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Clinical indicators of midface fracture in patients with trauma

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Abstract – *Background/Aim*: Midface fractures are commonly present and difficult to diagnose in trauma patients. The objective of this study was to determine clinically accessible indicators of midface fracture. *Material and Methods*: A case-control study design was used to determine clinical indicators of midface fracture. Population source was a level I trauma center registry for years 2007–2009. Cases had a documented midface fracture. Patient and trauma characteristics were compared between cases and controls. Multivariate logistic regression analysis determined significant indicators of midface fracture. *Results*: Study sample included 83 cases and 83 frequency-matched controls. Cases had a total of 211 fractures with a median of two midface fractures per person. Common fractures were orbital (41%), malar and maxillary (28%), and nasal bones (19%). Patients with midface fracture were significantly different than patients without midface fracture in severity of injury and were more likely to have a traumatic brain injury. Significant clinical indicators of fracture were maxillary sinus opacification, ethmoid sinus opacification, forehead laceration, periorbital contusion, epistaxis, and injury mechanism ($P < 0.05$). Patients with midface fracture had a 63 times greater odds for maxillary sinus opacification. The multivariable model correctly classified the presence and absence of midface fracture in 95% of study sample. *Conclusions*: Determined indicators of midface fracture provided a high level of discrimination in fracture status. Indicators can be used by clinicians to help detect possible midface fractures. Future prospective research on midface fracture indicators can assist in establishing their generalizability and impact on fracture detection, care, and outcomes.

Approximately 5–10% of trauma patients have a facial fracture (1, 2). These fractures can be difficult to assess and diagnose during emergency care. A prospective study by McAuley et al. (3), reported 8% of missed injuries in blunt trauma patients were classified as facial bone fractures. Another study reported undiagnosed midface fractures in unconscious trauma patients (4), while a review of frontal sinus fractures also reported missed fractures in pre-operative assessments of patients (5). Factors that may contribute to the difficulty of detecting facial fractures in patients with trauma include patients arriving with minimal or no accompanying information as well as those arriving unconscious, intoxicated, sedated, or intubated.

Currently, there is a paucity of research on indicators of midface fractures that may lead to better detection of these common fracture types. Midface bones support functions such as breathing, smelling, seeing, speaking, and eating. Early diagnosis of midface fracture may save time and prevent unnecessary additional radiologic scans that use equipment, personnel, radiation, and cost medical dollars. Determination of midface fracture indicators can also improve assessments, minimize the number of missed fractures, and potentially improve subsequent care. The objective of the presented study was to determine indicators of midface fracture that are clinically accessible during early trauma care.

Material and methods

Study design

A case-control study design was used to determine clinical indicators of midface fracture in early clinical care. The population source for the study was patients treated at a Midwest level I trauma center. Information was obtained using a trauma registry for the time period of 1 January 2007–31 December 2009. Trauma registry patients had at least one International Classification of Disease, Version 9, Clinical Modification [ICD-9-CM] code within the range of 800–959.9. The study was approved by the hospital's Institutional Review Board.

Cases and controls

Study cases had a documented midface fracture (ICD-9-CM: 802–802.9; excluding 802.20–802.39 [mandible] and frontal bone fractures), while potential study control patients did not have a midface fracture. An equal number of controls were frequency matched to cases. A randomly sorted list of all of the eligible controls served as the source for selecting the first-listed control receiving trauma care during the same month and year as the case. The process of frequency matching minimized sampling issues related to disproportionate injury clusters from seasonally based causes of injuries (e.g., falls on ice).

Inclusion and exclusion criteria

All patients in the study had to have received a head computed tomography (CT) scan during initial evaluation. Scans would have been originally used to examine for intracranial injury and was the source of information on potential blood-related sinus opacification from trauma injuries. Patients transferred from another facility and not directly admitted to the examined trauma center were excluded because of incomplete accompanying medical information. Also excluded were patients under the age of 18. Lastly, patients with an initial Glasgow Coma Scale (GCS) score <9 were excluded based on the rationale that these patients' head injuries were severe enough to render treatment of midface fractures inconsequential to immediate medical needs.

Data sources and variables

Study data included trauma and patient variables taken from the trauma registry, medical records, and initial head CT. Continuous variables obtained from the registry included age, Trauma Injury Severity Score (TRISS) (6), Injury Severity Score (ISS) (7), Abbreviated Injury Scale (AIS) scores (8), and length of stay (LOS). Categorical variables included gender, race, injury mechanism, injury type, injury intent, traumatic brain injury (TBI) status, initial Glasgow Coma Scale (GCS) score (9), ICD-9-CM codes, and discharge destination. Patient medical records were also reviewed using a standardized study form to abstract presence/absence of soft-tissue facial injury. Axial head CT scans were reviewed and adjudicated by a trauma surgeon for the appearance of blood-related opacification of the maxillary, ethmoid, and sphenoid sinuses.

Analysis

Descriptive statistics were conducted on trauma center and study patient characteristics. Measures of central tendency and dispersion were reported with medians and interquartile ranges (IQR). Comparative analyses were conducted for patient and trauma characteristic differences between cases and controls using Wilcoxon rank sum, chi-square, and Fisher's exact tests. Analyses were two-tailed and based on a 0.05 significance level.

Kappa (k) statistics were used to evaluate inter-rater reliability and validity of the trauma surgeon's classification of blood-related sinus opacification. A random 10% sample of the scans were taken from the first third of the surgeon's list and inserted into the last third of the list to examine intra-rater reliability. A random 20% of the trauma surgeon classified CT scans were compared against classifications made by a team of two board-certified radiologists to examine validity. Reviewers were blinded to midface fracture status.

Multivariable logistic regression analysis was performed to determine significant clinical indicators of midface fracture. Patient and trauma characteristics were examined as candidate variables based on 0.05 significance levels in bivariate analyses. Interaction terms were examined during model building. Specificity, sensitivity, positive predictive value (PPV), negative predictive value (NPV), along with adjusted odds ratio (AOR), and 95% confidence intervals (95% CI) were calculated for each significant midface fracture indicators. The receiver operating characteristic (ROC) curve for the model was graphed. Validity of the final logistic model was evaluated with internal model validation (10, 11), by constructing 1000 bootstrap samples of 100 patients taken randomly from the sample using replacement. Mean differences in area under the curve (AUC) between bootstrap samples and full sample were determined and subtracted from the full sample AUC, providing a validation correction. Analyses were performed with SAS, version 9.2 (SAS Institute, Cary, NC, USA).

Results

Descriptive trauma center characteristics

During 2007–2009, the trauma center admitted 4832 patients. These patients had a median age of 42 (IQR: 19–63) years; 91% were Caucasian, and 58% male. The type of injury was blunt trauma in 92% of patients. The most common trauma etiologies were falls (43%), motor vehicle crash (MVC) (30%), and Other (27%), with 95% of trauma being unintentional. Of patients, 24% had a TBI diagnosis. Initial GCS scores were <9 in 254 (5%) patients, 9–12 in 84 (2%) patients, and ≥ 13 in 4298 (93%) patients. The population had a median ISS of 9 (IQR: 4–10) and median TRISS of 0.991 (IQR: 0.968–0.996). The median hospital LOS was 2 (IQR: 1–5) days, 23% of patients discharged to skilled care or rehabilitation, and there were 150 (3%) patient deaths.

Study sample

The study sample consisted of 83 cases that met inclusion criteria and had a documented facial fracture (Fig. 1). The majority of excluded midface fracture patients had a low GCS score, age <18 years, were transferred, or had a combination of these criteria. Cases had a total of 211 fractures with a median of 2 (IQR: 2–4) midface fractures per person. Fractures were frequently present in the orbit (41%), malar and maxillary bones (28%), and nasal bones (19%). Two open fractures were documented in the nasal bone and three open fractures in malar and maxillary bones, along with 17 documented orbital floor blowouts. Of the eligible trauma patients that met inclusion criteria, 83 controls were frequency matched.

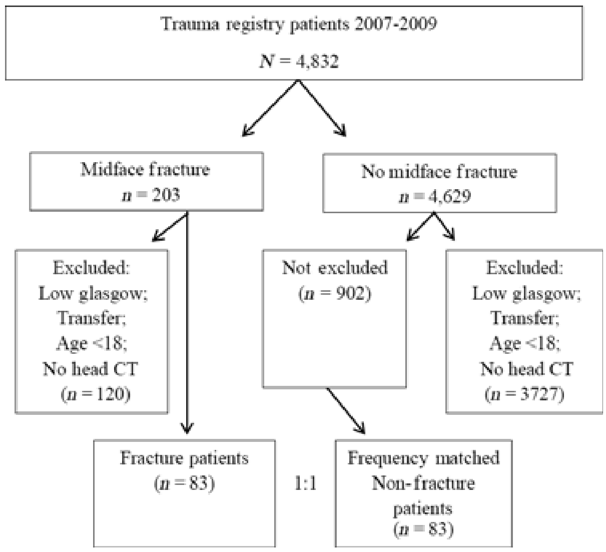

Fig. 1. Data source and study sample.

Cases and controls were comparable in age, gender, race, injury type, injury intent, initial GCS score, LOS, and discharge destination (Table 1). Differences between the groups were seen in mechanism of injury, with cases having fewer MVC (P = 0.0021). Additional differences included cases having a higher proportion of TBI (P = 0.0414), higher ISS (P = 0.0012), and lower TRISS (P = 0.0012). Cases compared with controls had higher median AIS scores for head/neck (2 [IQR: 0–3] vs 2 [IQR: 0–2]; P = 0.0333) as well as face (2 vs 0; P = 0.0001), and lower scores related to skin and subcutaneous tissue injuries (0 vs 1; P = 0.0005).

Sinus opacification

The k coefficient for the 10% redundancy in trauma surgeon adjudicated CT scans revealed excellent agreement (k = 0.94; 95% CI: 0.83, 1.00) on presence of sinus opacification. The k coefficient for the approximate 20% redundancy of head CT scans adjudicated by both the trauma surgeon and team of radiologists revealed excellent agreement (k = 0.87; 95% CI: 0.73, 1.00). Presence of sinus opacification by midface fracture type is presented in Table 2. There was a high frequency of maxillary sinus opacification; moderate frequency of ethmoid sinus opacification; and lower frequency of sphenoid sinus opacification in the midface fracture diagnoses seen in the study.

Indicators of midface fracture

Significant indicators of midface fracture included mechanism of injury, epistaxis, open wound of forehead, periorbital contusion, ethmoid sinus opacification, and maxillary sinus opacification. MVC were least commonly associated with midface fracture: patients with a midface fracture were more likely to be injured in a fall (AOR: 5.0; 95%: CI 1.3, 19.1) than injured in a MVC, and the adjusted odds of Other mechanism group were 12.5 (95% CI: 2.9, 53.2) times

Table 1. Comparisons of midface fracture cases and controls

Variable	Cases (n = 83)	Controls (n = 83)	P-value[1]
Number of midface fractures	211	0	
Number of fracture per patient	2 [2–4]	0	
Age (years)	50 [31–69]	47 [30–62]	0.3959
Male	57 (69%)	48 (58%)	0.1474
Female	26 (31%)	35 (42%)	
Race			0.4425
White	76 (92%)	73 (89%)	
Other	7 (8%)	10 (11%)	
Injury mechanism			0.0021
Motor vehicle crash	31 (37%)	53 (64%)	
Fall	28 (34%)	19 (23%)	
Other	24 (29%)	11 (13%)	
Injury type			0.4970
Blunt	81 (98%)	83 (100%)	
Penetrating	2 (2%)	0 (0%)	
Injury intent			0.0560
Unintentional	75 (90%)	80 (96%)	
Self-inflicted	1 (1%)	0 (0%)	
Assault	7 (9%)	3 (4%)	
Traumatic brain injury	54 (65%)	41 (49%)	0.0414
Initial Glasgow coma scale			0.9999
<9	0 (0%)	0 (0%)	
9–12	3 (4%)	2 (2%)	
≥13	80 (96%)	81 (98%)	
Trauma injury severity score	0.977 [0.952–0.989]	0.989 [0.970–0.996]	0.0012
Injury severity score	14 [8–22]	10 [4–17]	0.0012
Length of stay	4 [1–7]	2 [1–7]	0.0476
Discharge destination			0.4599
Skilled care category	21 (25%)	17 (20%)	
Home	62 (75%)	66 (80%)	

Data presented in medians [interquartile range]; counts (percentages).
[1]P-value presented for comparisons between cases and controls based on chi-square, Fisher's exact, and Wilcoxon rank sum tests.

the adjusted odds of injury by MVC. The top three Other mechanisms of injury were assault (eight patients, 5%), hit by object (five patients, 3%), and bicycle crashes (four patients, 2%). The adjusted odds of open wound of forehead (AOR: 6.8; 95%: CI 1.8, 26.0); periorbital contusion (AOR: 12.8; 95% CI: 2.5, 66.5); epistaxis (AOR: 20.0; 95% CI: 3.6, 109.7); ethmoid sinus opacification (AOR: 6.9; 95% CI: 1.1, 43.7); and maxillary sinus opacification (AOR: 62.9; 95% CI: 11.5, 343.0) were higher in patients with midface fractures (Table 3).

The ROC curve based on the final logistic model predicting midface fracture is presented as Fig. 2, with an AUC of 0.9519 (95% CI: 0.9206, 0.9831). Internal model validation revealed an optimistic correction of 0.0098, resulting in a final corrected AUC of 0.9421. The specificity, sensitivity, PPV, and NPV of individual

Table 2. Fracture type by sinus opacification[1]

Fracture type (*n*)	Maxillary sinus	Ethmoid sinus	Sphenoid sinus
Orbit (69)	60	41	7
Orbital floor blowout (17)	16	8	2
Nasal bones, open (2)	2	2	0
Nasal bones, closed (38)	22	23	4
Palate (1)	1	0	0
Malar and maxillae bones, open (3)	3	0	0
Malar and maxillae bones, closed (57)	50	26	7
Superior maxilla (2)	2	1	0
Zygoma/zygomatic arch (22)	17	8	3
Total number of fractures (211)	173 (82%)	109 (52%)	23 (11%)

[1]Diagnosis codes did not always distinguish between "malar and maxillae" fractures and specific subgroups of those bones such as maxilla or zygoma fractures. Patients could have had multiple fractures, with this table only reporting blood present with each individual fracture type.

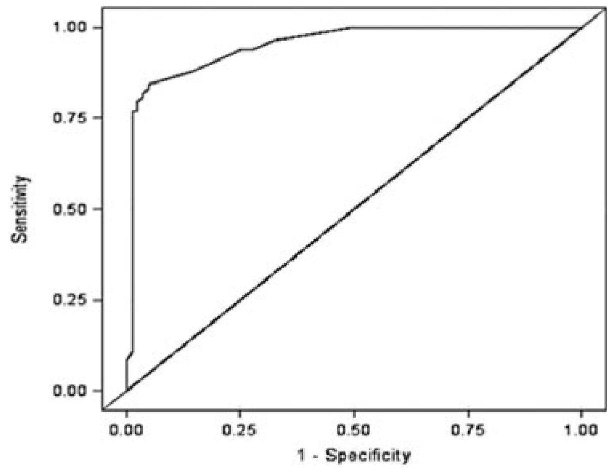

Fig. 2. Receiver operating characteristic curve for indicators of midface fracture.

fracture indicators are available in Table 4. Of note, maxillary sinus opacification had the highest sensitivity (0.65), specificity (0.98), PPV (0.96), and NPV (0.73) for midface fracture, while open wound of the forehead had the lowest sensitivity (0.23), specificity (0.90), PPV (0.70), and NPV (0.54) for fracture.

Discussion

The presented study determined indicators of midface fracture in a subset of less severely injured trauma patients. Patients with midface fractures were found to be statistically different than patients without midface fracture in severity of injury seen in higher ISS and lower TRISS. Patients with fracture were also more likely to have a positive TBI status (which included concussion). Midface fracture types were comparable to those seen in other study samples (12–14). Demonstrated significant clinical indicators of fracture included sinus opacification, soft-tissue facial injuries, epistaxis, and mechanism of injury. Indicators predicted absence or presence of midface fracture in 95% of the study sample.

Maxillary sinus opacification was the strongest indicator of midface fracture. The high rate of trauma to the orbital and maxillae bones in the study sample was probably causally related to the rate of maxillary sinus opacification. The high frequency of orbital fractures were probably also related to ethmoid sinus opacification. A lack of relationship between sphenoid sinus opacification and midface fracture may be because of the internal location of the sinus. Prior literature has only mentioned sinus opacification as an indirect sign of facial fracture (15–20). With the exception of a few single case accounts, no population-based clinical studies have assessed the predictive value of sinus opacification (21–23). The presented study demonstrated that sinus opacification occurred almost exclusively in the presence of midface fractures.

Soft-tissue injuries of the face were also associated with midface fracture. Open wounds of forehead and periorbital contusions were significant indicators. The discriminatory value of these injuries may have also been related to the frequency of orbital injury. Holmgren et al. (24) found in bivariate analyses that lips, nose, intraoral lacerations, periorbital contusions, and subconjunctival hemorrhages were significant indictors of facial fracture risk. Of these injuries, only periorbital contusion was found to be significant in predicting midface fractures in our study after controlling for other indicators of fracture in the final model. Also, the Holmgren et al. (24) study did not list the types of fractures seen in their sample, differing from our study.

Table 3. AORs for final facial fracture indicators (n = 166)

Facial fracture indicators[1]	Cases (%)	Controls (%)	Beta coefficient	Standard error	AORs (95% CI)	*P*-value
Injury mechanism						
MVC (reference group)	31 (35%)	53 (64%)	0.0000	0.0000	–	–
Falls	28 (34%)	19 (23%)	1.6090	0.6841	5.0 (1.3, 19.1)	0.0187
Other	24 (29%)	11 (13%)	2.5497	0.8404	12.5 (2.9, 53.2)	0.0074
Open forehead wound	19 (23%)	8 (10%)	1.9098	0.6887	6.8 (1.8, 26.0)	0.0056
Periorbital contusion	32 (39%)	4 (5%)	2.5497	0.8404	12.8 (2.5, 66.5)	0.0024
Epistaxis	19 (23%)	3 (4%)	2.9941	0.8692	20.0 (3.6, 109.7)	0.0006
Ethmoid sinus opacification	34 (41%)	3 (4%)	1.9339	0.9403	6.9 (1.1, 43.7)	0.0397
Maxillary sinus opacification	54 (65%)	2 (2%)	4.1416	0.8654	62.9 (11.5, 343.0)	0.0001

MVC, motor vehicle crash; AOR, adjusted odds ratio.
[1]Indicator groups were not mutually exclusive; patient could have had multiple indicators.

Table 4. Sensitivity, specificity, PPV, and NPV of significant indicators of midface fracture

Predictor	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Maxillary sinus opacification	0.65 (0.55, 0.75)	0.98 (0.94, 1.00)	0.96 (0.92, 1.00)	0.73 (0.65, 0.82)
Ethmoid sinus opacification	0.41 (0.30, 0.52)	0.96 (0.92, 1.00)	0.92 (0.83, 1.00)	0.62 (0.54, 0.70)
Periorbital contusion	0.39 (0.28, 0.49)	0.95 (0.91, 1.00)	0.89 (0.78, 0.99)	0.61 (0.52, 0.69)
Open wound forehead	0.23 (0.14, 0.32)	0.90 (0.84, 0.97)	0.70 (0.53, 0.88)	0.54 (0.46, 0.62)
Epistaxis	0.23 (0.14, 0.32)	0.96 (0.92, 1.00)	0.86 (0.72, 1.00)	0.55 (0.47, 0.64)

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value.

Documented epistaxis was present in midface fracture cases and rarely documented in controls. The variable continued to be a significant indicator of fracture after controlling for soft-tissue facial injury and blood in the sinus. The variable has been previously identified as a potential sign of facial injury and fracture (25–27).

Mechanism of injury was also a significant indicator of midface fracture. Mechanisms were categorized as MVC, falls, and Other (a diverse group of causes). The Other group and falls were more common among patients with a midface fracture. The study's sample size and the diverse nature of the Other group made it difficult to further categorize into meaningful and sufficiently sized subgroups. Facial injuries related to sports and assaults have been evaluated in other facial fracture research as causal groups (12, 28, 29), with these mechanisms not representing substantial mechanisms in the presented study sample. Patients injured by falls were primarily falls in the elderly and those from a variety of mechanisms including trips from standing and work-related falls. MVC was the least common mechanism among patients with midface fractures differing from those patients without fracture. Research literature has shown a decreasing risk for facial fracture in MVC over the past decades (30, 31).

Potential limitations

Registry data could have had missing or incorrectly entered information. All patient medical records were reviewed in an attempt to minimize this threat. CT adjudicators were not blinded to the study purpose, but were blinded to whether or not patients had a diagnosis of facial fracture, ratio of cases to controls, and presence of redundant cases and controls in the patient list. These actions should have minimized test review bias. Midface fracture indicators such as soft-tissue injuries of the face or sinus opacification may have originally led physicians to look more thoroughly for fracture during assessments. This bias could have inflated the predictive values of the determined facial fracture indicators. However, it should be noted that some patients without midface fracture received a maxillofacial CT scan without having any significant indicators of midface fracture. This would imply that other information may have influenced clinician decisions to order head and face scans. Lastly, the study was conducted at a single trauma center using a modest sample size. Internal model validation was performed to provide robust samples and evaluate the continued utility of the clinical indicators within varying patient samples.

Recommendations

Future research on midface fracture should examine indicators demonstrated in this study prospectively in a clinical setting with the goal of determining utility. Research may use identical collection of pertinent study information, including equal use of subsequent maxillofacial scanning of patients with or without suspected fracture. Future research may also help reveal types of fractures and mechanisms of injury with the greatest relationship with sinus opacification. Research should focus on better determining subgroups for mechanism of injury related to fracture using larger sample sizes, and with research occurring in comparable as well as in varying trauma populations.

Conclusion

Indicators of midface fracture in this study provided discriminatory benefits by predicting approximately 95% of patient fracture status. The model was internally validated and revealed sustained internal utility. Significant indicators of facial fracture included mechanism of injury, epistaxis, periorbital contusion, open wound of the forehead, as well as ethmoid and/or maxillary sinus opacification. These indicators can be used by emergency department clinicians to help detect midface fractures. Future prospective research on these indicators can assist in establishing their overall generalizability and impact on fracture detection, care, and outcomes.

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Conflicts of interest and funding

None to declare.

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