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*AJNR Am J Neuroradiol* 1992, 13 (3) 897-902

http://www.ajnr.org/content/13/3/897

This information is current as of December 10, 2023.
Frontal Sinus Fractures: Evaluation of CT Scans in 132 Patients

Erik M. Olson,¹ Darin L. Wright,¹ Henry T. Hoffman,² David B. Hoyt,³,⁴ and Robert D. Tien¹

Purpose: To determine the frequency of detection of frontal sinus fractures on initial CT scans of patients with intracranial injuries, and to characterize associated injuries. Methods: The initial head CT scans in 132 patients with clinical or radiographic evidence of a frontal sinus fracture were retrospectively reviewed to further characterize the fracture. Additional radiographic studies and medical records were reviewed to determine associated injuries, therapy, clinical outcome, and complications. Results: In 90% (124) of the patients, the frontal sinus fractures were visualized on initial head CT scans that were obtained to evaluate suspected intracranial injury. Complex fractures involving both the anterior and posterior wall of the sinus accounted for 65% of cases (86 patients), whereas fractures of the anterior wall only or posterior wall only occurred in 24% (32) and 11% (14) of patients, respectively. Significant intracranial hemorrhage occurred in over 90% of patients with fractures involving the posterior wall. Conclusions: In general, fractures that involved the posterior wall had more complications and a worse clinical outcome than fractures that only involved the anterior wall; nearly all frontal sinus fractures can be detected on head CT studies in patients with intracranial injuries.

Index terms: Sinus, computed tomography; Sinus, frontal; Head, trauma


Frontal sinus fractures account for 5% to 15% of all facial fractures (1–5). Frontal sinus fractures are frequently first detected on the initial head computed tomography (CT) scan of trauma patients being evaluated for suspected intracranial injury. The evaluation of frontal sinus fractures has previously received little attention in the radiology literature; to our knowledge, no study has fully described their CT scan appearance and their associated injuries in a large series of patients. This study was undertaken to determine how frequently frontal sinus fractures could be detected on the initial head CT scan, and to characterize and define associated injuries and complications.

Materials and Methods

San Diego County trauma registry records of patients entering the trauma units at University of California San Diego Medical Center, Mercy Hospital and Medical Center, Palomar Medical Center, Scripps Memorial Hospital, and Sharp Memorial Hospital between January 1, 1985 and May 1, 1990 were reviewed to identify patients with a discharge diagnosis of frontal sinus fracture. Data collected for the trauma registry during the initial hospitalization included age, sex, mechanism of injury, associated injuries, therapy, and immediate complications. The complete medical record of each patient was retrospectively reviewed at the time of this study to confirm the trauma registry data and obtain clinical follow-up.

Of the 204 patients with frontal sinus fractures recorded in the trauma registry, 132 patients were included in the study. Patients were only included in this study if the initial CT scans were available, and included 10-mm thick, contiguous slices with brain, bone, and subdural window settings. Patients with missing or incomplete head CT scans were not included in the study. The initial head CT scans of these 132 patients (obtained shortly after admission to evaluate suspected intracranial trauma) were retrospectively reviewed to determine if a frontal sinus fracture was imaged on the initial scan.
CT scans were performed on either a GE 9800 or GE 8800 (General Electric Medical, Milwaukee, WI), a Picker International 1200SX (Picker International, Cleveland, OH) or a Somaton (Siemens Medical Systems, Iselin, NJ) CT scanner. All scans were interpreted at the time the patient presented by at least one radiologist. At the time of this study, at least two of the authors reviewed the scans without knowledge of the initial interpretation. If these two interpretations of initial head CT scan differed, an additional radiologist reviewed the scan to arrive at a final interpretation.

After the final interpretation of the initial scan was determined, thin-cut facial CT scans, follow-up head CT scans, and plain radiographs of the face was retrospectively reviewed to further classify the frontal sinus fractures, determine additional facial and skull fractures, and evaluate soft-tissue injury to the brain and face. The frontal sinus fractures were characterized as anterior wall nondisplaced, anterior wall displaced, posterior wall nondisplaced, posterior wall displaced, or no fracture demonstrated. No attempt was made to evaluate the integrity of the nasofrontal duct. Additional facial and skull fractures, the presence of abnormal soft-tissue or air-fluid levels within the paranasal sinuses, orbital hematomas, and intracranial hemorrhage, hematomas, and contusions were also recorded.

Results

The average age of the 132 patients was 32 years, with an age range of 14 to 83 years. There was a 9:1 male to female predominance, with fractures in 119 (90%) males and 13 (10%) females. The majority (119, 90%) of fractures were the result of blunt trauma, with penetrating trauma accounting for 13 (10%). Motor vehicle accidents accounted for 84 (64%) cases. The second and third most frequent causes were falls from heights 16 (14%), and gunshot injuries 12 (9%). Miscellaneous blunt trauma, usually assaults, accounted for 17 (13%) of the fractures. Each type of frontal sinus fracture had a similar distribution of etiologic mechanisms.

A frontal sinus fracture was detectable on the initial head CT scan in 124 (94%) patients. Of the eight (6%) patients whose fractures were not detected on the initial scan, fractures were discovered in six patients on thin-slice axial and coronal facial CT scans performed to evaluate other facial injuries. Fractures in two of the patients were discovered on physical examination but were not seen on the head CT scan. One was a small, minimally displaced, open anterior wall fracture and the other was a nondisplaced posterior wall fracture discovered incidently at craniotomy for evacuation of a hemorrhagic frontal lobe contusion.

Most of the patients, 86 (65%), had complex fractures involving both the anterior and the posterior wall. Fractures of the anterior wall only were present in 32 (24%) patients, while isolated posterior wall fractures were present in 14 (11%) patients. Fractures were displaced for a distance greater than the width of the wall in 59% of the anterior wall fractures and 54% of the posterior wall fractures.

Figure 1 shows typical examples of displaced and nondisplaced fractures. Most (86%) of the posterior wall fractures were associated with either nasoethmoid or orbital roof fractures. Linear fractures through the anterior and posterior wall without involvement of the floor or ethmoid air cells were uncommon, occurring in only four (3%) of the patients.

In general, the patients with frontal sinus fractures had significant associated facial or skull fractures or intracranial injury (Table 1). Abnormal soft-tissue findings within the sinuses, orbits, and brain parenchyma were also relatively common (Table 2, Fig. 2). Periorbital hematoma or intraorbital abnormalities (hematoma, gas, bone fragments, or foreign bodies) were seen in 36 (27%) of the patients. Pneumocephalus was present in 47 (37%), over one third of the patients. Frontal lobe contusion (43%), frontal subdural hematoma (14%), and subarachnoid hemorrhage (7%) were the most common intracranial abnormalities (Table 3). Over 90% of the intracranial injuries were associated with fracture of the posterior wall of the frontal sinus. Of the 100 patients whose injuries involved the posterior wall, 73% had radiographic evidence of intracranial hemorrhage or contusion. Although, the more severely comminuted or displaced fractures had a higher incidence of associated injuries, involvement of the posterior wall was the best predictor of associated injuries.

Therapy was variable and often dependent on associated injuries. Observation alone was the treatment in 38 (29%) of the patients. Seventeen (13%) patients died from associated injuries before receiving treatment. Surgical therapy, usually a combination of sinus obliteration, elevation of bony fragments, or sinus cranialization, was performed in 59 (45%) cases. Eighteen (14%) patients were lost to follow-up before treatment could be completed.

Frontal sinus fractures frequently have significant complications. Because of the short duration of the study and the poor clinical follow-up, only the complications apparent during the initial hos-
Fig. 1. Frontal sinus fractures seen on initial head CT scans in three separate patients involved in automobile accidents. A, CT scan showing a displaced fracture of the anterior wall with the fragment (arrow) adjacent to the posterior wall and a large overlying soft-tissue defect. B, A relatively subtle nondisplaced posterior wall fracture (arrows) is well shown on this initial head CT scan. C, CT scan demonstrating a minimally displaced anterior wall fracture on the right (arrow) and severely displaced anterior and posterior wall fracture on the left (open arrows). Note the abnormal soft tissue within much of the frontal sinus.

TABLE 1: Frequency of associated fractures with frontal sinus fractures

<table>
<thead>
<tr>
<th>Fracture Site</th>
<th>Frequency (%)</th>
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<tbody>
<tr>
<td>Orbit</td>
<td>110 (83)</td>
</tr>
<tr>
<td>Nasoethmoid</td>
<td>90 (68)</td>
</tr>
<tr>
<td>Cranium</td>
<td>77 (58)</td>
</tr>
<tr>
<td>Maxillary sinus</td>
<td>72 (54)</td>
</tr>
<tr>
<td>Zygomatic arch</td>
<td>28 (21)</td>
</tr>
<tr>
<td>Sphenoid sinus</td>
<td>12 (9)</td>
</tr>
<tr>
<td>Le Fort type</td>
<td>11 (8)</td>
</tr>
</tbody>
</table>

TABLE 2: Frequency of abnormal soft tissue findings associated with frontal sinus fractures

<table>
<thead>
<tr>
<th>Site</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethmoid sinus</td>
<td>122 (92)</td>
</tr>
<tr>
<td>Frontal sinus</td>
<td>120 (91)</td>
</tr>
<tr>
<td>Maxillary sinus</td>
<td>62 (47)</td>
</tr>
<tr>
<td>Sphenoid sinus</td>
<td>51 (39)</td>
</tr>
<tr>
<td>Orbit (hematoma)</td>
<td>54 (41)</td>
</tr>
<tr>
<td>Frontal lobe (contusion)</td>
<td>57 (43)</td>
</tr>
<tr>
<td>Other brain injuries</td>
<td>31 (24)</td>
</tr>
</tbody>
</table>

Hospitalization were documented in this series. There were 15 (11%) cases of significant ocular complications, such as blindness, extraocular muscle disorders, or diplopia. Meningitis occurred in six (5%) patients. Persistent cerebrospinal fluid leaks, requiring surgery for repair, occurred in three (2%) patients.

Discussion

The frontal sinuses, air-filled cavities within the frontal bone, arise as small invaginations from an anterior ethmoidal cell tract (6). These cells may belong to the uncinate process, middle meatus, or ethmoidal bullae, which accounts for the variability in the drainage of the frontal sinus (7). The adult frontal sinus, a pyramid-shaped structure with its base inferior and apex superior, has a thick, strong anterior wall and a thin, relatively fragile posterior wall and floor. A bony septum separates the sinus into two asymmetric cavities, each with its own drainage system via a nasofrontal duct into the anterior part of the middle meatus or the anterior portion of the ethmoid infundibulum (8-10). The ducts originate near the intrasinus septum in the anterior portion of the floor of the sinus. They run posteriorly and caudally, through the anterior ethmoidal air cells, into the meatus or infundibulum (7, 11).

Frontal sinus fractures have traditionally been characterized as anterior wall, posterior wall, or nasofrontal duct fractures (1, 5, 6, 9, 12). Some
Fig. 2. An example of a frontal lobe hemorrhagic contusion complicating a severe posterior wall frontal sinus fracture.

A, Initial head CT scan showing a non-displaced fracture through the anterior and posterior wall of the left frontal sinus (small arrows). There is also a fracture through the posterior wall of the right frontal sinus (large arrow), which was subsequently shown to be comminuted and displaced on a facial CT scan (data not shown). There are also fractures through both sphenoid bones (open arrows) and through the lateral aspect of the left frontal bone (arrowhead).

B, Follow-up head CT scan on the same patient demonstrates a huge left frontal lobe hematoma (arrows).

TABLE 3: Intracranial hemorrhage associated with frontal sinus fractures

<table>
<thead>
<tr>
<th>Brain Injury</th>
<th>No. of Patients</th>
<th>Percent with Posterior Wall Fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal lobe contusion</td>
<td>57 (43)</td>
<td>91</td>
</tr>
<tr>
<td>Frontal subdural hematoma</td>
<td>18 (14)</td>
<td>100</td>
</tr>
<tr>
<td>Temporal lobe contusion</td>
<td>9 (7)</td>
<td>100</td>
</tr>
<tr>
<td>Temporal subdural hematoma</td>
<td>4 (3)</td>
<td>100</td>
</tr>
<tr>
<td>Other contusion/hematoma</td>
<td>3 (2)</td>
<td>100</td>
</tr>
<tr>
<td>Other subdural hematoma</td>
<td>3 (2)</td>
<td>100</td>
</tr>
<tr>
<td>Subarachnoid hematoma</td>
<td>10 (8)</td>
<td>80</td>
</tr>
<tr>
<td>Shear injury</td>
<td>6 (5)</td>
<td>67</td>
</tr>
<tr>
<td>Epidural hematoma</td>
<td>4 (3)</td>
<td>75</td>
</tr>
<tr>
<td>Intraventricular hematoma</td>
<td>4 (3)</td>
<td>75</td>
</tr>
</tbody>
</table>

authors include through-and-through fractures, involving both the anterior and posterior wall, as a separate category (9). The fractures are further categorized as linear or comminuted and depressed or nondepressed. High-resolution CT is the method of choice for defining and characterizing anterior and posterior wall fractures (13-18). Nasofrontal duct fractures can seldom be imaged directly even with high-resolution CT scans (11). However, fractures through the ethmoid air cells and the orbital roof are easy to visualize and have a high association with nasofrontal duct involvement (11, 12, 19-23). In our series, posterior wall fractures that did not involve the ethmoid air cells or orbital roof were very uncommon. Extension of a fracture from the orbital roof into the posterior wall accounted for most of the fractures of the posterior wall that did not also involve the anterior wall.

Proper characterization of the fractures is essential for planning treatment. Nondisplaced fractures of the anterior wall require no treatment. Displaced anterior wall fractures require cosmetic elevation. Posterior wall fractures and fractures that may involve the nasofrontal duct usually require surgical exploration with repair of the fracture and duct, or obliteration or cranialization of the sinus (3-6, 9). If the frontal sinus is functionally eliminated, involvement of the nasofrontal duct is irrelevant, as the sinus will no longer produce secretions.

No large imaging study of frontal sinus fractures has been conducted since CT scanning has become the standard method of evaluating facial trauma. Associated facial fractures are common, but the exact frequency is not known (9). One series of 21 patients described facial fractures in 14 patients, usually nasoethmoid or Le Fort fractures (24). In another series (25), nasoethmoidal, maxillary and zygomatic, and mandibular fractures were reported in 64%, 25%, and 11% of patients, respectively, with frontal sinus fractures. The incidence of associated facial or skull fractures (94%) in our study was very high. This is due partly to improved detection with CT scanning and partly to a more seriously injured patient population. Orbital fractures, nasoethmoidal fractures, and maxillary sinus fractures were the most common associated facial fractures. Interestingly, Le Fort fractures were present in only 8% of the patients. Fractures of the posterior wall had the highest incidence of associated facial fractures. This high incidence is not surprising, as it has been shown that two to three times greater force is required to fracture the frontal sinus than any other facial bone (26). Accordingly, most (64%) of the fractures in this series were caused by high-speed motor vehicle accidents.

The strong forces required to fracture the frontal sinus also account for the extremely high incidence of associated brain injuries. The poste-
rior wall of the frontal sinus is the anteroinferior wall of the anterior cranial fossa. Over 70% of the patients with fractures of the posterior wall developed detectable brain contusion or hemorrhage, and over 90% of the patients with serious brain injury had fractures involving the posterior wall (Fig. 2). The brain injury was not always apparent on the initial head CT scan. The high frequency of brain injury with posterior wall fractures suggests that patients with posterior wall fractures should have follow-up CT scans or MR scans to exclude brain injury if the initial CT scan of the brain is normal.

Frontal sinus fractures are frequently associated with ocular complications. One study of 727 patients receiving formal ophthalmologic consultation for facial fractures revealed that 89% of the patients with frontal sinus fractures had associated ocular injuries (27). Although our study had a much different patient selection bias, which should have had a lower frequency of associated eye injuries, the incidence of ocular trauma was still high: 83% of patients had orbital fractures and 11% had significant ocular complications. Most of these complications occurred in patients with severely comminuted fractures involving the posterior wall and floor of the frontal sinus.

The incidence of cerebrospinal fluid leaks and meningitis were similar but slightly lower than that reported in previous series (28, 29). No mucoceles were reported in our study; however, long-term follow-up was poor and post-traumatic mucoceles can take years to develop (30, 31). Twenty-seven percent of the patients either died or were lost to follow-up before evaluation and therapy could be completed.

Our study demonstrates that nearly all frontal sinus fractures can be detected on head CT scans obtained to evaluate intracranial injury. The patients in this series were not randomly selected, but chosen from trauma unit registries, which biases the group toward more serious injuries. The 94% detection rate would likely be lower in less critically injured or randomly selected patients. Even so, the detection rate on head CT scans is undoubtedly quite high. Detecting a frontal sinus fracture on an initial head CT scan may lead the patient, if hemodynamically and neurologically stable, to receive a thin-cut facial CT scan during initial evaluation without moving the patient from the scanner.

Frontal sinus fractures are relatively uncommon but serious manifestations of facial trauma. High-resolution, thin-slice axial and coronal facial CT scans are required to define details of the fractures and associated injuries. All frontal sinus fractures, but particularly posterior wall fractures, have a high incidence of associated facial fractures and intracranial hemorrhage and contusion.

Acknowledgment

We gratefully thank the Department of Surgery, UCSD Medical Center and the Trauma Research and Education Foundation of San Diego for assistance in collecting the clinical material.

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