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*Original Article*

# Predictors of radiological contusion progression in traumatic brain injury

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**Abstract:** Background: Traumatic brain injury, mainly caused by the unintentional falls and motor vehicle accidents, is a serious condition encompassing a spectrum of pathological features from axonal to hemorrhagic injuries. Among these, cerebral contusions significantly contribute to death and disability following the injury and occur in up to 35% of cases. This study aimed to investigate the predictors of radiological contusion progression in traumatic brain injury. Methods: We performed a retrospective cross-sectional study using the files of the patients with mild traumatic brain injury who had cerebral contusions from 21 March 2021 to 20 March 2022. The severity of brain injury was determined using the Glasgow Coma Score. Furthermore, we used a cut-off value of a 30% increase in contusion size in the secondary CT scans (up to 72 hours) compared to the first one to define the significant progression of the contusions. For the patients with multiple contusions, we measured the biggest contusion. Results: 705 patients with traumatic brain injury were found, the severity of the injury was mild in 498 of them, and 218 had cerebral contusions. 131 (60.1%) patients were injured in vehicle accidents. 111 (50.9%) had significant contusion progression. Most patients were conservatively managed, but 21 out of them (10%) required delayed surgical intervention. Conclusion: We found that the presence of subdural hematoma, subarachnoid hemorrhage, and epidural hematoma were predictors of radiological contusion progression, and the patients with a subdural hematoma and epidural hematoma were more likely to undergo surgery. In addition to providing prognostic information, predicting risk factors for the progression of the contusions is crucial for identifying patients who might benefit from surgical and critical care therapies.

**Keywords:** Traumatic brain injury, brain contusion, contusion progression

## Introduction

Traumatic brain injury (TBI) is a significant cause of neurological morbidity and mortality worldwide, with more than 50 million new cases annually. TBI may progress after initial recovery, leading to cognitive, physical, and psychological disabilities [1, 2]. Sports-related injuries, fallings, motor vehicle accidents, and military incidents are common causes of TBI [3, 4].

Mild Traumatic Brain Injury (mTBI) accounts for 80-90% of all TBI cases, of which more than 20-30% suffer from persistent symptoms for six months or more. Although most people with mTBI fully recover, it is difficult to predict who will suffer long-lasting symptoms [5, 6].

Brain tissue is badly damaged in cerebral contusions, and because of the swelling of the brain cells and the resulting rise in intracranial pressure, the patient may pass away; in milder instances, the patient makes a slow recovery [7, 8]. Pathologically, small and numerous hemorrhages are seen along with swelling and rupture of brain cells [9]. Cerebral contusion consists of a mixture of intracerebral hemorrhage and cellular death. It is a combination of bleeding around small vessels, and cell necrosis, which can be seen in a CT scan as a hyperdense and heterogeneous mass with unclear borders, where the hyperdense points are related to bleeding and hypodense points are related to necrosis [10, 11]. Sometimes the bleeding is vast enough that it becomes a hemorrhagic contusion, similar to an intracerebral hematoma. Vasogenic edema appears 24 hours after the injury [12].

The initial CT scan performed during admission provides information about the type and extent of intracranial pathologies and determines the need for emergency neurosurgical intervention. Since such imaging is widely performed, identifying early radiological factors contributing to the progression of traumatic contusions is of great clinical importance. However, the timing of the initial scan is related to how the contusion progresses. Patients whose scans were performed earlier than the injury time are more likely to show natural progression in subsequent imaging [13, 14].

Therefore, knowing the factors predicting the natural progression of brain contusions will be necessary for managing and treating these patients. This study aimed to determine the influential risk factors for increasing the size of brain contusions or their natural progression in patients with mTBI in Isfahan, Iran.

## Methods and material

### *Study design*

This research was conducted by an analytical retrospective cross-sectional study using the files of patients with mild TBI from 21 March 2021 to 20 March 2022. Our initial search of patients with brain injuries admitted to our unit yielded 705 patients, 498 patients had mTBI, and 218 patients met our inclusion criteria which were included in the study by census method. The study design was approved by the Ethics Committee of Isfahan University of Medical Sciences with the code of IR.MUI.MED.REC.1400.168.

### *Inclusion and exclusion criteria*

The inclusion criteria included patients who had mild TBI (Glasgow Coma Score (GCS) of at least 13) and complete medical records. Brain contusion was diagnosed by the attending physician and recorded in the patient's file and consented to participate in the study. In addition, the files of patients who died during the study period, or had a deficit of more than 15% in the information recorded in their files, were excluded from the study. The largest contusion was considered in cases where more than one contusion was found.

### *Data assessments*

The severity of TBI was assessed using Glasgow Coma Score (GCS). According to GCS, the patient's consciousness is scored based on the eye (4 scores), verbal (5 scores), and motor (6 scores) functions. The severity of TBI was assessed as mild in cases with GCS of 13-15, moderate in cases with GCS of 9-12, and severe in patients with GCS of 3-8.

### *Data collection*

After determining the files of patients eligible for the study, the data related to the desired variables, such as demographic information, CT scan findings, underlying diseases, Initial brain contusion size, location of the brain damage, cause of trauma, and common symptoms were extracted and entered into the checklist. The severity of brain injury was determined using the GCS. In this study, we used a cut-off value of a 30% increase in contusion size in the secondary CT scans (up to 72 hours) compared to the first CT scan to determine the clinical progress of the contusions.

In our medical center, all patients with TBI undergo an initial head CT scan and complete neurological examinations at the time of admission. Physical examinations are conducted daily during hospitalization, and head CT scans are repeated in cases with abnormalities. Therefore, the chances of missing a patient are meager.

We reviewed all CT scans and calculated the size of the contusion hematoma and necrosis volume using the formula (ABC/2). In this formula: A = greatest hemorrhage diameter in the axial plane, B = hemorrhage diameter at 90° to A in the axial plane, and C = originally described as the number of CT slices with hemorrhage multiplied by the slice thickness, but can simply be substituted with the craniocaudal diameter of the hemorrhage where there is access to multiplanar reformats. If the measurements are made in centimeters (cm), then the volume will be in cubic centimeters ($cm^3$) or milliliters (ml) (numerically equivalent). This formula is used in most studies, and its accuracy has been validated [14].

**Table 1.** Summary of patient characteristics

| Variable | No of the patients (%) |
|---|---|
| Gender | |
| Men | 192 (88) |
| Women | 26 (12) |
| HTN | |
| (+) | 28 (12.8) |
| (-) | 190 (87.2) |
| IHD | |
| (+) | 28 (12.8) |
| (-) | 190 (87.2) |
| History of any Brain Problem | |
| (+) | 10 (4.6) |
| (-) | 208 (95.4) |
| Cause of Injury | |
| Accident | 131 (60.1) |
| Falling | 55 (25.2) |
| Assault | 32 (14.7) |
| Location of the Contusion | |
| Temporal | 71 (32.6) |
| Parietal | 68 (31.2) |
| Frontal | 58 (26.6) |
| Occipital | 21 (9.6) |
| Intracerebral Findings | |
| SAH | 85 (39.4) |
| SDH | 67 (31) |
| EDH | 52 (24.1) |
| None | 14 (5.5) |

*SAH: Subarachnoid Hemorrhage; SDH: Subdural Hematoma; EDH: Epidural Hematoma; HTN: Hypertension; IHD: Ischemic Heart Disease.

*Statistical analysis*

Mean, standard deviation, and median limits were used to describe quantitative variables, and numbers and percentages were used for qualitative data. Also, a logistic regression model and odds ratio were used to determine the risk factors. All statistical analyzes were performed using SPSS version 22 software, and the significance level of statistical tests was considered to be 0.05.

**Results**

*Study population and characteristics*

In this study, a total of 218 patients, 192 (88.1%) males with an average age of 44.68 ± 21.65 years and 26 females with an average age of 45.77 ± 22.72 years, with mTBI were included in the analysis. 131 (60.1%) patients were injured due to vehicle accidents. The clinical findings of the patients showed that the most frequent location of the contusions was trauma in the temporal lobe with 71 (32.6%) patients. A linear fracture was reported in 37 (17%) patients. The most common bleeding was subarachnoid hemorrhage in 85 (39.4%) patients and subdural and epidural hematoma in 67 (31.0%) and 52 (24.1%) patients, respectively (**Table 1**).

*Evolution of contusion and outcomes*

The average initial contusion size was 2.7 ± 3.15 ml, and the median initial size was 2.1 ml (0.1-23 ml) (**Figure 1**; **Table 2**).

Concerning the outcomes of interest, 111 patients (50.9%) displayed natural radiographic progression on CT scans during their initial hospital course, and 21 (10%) required subsequent surgical intervention. Among them, four cases underwent contusion evacuation due to less difficult situations than others (**Figure 2**; **Table 2**). These four cases had lower GCS levels compared to other patients (Total GCS score was 13 in all 4 patients). Imaging studies of these cases revealed that they had higher contusion size compared to others (≈ 30 ml in these patients, while most cases had 0-5 ml contusion size) (**Figure 2**).

*Associations and risk assessments*

Regarding the association between the contusions' progression and the patients' demographic history, the presence of SAH, SDH, and EDH were predictors of the clinical progression of the contusion size. In other words, patients who had SAH, SDH or EDH in the initial CT scan were more likely to have contusion progression in the secondary CT scans than those who didn't (*P*-value = 0.001, *P*-value = 0.045, *P*-value = 0.002, respectively). Our findings also indicate that larger contusions are more likely to progress (*P*-value = 0.002, OR = 3.96) (**Table 3**).

The chance of people who had SDH and underwent surgery was about 6.5 times higher (*P*-value = 0.012, OR = 6.62). This ratio for EDH was more than twice that of SDH (*P*-value = 0.002, OR = 14.23) and patients who had significant contusion progression were more

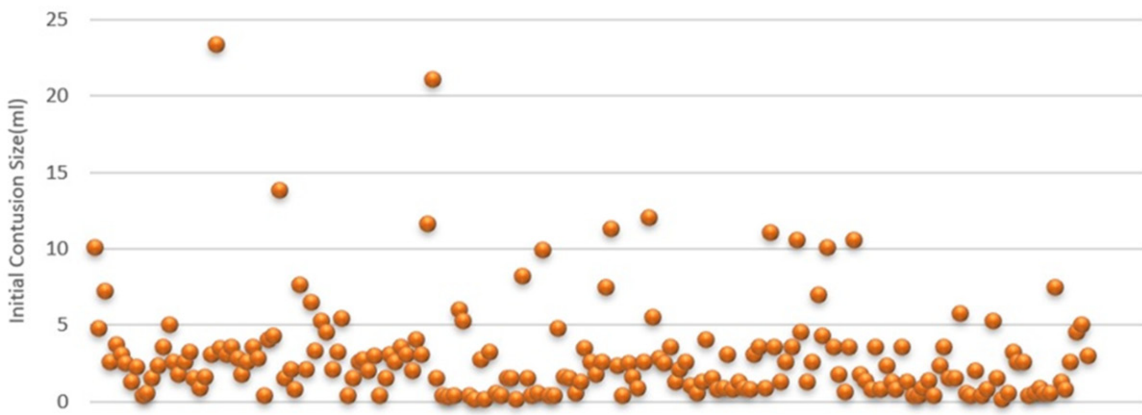


**Figure 1.** Initial contusion size.

**Table 2.** Summary of contusion characteristics

| Variable | No of the patients (%) |
|---|---|
| Initial Contusion size | |
| >10cc | 11 (5) |
| 5<10cc | 14 (6.5) |
| <5 | 193 (88.5) |
| *Sig Contusion Progression | |
| Yes | 111 (50.9) |
| No | 107 (49.1) |
| Treatment | |
| Conservative | 197 (90) |
| **Surgical | 21 (10) |

*Significant contusion progression was defined as a 30% and more increase in contusion size on CT scans. **Surgical interventions: Contusion evacuation: 4 patients, SDH evacuation: 5 patients, EDH evacuation: 5 patients.

likely to need delayed surgical intervention (*P*-value = 0.001, OR = 2.33) (**Table 4**).

## Discussion

In this study, we discussed the phenomenon of contusion progression, its predicting factors, and its impact on clinical outcomes. We used the criterion of a 30% or more increase in contusion size, which minimized the potential errors in the detection of contusion progression. About half of the patients (49.5%) in this study had significant contusion progression, which is similar to the results reported by other authors, including Alahmadi and colleagues in Toronto (45%), Oertel and colleagues in California (51%), and Narayan and colleagues in Cincinnati, (51%) [13, 15, 16].

The results of our study showed that considering this criterion, SAH, SDH, and EDH were the predicting factors that had a significant relationship with the clinical progression of the contusion. Similar to the findings of our study, Allison and colleagues in Texas and Cepeda and others in Madrid, Spain, reported the presence of SDH and SAH in the initial CT scan as a predictor of subsequent contusion progression. They found that the presence of SDH increases the risk of progression two to three times and the presence of SAH increases the risk two to six times [17, 18].

In this study, the volume of the initial contusion on the baseline CT was related to the progression of the contusion. More extensive primary contusions were more likely to progress, similar to the findings of Iaccarino and colleagues, who reported that contusions with an initial volume ≤4 ml were unlikely to progress [19]. Carnevale and others (2018) also showed that smaller lesions remain relatively stable while larger ones are more likely to progress and grow by larger amounts [20]. However, Cepeda and colleagues found the opposite and showed that small lesions might have more room to expand compared to larger lesions [18].

TBI-induced contusions are usually seen in the frontal and temporal lobes but may occur throughout the brain. In this study, the most common site of contusions was the temporal lobe, but there was no statistically significant difference between the site of the contusion and the contusion progression. Studies have shown that the location of contusion is an important predictor of subsequent progression.

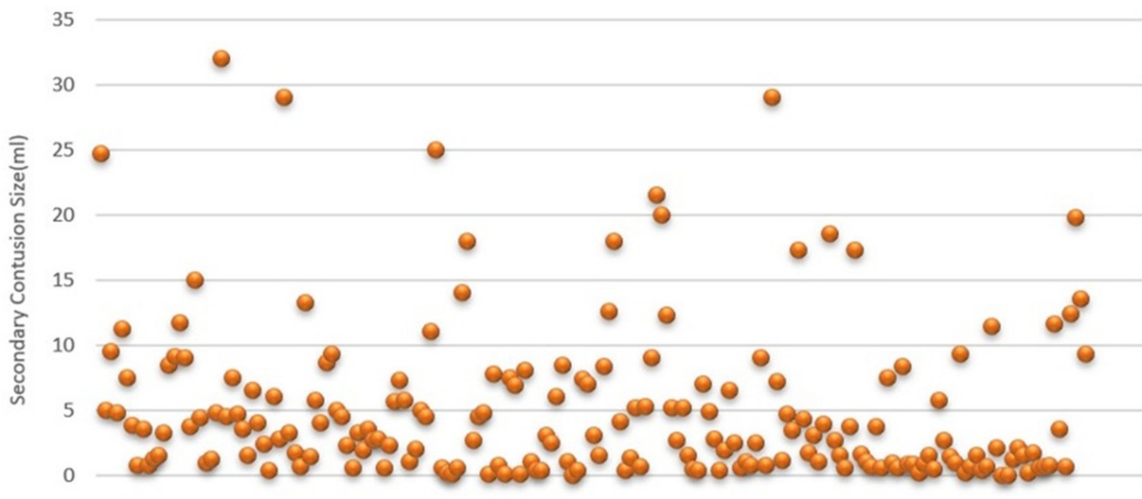


**Figure 2.** Secondary contusion size.

**Table 3.** Results of the regression analysis of contusion progression

| Variable | *P* value | Odds ratio |
|---|---|---|
| SDH | 0.045 | 2.10 |
| SAH | 0.001 | 3.31 |
| EDH | 0.002 | 3.71 |
| Depressed Fracture | 0.066 | 0.60 |
| Linear Fracture | 0.469 | 1.35 |
| HTN | 0.749 | 0.77 |
| IHD | 0.791 | 1.21 |
| Diabetes | 0.788 | 1.25 |
| Age | 0.812 | 0.92 |
| Site of the injury | 0.912 | 0.98 |
| Initial Contusion Size | 0.002 | 3.96 |

**Table 4.** Results of the regression analysis of required surgical intervention

| Variable | *P* value | Odds ratio |
|---|---|---|
| SDH | 0.012 | 6.62 |
| SAH | 0.027 | 0.59 |
| EDH | 0.002 | 14.23 |
| Depressed Fracture | 0.394 | 0.47 |
| Linear Fracture | 0.082 | 0.11 |
| HTN | 0.857 | 1.28 |
| IHD | 0.806 | 0.71 |
| Diabetes | 0.245 | 5.22 |
| Age | 0.650 | 1.00 |
| Site of the Injury | 0.383 | 1.33 |
| Sig Contusion Progression | 0.001 | 2.33 |

Rehman and colleagues found that the probability of the progression of frontal contusions is 1.5 times higher compared to other locations [14].

Understanding the clinical significance of this radiological phenomenon and its impact on treatment in these patients is important because not all patients with radiological progression show clinical deterioration or require surgical intervention. Patients with radiological progression in our series were more likely to require delayed surgical intervention. In reviewing the charts of the four patients who underwent delayed contusion evacuation, we noted that they all showed radiological contusion progression.

The limitations of this research were restricted study cases and retrospective design of this research. This study could have unknown potential confounders. We used the data originally collected for these purposes, only some of the relevant information, and we also had an inferior level of evidence compared with prospective studies. It is recommended that further clinical trials should be conducted in this regard. Furthermore, physicians should pay more attention to patients with subdural hematoma, subarachnoid hemorrhage, and epidural hematoma in TBI cases.

## Conclusion

TBI, caused mainly by motor vehicle accidents and fallings, is a severe condition that can lead to neurosurgical disabilities and deaths. Progression of contusion is associated with poor neurological outcomes in the hospital and requires surgical interventions and conservative treatment. Although the criteria for determining the progression of contusions vary among studies, predicting risk factors for that is essential to provide prognostic information and identify patients who should benefit from intensive care and surgical interventions.

## Disclosure of conflict of interest

None.

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