with TBI.[8] Follow-up CT brain imaging within 10 hours might thus aid in determining appropriate care for patients with TBI undergoing treatment.

Limitations

The small sample size of this study prevents generalization of these findings to the larger population of patients with TBI. The authors did not investigate factors that might have caused patients to present with late neurological complications. It is recommended that further studies be conducted to explore why neurological complications develop after typical baseline CT brain scans. To enhance the diagnosis of TBI, the authors recommend based on findings of this study that data be recorded accurately and completely for all patients with TBI: sex, age, mechanisms of trauma, exhibited neurological status, GCS score, blood pressure, time of trauma occurrence, time of hospital observation, and time of CT brain imaging. It also is suggested that larger studies be conducted to verify the findings of this study. There is no TBI databank in Zimbabwe. As such, no contemporaneous studies were found relating to statistics and data on TBI patterns.

Conclusion

Follow-up CT brain imaging was found to be of value in detecting the evolution of intracranial lesions in more than one-third of patients in this study. Risk factors identified as associated with the evolution of intracranial lesions were male sex, younger age (26-35 years), a decline in GCS score and/or neurological status, stage 2 hypertension, and involvement in motor vehicle collisions. The care of patients with TBI might be improved by performing follow-up CT brain imaging within 10 hours after a typical baseline CT brain scan and within 18 hours after trauma.

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