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Posted Date: 12 June 2023

doi: 10.20944/preprints202306.0788.v1

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Concurrent Traumatic Brain Injury with Craniofacial Trauma: A 10-Year Analysis of a Single Institution's Trauma Registry

Yuchen You DO [1,*], Javier Romero MD [2], Graal Diaz PhD [2] and Robin Evans MD [2]

[1] Ventura County Medical Center; yyou1@cmhshealth.org
[2] Ventura County Medical Center; Javier.romero@ventura.org
* Correspondence: yyou1@cmhshealth.org

Abstract: Background: Craniofacial injuries are thought to be commonly associated with traumatic brain injury (TBI), but there is conflicting evidence in the literature. This retrospective cohort study aims to evaluate the incidence of TBI in patients with craniofacial trauma. Methods: The study included 2982 consecutive patients with either solitary or concurrent diagnoses of TBI and facial fractures, seen and evaluated at a single level II trauma center between January 1, 2010, and December 31, 2020. Continuous variables were compared against whether the patient had one or both diagnoses. Results: Of the target population, 55.8% had a solitary diagnosis of TBI, 30.28% had a solitary diagnosis of facial fractures, and 13.92% had concurrent diagnoses of both TBI and facial fractures. Patients with concurrent diagnoses had a significantly longer mean length of stay (LOS) compared to those with solitary diagnoses (9.92 ± 16.33 days vs. 6.21 ± 10.96 days, p<0.01), but age (p=0.68) and ICU LOS (p=0.09) did not differ significantly between the two groups. Conclusions: Trauma to the face should be given special attention due to the increased chance of TBI with craniofacial fractures. Patients with concurrent diagnoses of TBI and facial fractures had worse hospital outcomes than those with solitary diagnoses of either TBI or facial trauma.

Keywords: craniofacial trauma; traumatic brain injury; concurrent diagnosis

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1. Introduction

Craniofacial trauma is a cause of significant morbidity and mortality. Since the facial bones are intimately associated with the brain, there is a presumed relationship between facial trauma and traumatic brain injuries (TBI). However, the relationship between facial trauma and TBI is unclear, and evidence from the current literature is discrepant. For example, Chen et al. (1) and, more recently, Lee et al. (2) suggested that facial bones act as a decelerating protective barrier for the intracranial structures. This is due to their energy-absorbing architecture. Therefore, the chance of a concurrent TBI should decrease.

Three studies, however, do not support the idea that the face is protective of the brain. First, results from a Malaysian multisite cross-sectional study by Nordin et al. (3) showed that facial fractures were, in fact, positively correlated with injury severity scores (ISS). Second, Keenan et al. (4) studied 3849 bicyclists from 7 hospitals in the Seattle, Washington area and demonstrated an increased risk of intracranial injury associated with facial fractures after adjusting for confounders (odds ratio 2; 95% confidence interval 1.1-3.7). Lastly, Rajandram et al. (5), from a retrospective review of 11294 trauma patients, found a 1.5 increased risk of having TBI with facial fractures (95% confidence interval 1.2 – 1.9).

Our study aims to determine the incidence of TBI among individuals with craniofacial fractures among our local trauma patients. By retrospectively examining and comparing the data of our local patients with TBI and craniofacial trauma, we hope better to understand the relationship between the face and the brain. This information may provide a basis for improved counseling of craniofacial trauma patients and increase awareness of the potential for TBI.

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2. Materials and Methods

This retrospective cross-sectional study evaluated how many diagnoses of traumatic brain injuries (TBI) were in patients with maxillofacial traumas in ten years (January 1, 2010, to December 31, 2020). Data were collected from 2982 consecutive adult patients (> 18 years) seen and evaluated in a single level II trauma center in Ventura, California for either the solitary or concurrent diagnoses of traumatic brain injury (TBI) or facial fractures. These cases were identified from the medical center's Trauma Registry using admission date and TBI or maxillofacial-related International Classification of Diseases, Ninth and Tenth revision (ICD-CM 9th and 10th edition) codes, either as a primary or secondary diagnosis. The main outcomes included hospital length of stay, Intensive Care Unit (ICU) length of stay, and mortality (E.D. and in-hospital deaths). In addition, we examined outcomes by whether patients had a solitary diagnosis of TBI, facial fractures, or both. Descriptive and bivariate analyses were performed using SAS version 9.4. This study is registered with Research Registry, and the identifying number is researchregistry8351. Our work is fully compliant with the STROCSS 2021 criteria. (6)

3. Results

2,982 cases were identified that met inclusion criteria. Most participants were male (76% vs. 24%, P=<0.01) and white (73% vs. 27% other races, P=<0.001). Most of these patients were discharged home (53.52%), 5.6% were transferred out of the facility, 6.5% went to a skilled nursing facility, and 5.94% died. 33.8% of these patients required ICU admission. The most prevalent mechanism of injury was motor vehicle crashes (40.3%), falls (26%), assaults (14.4%), penetrating (4.16%), and others (11.5%). 1664 patients (55.8%) had a solitary diagnosis of TBI, 903 patients (30.28%) had a solitary diagnosis of facial fractures, and 415 patients (13.92%) had concurrent diagnoses of both TBI and facial fractures (Table 1). Continuous variables of interest were compared amongst patients with both versus solitary diagnoses of either TBI or facial fractures. The mean length of stay (LOS) of patients who had concurrent diagnoses (9.92 ± 16.33 days) was found to be significantly higher than those who only had one of the two diagnoses (6.21 ± 10.96 days) (p<0.01). In contrast, there was no significant difference in age (p=0.68) and ICU length of stay (p=0.09) between the two groups (Table 2). The odds of being diagnosed with concurrent diagnoses were 30% greater for males than females (OR: 1.30; p=0.04), 152% greater for those who were admitted to the ICU (OR: 2.52; p<0.01), and 76% greater amongst those who eventually died during their hospital encounter (OR: 1.76; p<0.01) (Table 3.)

Table 1. Demographic Characteristics of Patients Seen with Traumatic Brain Injury, Facial Fractures, or Concurrent Diagnoses from January 1, 2010, to December 31, 2020

Variable	N	Percent (%)
Diagnoses		
Only Traumatic Brain Injury Diagnosis	1664	55.80%
Only Facial Fracture Diagnosis	903	30.28%
Concurrent Diagnoses	415	13.92%
Gender		
Male	2260	75.79%
Female	722	24.21%
Race		
White	2164	72.57%
Black	69	2.31%
Asian	57	1.91%
Native American	22	0.74%
Native Hawaiian	5	0.17%

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Other/Not Disclosed	665	22.30%
Hospital DC		
Home	1596	53.52%
SNF	194	6.51%
Death	177	5.94%
Hospital Transfer	168	5.63%
Other	847	28.40%
ICU Hospitalization	847	28.40%
Admitted to ICU	1008	33.80%
Not Admitted to ICU	1974	66.20%
NTDB Grouping		
Motor Vehicle Traffic/Non-Traffic	988	40.27%
Fall	768	25.75%
Assault	429	14.39%
Pedal Cycle	185	6.20%
Pedestrian	91	3.05%
Motorcycle Crash (MCC)	55	1.84%
Penetrating	124	4.16%
Other/Unspecified	342	11.47%

Table 2. Single vs. concurrent diagnosis status compared against compared against continuous variables of interest

	Patients with TBI and Facial Fracture Diagnoses					
Variable	**Concurrent Diagnoses** *mean ± S.D.*	**Only One Diagnosis** *Mean ± S.D.*	**Total (n=2982)** *mean ± SD*	***t* (95% C.I.)**	***P*-Value**	
Age	*43.44 ± 20.24*	*42.99 ± 22.63*	*43.05 ± 22.31*	-0.41 (-2.59, 1.69)	0.68	
Length of Stay	*9.92 ± 16.33*	*6.21 ± 10.96*	*6.77 ± 12.00*	-4.25 (-5.43, -2.00)	<0.01	*
ICU Length of Stay	*5.88 ± 6.42*	*5.04 ± 6.83*	*5.22 ± 6.75*	-1.68 (-1.82, 0.14)	0.09	

**Note: Significance level was set at <0.05*

Table 3. Single vs. concurrent diagnosis status compared against categorical variables of interest.

	Patients with TBI and Facial Fracture Diagnoses				
	Concurrent Diagnoses	**Only One Diagnosis**	**Total (n=2982)**	**Odds Ratio (95% C.I.)**	***P*-Value**

Variable	*n (%)*	*n (%)*	*n (%)*			
Gender						
Male	*331 (11.09)*	*1929 (64.69)*	*2260 (75.79)*	1.30 (1.00 - 1.70)	0.04	*
Female	*84 (2.82)*	*638 (21.40)*	*722 (24.21)*			
ICU Hospitalization						
Admitted to ICU	*219 (7.34)*	*789 (26.46)*	*1008 (33.80)*	2.52 (2.03 - 3.12)	<0.01	*
Not Admitted to ICU	*196 (6.57)*	*1778 (59.63)*	*1974 (66.20)*			
Death						
Yes	*38 (1.28)*	*139 (4.66)*	*177 (5.94)*	1.76 (1.18 - 2.58)	<0.01	*
No	*377 (12.64)*	*2428 (81.42)*	*2805 (94.06)*			

Note: Values are given as counts (percentage of total).

**Significance level was set at <0.05*

4. Discussion

The current study suggested an increased chance of TBI with craniofacial fractures. Fourteen percent (14 %) of the patients in our study had a concurrent diagnosis of TBI and facial trauma. Other studies have reported a higher percentage of concurrent diagnoses. For example, Rajandram et al. (5) said that 36.7% of their study population had sustained simultaneous facial bone and traumatic brain injuries. Nordin et al. reported 37.4% (3); David off et al. reported 55% (7); Zandi et al. 23.3% (8) and Joshi et al. (9) and Grant et al. (10) reported 67 %. We found fewer concurrent diagnoses of head injury and facial trauma than most of the other studies listed above (36 %- 67%). Unlike these related studies, we suspect that our population of interest was isolated to trauma patients and not all E.D. presentations. On the other hand, our results were consistent with other studies that focused only on the trauma population. For example, Pappachan et al. (11) found 14%, and Isik et al. (12) found that 15% of their respective study populations had concurrent diagnoses.

Diagnosis of TBI in the craniofacial trauma population can be difficult. Initial presentations may not be clinically apparent. Loss of consciousness, amnesia, and low GCS score are good predictors for intracranial injury, but mild TBI may be seen without these findings in patients with craniofacial trauma. (12) Although GCS is sensitive to significant neurologic injury (13), it is not specific. Paralyzing injuries, sedatives, and baseline neurological deficits can make their use in TBI diagnosis inaccurate (14). Abnormal Computed Tomography (C.T.) scan findings indicating mild head injury have been found in trauma patients with GCS scores of 13-15 (15). Although imaging provides anatomic information at a given point, functional impairments, such as cognitive deficits, motor abnormalities, and behavior changes, often develop slowly. Furthermore, CT scans provide only a macroscopic view of the brain. It does not capture subtle changes such as grade 1 diffuse axonal injury (14). Other studies have attempted to solve this diagnostic problem by examining specific serum markers such as Neuron-specific enolase (NSE). NSE has been used as an indicator for mild TBI (16). Future study is required to adopt these markers into the current standard of care. Therefore, the true Incidence of TBI within the maxillofacial trauma population is likely underestimated in our study.

In our study, patients with concurrent diagnosis compared to a solitary diagnosis of either TBI or facial trauma were associated with a higher ICU admission rate, a longer length of stay, higher

 doi:10.20944/preprints202306.0788.v1

mortality, and male sex. The relationship between these variables is currently unknown, and future studies are required to address this. However, our study suggests that TBI worsens clinical outcomes. Early detection of TBI is critical to preventing morbidity and mortality. Treating significant facial trauma can distract from the subtle and often evolving diagnosis of TBI.

Interestingly, the majority (73%) of the brain injury patients in our study had a mild form of TBI, also known as a concussion. This is consistent with findings from other authors who reported that the most common associated head injury was a concussion (4, 8, 17, 18). Nordin et al. reported that 76.9% of their TBI patients were mild. (3) Abdul Razak et al. reported that 41.4% of people diagnosed with facial injuries were also found to have mild TBI (19) Residual cognitive deficits in patients with even mild TBI were not infrequent. Thornhill et al., in their study of the Incidence of disability in young adults with a head injury, found that the high Incidence of disability can be attributed to the fact that most patients with brain injury have mainly gone unrecognized during their initial presentation (20). Hammond et al. report that only a small number of these patients were referred to neurosurgery clinics due to poor recognition and management of concussions by craniofacial surgeons (21). Even though studies have shown that most (8%) patients with mild TBI would recover from their symptoms within 10 days, this also meant that 20% of the patients would develop long-lasting post-concussion syndromes. Failure to discover these patients and provide appropriate rehabilitation could harm their mental health, interpersonal relationships, and professional lives. Elbaih AH et al., in their study, confirm the value of quick diagnosis and early intervention, which was the key to preventing permanent neurological damage (22).

Our study has several limitations that should be considered when interpreting the findings. Firstly, the retrospective nature of our database review introduces inherent limitations such as the potential for incomplete or missing data. Consequently, establishing causal relationships between variables is restricted by the study design's retrospective nature. Furthermore, the inclusion of patients from a single center may introduce selection bias and limit the generalizability of our results to other healthcare settings. Additionally, although efforts have been made to account for confounding variables, there may still be uncontrolled factors, such as the Injury Severity Score (ISS), that could influence the observed outcomes. As mentioned above, we also acknowledge that our study underestimates the true incidence of traumatic brain injury (TBI) within the population of patients with craniofacial trauma. The challenge in diagnosing mild TBIs and the absence of a standardized screening tool specifically designed for identifying concussions in this population may contribute to this underestimation.

To address these limitations, we need to conduct further research. Prospective studies employing standardized concussion screening tools should be conducted to obtain a more accurate estimation of the incidence of TBI among patients with craniofacial trauma. Implementing such tools can enhance the early detection and management of concussions, thereby potentially mitigating long-term cognitive deficits and disabilities associated with these injuries.

The PROCESS 2021 Guideline: Strengthening the reporting of cohort studies in the surgery checklist was used as a guide in writing this manuscript (21). There was no funding for this study.

Author Contributions: The authors made the following contributions: Yuchen You and Javier Romero conceptualized the study. Yuchen You developed the methodology and software and performed the formal analysis, investigation, resource acquisition, and data curation. Yuchen You also wrote the original draft and created the visualizations. Yuchen You supervised the project and provided project administration. Javier Romero provided funding acquisition. Yuchen You, Javier Romero, Graal Diaz, and Robin Evans contributed to the writing, review, and editing of the manuscript. All authors have read and agreed to the published version of the manuscript. The CRediT taxonomy was used to explain the term explanation, and authorship was limited to those who substantially contributed to the work reported.

Funding: it should be noted that this research received no external funding. The article processing charge (APC) was not funded by any external sources.

Institutional Review Board Statement: In accordance with the Declaration of Helsinki, it should be noted that the research article titled "Concurrent Traumatic Brain Injury with Craniofacial Trauma: A 10-year Analysis of a Single Institution’s Trauma Registry" was approved by the Institutional Review Board (IRB#328) of Ventura County Medical Center on [06/01/2022].

 doi:10.20944/preprints202306.0788.v1

Informed Consent Statement: Patient consent was not required for our study because this was a retrospective study, and de-identified data was used for analysis.

Data Availability Statement: Data is unavailable due to our hospital's privacy restrictions.

Conflicts of Interest: The authors declare no conflict of interest.

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