Facial Fractures: Independent Prediction of Neurosurgical Intervention

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Abstract

Background:

Over half of patients with facial fractures have associated traumatic brain injury. Based on previous force dynamic cadaveric studies, Lefort type 2 and 3 fractures are more associated with severe injury. Whether this correlates to neurosurgical intervention have not been well characterized. The purpose of this retrospective data analysis is to characterize fracture pattern types in patients requiring neurosurgical intervention and to see if this is different from those not requiring intervention.

Methods:

Retrospective data was collected from the trauma registry from 2010-2019. Inclusion criteria: adults over 18, confirmed facial fracture with available neuroimaging, reported traumatic brain injury, and admission to ICU or floor bed. Exclusion criteria: patients less than 18 years old, patients with no neuroimaging, and patients that were deceased prior to initiation of neurosurgical intervention. Data included: basic demographic data, presenting Glasgow Coma Scale (GCS) score, mechanism of injury, type of traumatic brain injury, neurosurgical intervention, and facial fracture type. Retrospective Contingency Analysis with Fraction of Total Comparison was used with Chi-Square analysis for demographic and injury characteristic data.

Results:

1172 patients met inclusion criteria. 1001 required no neurosurgical intervention and 171 required intervention. No significant difference was seen between the non-intervention group and intervention group in terms of demographic data or baseline injury characteristics except for presenting GCS. A significant difference was seen between groups for presenting Glasgow Coma Scale ($\chi^2=67.71$, $p<0.001$). The intervention group had greater number of patients with $GCS<8$ compared to the non-intervention group. Fracture patterns were overall similar between the non-intervention group compared to intervention group ($\chi^2=4.518$, $p=0.92$), however subset analysis did reveal a 2 fold increase in Lefort type 2 fractures and notable increase in Lefort type 3 and panfacial fractures in the intervention group. The intervention group was further divided into those requiring external ventricular drain or intracranial pressure monitor only vs. patients requiring craniectomy, craniotomy, or burr holes with or with external ventricular drain or intracranial pressure monitor. A significant difference was seen between groups ($\chi^2=20.02$, $p=0.03$). The craniectomy, craniotomy, or burr hole group was much more likely to have Lefort type 2 or 3 fractures compared to the external ventricular drain or intracranial pressure monitor group only.

Conclusions:

Lefort type 2 and type 3 fractures are significantly associated with requiring neurosurgical intervention. An improved algorithm for managing these patients has been proposed in the discussion. Ongoing work

will focus on validating and refining the algorithm in order to improve patient care for trauma patients with facial fracture and traumatic brain injury.

Introduction

Trauma is one of the leading causes of disability globally and represents the leading cause of death in the first four decades of life.¹ Roughly one of seven trauma patients admitted to the emergency room had maxillofacial fractures.^{2,3} These include nasal bone, mandible, orbital, alveolar ridge, zygomatic, teeth, panfacial, isolated maxillary, and Le Fort type I-III fractures.⁴⁻⁶ While facial fractures are often associated with injuries to nearby vital structures such as the airway, vasculature, and nerves, approximately half of facial fracture victims also present with concomitant traumatic brain injury (TBI).⁷⁻¹⁰ Depending on the severity, TBI may be difficult to detect using current technology, potentially delaying treatment and worsening prognosis for patients.⁸ Previous studies have also suggested an association between maxillofacial fractures and TBI.^{3,7,8,11-24}

A recent study by McCarty et al. proposed that Le Fort type fractures may be associated with more severe TBI.⁸ This is likely due to diffuse axonal injury and shearing forces contributing to epidural and subdural hemorrhages secondary to the high-velocity facial trauma required to produce these fractures.^{6,8} In a study by Elbaih et al., mid-facial fractures were correlated with an increased likelihood of concurrent epidural hemorrhage, subdural hemorrhage, and pneumocephalus.⁵ Despite these findings, little is known about how fracture types predict TBI severity and which patients eventually require neurosurgical intervention such as intracranial pressure (ICP) monitoring, external ventricular drain (EVD) placement, or craniotomy or craniectomy. Thus, the present study is designed to develop an improved algorithm for the management of TBI in the context of known facial fractures with a hypothesis that patients with mid-face fractures are at increased risk for severe TBI (GCS < 8) warranting more aggressive neurosurgical intervention.

Methods

The study was submitted for institutional board review at University of Florida and abided by the highest international ethical research standards. Retrospective analysis of patients from 2010–2019 obtained through our trauma registry. Inclusion criteria: adults over 18, confirmed facial fracture with available neuroimaging, reported traumatic brain injury, and admission to ICU or floor bed. Exclusion criteria: patients less than 18 years old, patients with no neuroimaging, and patients that were deceased prior to initiation of neurosurgical intervention.

In addition to basic demographic data, data collected included presenting Glasgow Coma Scale (GCS) score, mechanism of injury, facial fracture type, traumatic brain injury type, and type of neurosurgical intervention. Age was grouped into 7 categories: 1 (18–24 years old), 2 (25–34 years old), 3 (35–44 years old), 4 (45–54 years old), 5 (55–64 years old), 6 (65–74 years old), 7 (> 75 years old). Race was grouped

into 5 categories: 1 (Caucasian), 2 (Black), 3 (Asian), 4 (Hispanic), 5 (Other). Sex was classified as male or female. GCS score was arranged: mild (14–15), moderate (9–13), or severe (8 or less). Mechanism of Injury was grouped into 7 categories: 1 (Assault), 2 (All-terrain vehicle or dirtbike accident), 3 (Gunshot wound or knife injury), 4 (Bicycle or moped accident), 5 (Motorcycle collision or motor vehicle collision), 6 (Fall), 7 (Other). Type of traumatic brain injury: 1 (Contusion), 2 (Diffuse axonal injury), 3 (Epidural hematoma), 4 (Subdural hematoma), 5 (Traumatic subarachnoid hemorrhage), 6 (Intracranial hemorrhage or intraventricular hemorrhage), 7 (Penetrating injury). Additional radiographic findings: 1 (Edema), 2 (Herniation), 3 (Pneumocephalus), 4 (Cerebral/Cerebellar laceration).

Patients were divided into those with facial fracture and traumatic brain injury without neurosurgical intervention and into those with facial fracture and traumatic brain injury with neurosurgical intervention. Graphpad Prism 8.0 Software was used for analysis. Retrospective Contingency Analysis with Fraction of Total Comparison was used with Chi-Square analysis for demographic and injury characteristic data. $P < 0.05$ was considered statistically significant.

Results

Based on the above inclusion/exclusion criteria 1985 patients were pooled from the overall trauma registry. On further review, 316 were too young, 403 had no traumatic brain injury, and 94 had no facial fracture. 1172 therefore met criteria for inclusion into the study. 1001 had facial fracture and traumatic brain injury with no neurosurgical intervention, 171 had facial fracture and traumatic brain injury with neurosurgical intervention. Table 1 has baseline demographic data. No significant difference was seen between groups for age ($\chi^2 = 8.08$, $p = 0.23$). No significant difference was seen between groups for race ($\chi^2 = 0.6$, $p = 0.96$). No difference was seen between groups for gender ($\chi^2 = 1.33$, $p = 0.25$).

Injury characteristics were compared in Table 2. A significant difference was seen between groups for presenting Glasgow Coma Scale ($\chi^2 = 67.71$, $p < 0.001$). Of note, in the non-intervention group 64% had mild TBI (GCS score 14–15) compared to 10% of the intervention group. Conversely, 74% of the intervention group had severe GCS score (3–8) compared to 22% of the non-intervention group. No significant difference was seen between groups for mechanism of injury ($\chi^2 = 7.58$, $p = 0.27$), type of TBI ($\chi^2 = 3.09$, $p = 0.8$), or additional radiographic findings ($\chi^2 = 1.71$, $p = 0.63$).

Fracture type patterns were similar between the non-intervention and intervention group ($\chi^2 = 4.518$, $p = 0.92$) as seen in Fig. 1. Subset analysis did however reveal a twofold increase in Lefort type 2 and panfacial fractures in the intervention group compared to non-intervention group. In the intervention group, 136/171 required an ICP monitor or EVD only, 12/171 required a craniotomy, craniectomy, or burr holes only, 23/171 required a craniotomy, craniectomy, or burr holes with EVD or ICP monitor (Fig. 2). A significant difference was seen in type of intervention depending on presenting facial fracture pattern ($\chi^2 = 20.02$, $p = 0.03$). Of note, 24% of the craniotomy, craniectomy, burr hole group had Lefort type 2 fracture compared to only 9% in the ICP monitor only group. 15% of the craniotomy, craniectomy, burr hole group had Lefort Type 3 fracture compared to only 7% in the ICP monitor only group. 29% of the

craniotomy/burr hole group had panfacial fractures compared to 7% of the ICP monitor only group (Fig. 3).

Discussion

Traumatic injury is a leading cause of death and disability worldwide.¹ A significant number of trauma victims present with maxillofacial fractures, with roughly half of these patients presenting with TBI.^{2,25,3} There is a growing body of literature suggesting that maxillofacial fractures serve as predictors for the presence and severity of TBI.^{5,8,13,15,16,19,23} This study aimed to determine whether certain types of maxillofacial fractures can predict the need for neurosurgical interventions in an effort to produce an algorithm for the management of TBI patients presenting with known facial fractures.

A retrospective analysis of patients admitted to the UF Health Shands Hospital between 2010 and 2019 with known facial fractures and concurrent TBI was performed. Most patients were victims of motor vehicle collisions, motorcycle accidents, and falls. Most suffered orbital, nasal, and maxillary fractures in a distribution similar to the study done by Menon et al. with patients sharing similar demographics.⁴ Patients were not more likely to require intervention based on age, race, gender, mechanism of injury, or specific radiologic findings of edema, herniation, pneumocephalus, or laceration. As anticipated, those taken for intervention had lower GCS scores.

Patients with Le Fort type II, type III, and panfacial fractures were more likely to undergo neurosurgical intervention. Further, those presenting with these severe fractures were more likely to receive higher levels of neurosurgical intervention involving craniotomies, craniectomy, and burr holes compared to only EVDs or ICP monitors. This is consistent with the initial hypothesis that the high-velocity impacts required to produce the more severe type II and III Le Fort type fractures^{6,26} are also more likely to lead to more severe neurologic injury. These results also support previous investigations that showed associations between midface fractures and more severe TBI.⁵

Improved algorithms to identify and triage patients with facial fractures that are more likely to require neurosurgical interventions are being designed in collaboration with the UF Health Shands trauma, plastic, and oral and maxillofacial surgeon colleagues. Figure 4 shows an improved decision tree algorithm for managing patients with severe TBI. This algorithm is influenced by this study's findings and Czerwinski's and colleagues' proposition for mandatory early CT-head to rule out TBI in patients presenting with facial fractures. This argument was also supported by Shibuya and colleagues' study which showed that 11% of patients who underwent facial fracture repair had worsened GCS score following intervention due to underlying TBI.^{27,28} Early surgical interventions improve outcomes.²⁹ The hope is that through initiation of the improved algorithm early imaging can be obtained, improved interactions between specialties can enhance patient care, and providers can ultimately act more quickly to intervene when indicated.

This study's retrospective nature serves as a limitation. The study was also limited by the trauma registry. For example, it was not possible to separately consider the use of EVDs versus other intracranial pressure monitoring devices because providers sometimes did not use specific International Classification of Diseases (ICD) coding. ICD coding also sometimes did not specify fracture types, only indicating the presence of a facial fracture. These injuries were successfully categorized by chart review. However, it is possible that some facial fractures for patients within this group were not recorded.

We hope that the data and results from this initial study will serve as a catalyst for prospective investigations. Subsequent studies will look at the prospective implementation of the algorithm for patients with facial fractures and TBI. This will allow direct evaluation of effectiveness. Future studies can also implement the finite element head models reviewed and developed by Tse et al. to further determine fracture patterns more likely to be associated with severe TBI.^{30,31}

Declarations

Funding: None

Conflicts of Interest: none

Data Material: University of Florida Trauma Registry

Code: None

Ethics: Marked Exempt by University of Florida IRB

Consent: Not applicable; retrospective deidentified data

Publication: all authors have seen and agree with the contents of this work for publication

Contributions: BL formulated the project, collected the data, wrote the manuscript. KP helped with data collection and manuscript preparation. SA helped with data collection and manuscript preparation. GM was the primary PI for the project and coordinated support through the registry.

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Tables

Table 1: Demographics

Age in Years	Non-Intervention (n=1001)	Intervention (n=171)	
1. 18-24			
2. 25-34	1. (176) 17%		
3. 35-44	2. (165) 17%	1. (36) 21%	
4. 45-54	3. (151) 15%	2. (39) 23%	
5. 55-64	4. (169) 17%	3. (21) 12%	P>0.05
6. 65-74	5. (128) 13%	4. (33) 19%	
7. 75+	6. (94) 9%	5. (28) 16%	
	7. (118) 12%	6. (10) 6%	
		7. (4) 3%	
Race			
1. Caucasian	1. 826 (83%)	1. 135 (79%)	P>0.05
2. Black	2. 118 (11%)	2. 24 (14%)	
3. Asian	3. 5 (1%)	3. 1 (1%)	
4. Hispanic	4. 34 (3%)	4. 7 (4%)	
5. Other	5. 18 (2%)	5. 4 (2%)	
Gender			
1. Male	1. 723 (72%)	1. 136 (79%)	P>0.05
2. Female	2. 278 (28%)	2. 35 (21%)	

Table 2: Injury Characteristics

Glasgow Coma Scale	Non-Intervention (n=1001)	Intervention (n=171)	
1. Mild (14-15) 2. Moderate (9-13) 3. Severe (3-8)	1. (636) 64% 2. (140) 14% 3. (226) 22%	1. (17) 10% 2. (27) 16% 3. (127) 74%	P<0.001
Mechanism of Injury			
1. Assault	1. 160 (16%)	1. 16 (9%)	P>0.05
2. ATV/Dirtbike	2. 44 (4%)	2. 11 (6%)	
3. GSW/Knife	3. 46 (5%)	3. 9 (5%)	
4. Bicycle/Moped	4. 74 (7%)	4. 18 (11%)	
5. MCC/MVC	5. 381 (38%)	5. 77 (45%)	
6. Fall	6. 212 (22%)	6. 19 (12%)	
7. Other	7. 84 (8%)	7. 21 (12%)	
Types of TBI			
1. Contusion	1. 61 (6%)	1. 21 (12%)	P>0.05
2. DAI	2. 31 (3%)	2. 23 (13%)	
3. EDH	3. 49 (5%)	3. 22 (13%)	
4. SDH	4. 201 (20%)	4. 63 (37%)	
5. tSAH	5. 295 (29%)	5. 79 (46%)	
6. ICH/IVH	6. 66 (7%)	6. 27 (16%)	
7. Penetrating injury	7. 11 (1%)	7. 1 (1%)	
Additional Radiographic Findings			
1. Edema	1. 25 (2%)	1. 20 (12%)	P>0.05
2. Herniation	2. 32 (3%)	2. 25 (15%)	
3. Pneumocephalus	3. 34 (3%)	3. 10 (6%)	
4. Cerebral/Cerebellar Laceration	4. 5 (1%)	4. 4 (2%)	

Figures

Figure 1

Percentages of overall patients for the intervention vs. non-intervention group for type of facial fracture. 1-Nasal, 2-Alveolar Ridge, 3-Zygomatic, 4-Maxillary not specified, 5-Lefort 1, 6-Lefort 2, 7-Lefort 3, 8-Orbital, 9-Panfacial, 10-Mandible, 11-Teeth. No overall significant difference in aggregate fracture pattern between groups. There was a 2-fold increase however in Lefort Type II fractures in the intervention group. Additionally, more Lefort type 3 and panfacial fractures were seen in the intervention group.

Figure 2

Type of neurosurgical intervention for trauma patients with facial fractures. ICP-intracranial pressure, EVD-external ventricular drain, Crani-decompressive craniectomy, craniotomy, or burr holes

Figure 3

A significant difference was seen in type of intervention depending on presenting facial fracture pattern. Lefort type 2 fractures were >2 fold as common in the craniotomy, craniectomy, burr hole group compared to ICP monitor only group. Similarly, there was a 2-fold increase in the craniotomy, craniectomy, burr hole group for Lefort Type 3 fracture compared to the ICP monitor only group. 29% of the craniotomy, craniectomy, burr hole group had panfacial fractures compared to 7% of the ICP monitor only group.

Figure 4

Improved algorithm for managing patients with suspected TBI and facial fractures. Patients with Lefort type 2 or 3 fractures are at greater likelihood for requiring neurosurgical intervention and should be grouped accordingly.