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Vertical Fractures of the Dens

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PURPOSE: To establish the mechanism of injury that causes vertical fractures of the dens. **METHODS:** Over a 3-year period, 30 patients with dens fractures were seen at our institution. From these records, we identified and retrospectively reviewed the radiographs (n = 3), CT scans (n = 3), and MR images (n = 1) of three patients with vertical fractures of the dens to assess the characteristics of these fractures and other associated injuries. Medical records of these three patients were also reviewed in an attempt to elucidate the mechanism of injury. Additionally, we reviewed three cases reported in the literature and compared them with findings in our patients. **RESULTS:** In all patients, radiographs showed fractures involving the base of the dens (type 2), but they did not show the vertical fractures. Axial CT scans and sagittal reformations clearly showed the vertical dens fractures. One patient also had a unilateral Jefferson-type fracture. The atlanto-dental space was preserved in all patients. In one patient, there was posterior displacement of the fractured dens. All three patients were neurologically normal. After a 6-month period of external fixation, two patients healed adequately. **CONCLUSION:** Vertical dens fractures probably result from axial loading and slight extension of the head. In our cases, vertical dens fractures were accompanied by other fractures of C-1 and C-2. CT with sagittal reformations is the ideal imaging method to detect vertical dens fractures.

Index terms: Atlas and axis; Spine, fractures

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Traditionally, fractures of the dens have been classified according to the scheme proposed by Anderson and D'Alonzo, who divided these fractures into three types: type 1, involving the apex of the dens; type 2, reaching through the base of the dens; and type 3, extending into the body of C-2 (1). Vertical fractures of the dens are thought to occur separately from those mentioned above. When isolated (pure), vertical dens fractures may be considered a fourth type; however, vertical dens fractures commonly occur in association with other fractures of the atlas and axis. The mechanism of injury responsible for the more common dens fractures is accepted to be related to a combination of hyperextension, hyperflexion, and rotation (2). The mechanism responsible for pure vertical dens fractures, however, has not been reliably established. In this article, we review the imaging features in three cases of vertical dens fractures. In all cases, type 2 fractures were also present and in one case a unilateral Jefferson fracture was also present.

Materials and Methods

Three adult men (age range, 35 to 70 years) were admitted to the emergency department after high-speed motor vehicle accidents (n = 2) or after being hit on the vertex of the head by a large piece of ice falling from a roof (n = 1). All patients were initially examined with cross-table lateral radiography of the cervical spine followed immediately by computed tomography (CT) in which 3-mm-thick contiguous axial sections were obtained from the base of the skull to C-3. Images were processed with bone and soft-tissue window settings and reformatted in multiple sagittal and coronal 3-mm-thick planes. In one case, magnetic resonance (MR) imaging was done using sagittal T1-weighted (500/14/2 [repetition time/echo time/excitations]) and fast spin-echo T2-weighted (3500/22,90/1) sequences (imaging in the axial plane was not tolerated by this patient). All images were reviewed with special attention to the presence and orientation of fractures and to narrowing of the diameter of the spinal canal. Medical records were reviewed to assess the possible

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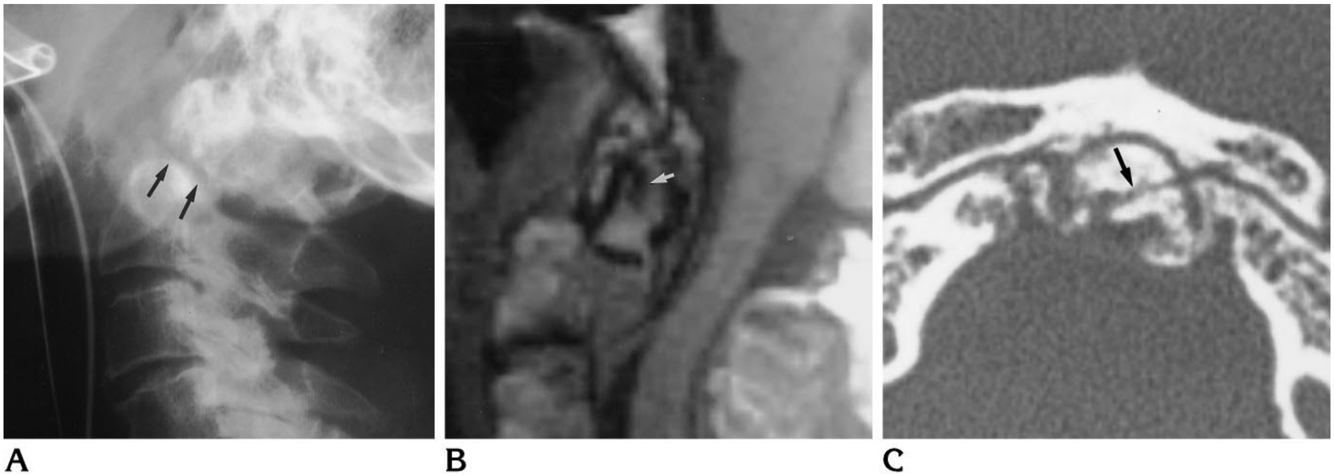


Fig 1. *A*, Lateral radiograph obtained with cross-table lateral technique shows type 2 fracture (*arrows*) at base of dens with posterior angulation. The vertical dens fracture is not appreciated on this study.

B, Midsagittal T1-weighted (500/14/2) MR image shows significant posterior displacement of dens with a linear hypointensity (*arrow*) at site of vertical fracture. Note increased subluxation as compared with radiograph. Prominence of the ventral epidural space posterior to the dens may be related to hematoma. The posterior subluxation of C-1 on C-2 is responsible for the maintenance of the atlantoodontoid distance.

C, Axial CT scan shows vertical dens fracture (*arrow*). Note normal atlantodental distance.

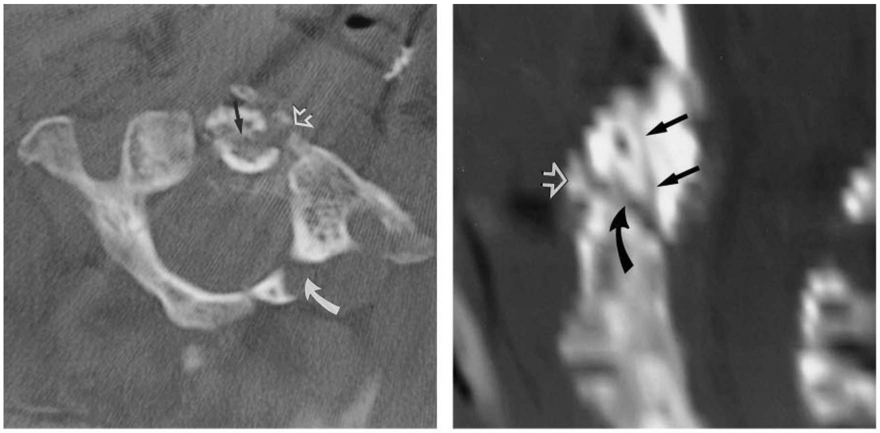
mechanism of injury, the mode of therapy, and the clinical outcome.

Results

Lateral plain radiographs clearly showed type 2 dens fractures in all three patients, but the vertical fractures were not seen on these radiographs (Fig 1). In two patients, the injuries occurred as a consequence of high-speed motor vehicle accidents and in one it was the result of a large slab of ice falling from a roof and striking the patient on the head. In one patient, there was significant posterior displacement of the dens and narrowing of the spinal canal diameter at that level (Fig 1). The atlantodental interval was normal (less than 2 mm) in all three patients. Prevertebral soft-tissue swelling was present in all patients. Axial CT sections showed the vertical fractures extending obliquely from the top of the dens into the fractures at their bases (Figs 1–3). In all cases, the fractures had an oblique-coronal projection rather than a pure vertical one. The vertical fracture gap was measured as 1 to 3 mm using computer calipers in all cases. All vertical and type 2 fractures were well demonstrated on the sagittal reformations (Fig 2B). Coronal reformations did not show the vertical fractures but showed the type 2 fractures. In two patients, no other fractures were present. In one patient, there were fractures of the left anterior and posterior arches of C-1, compatible with a unilateral Jefferson fracture (Fig 2A). MR imaging in one instance showed considerable posterior displacement of the fractured dens and prominent epidural soft tissues with compression of the spinal cord. The spinal cord itself was of normal signal intensity on both T1- and T2-weighted sequences. MR imaging also showed a linear hypointensity corresponding to the vertical dens fracture in this patient (Fig 1B). All patients were neurologically asymptomatic. Because of their vertical component, these fractures were not deemed amenable to anterior internal fixation with a screw, and the patients were placed in rigid orthoses (Philadelphia collar). In two cases, 6-month follow-up plain radiographs showed healing of the fractures, and flexion-extension views revealed no instability. One patient died of unrelated chronic liver disease while he was hospitalized during the acute phase of his injury.

Discussion

Dens fractures account for approximately 9% of all fractures of the cervical spine (3). Of these, type 2 is the most common. Vertical fractures of the dens have recently been described (2, 4, 5): in two of those cases, the fractures were isolated, and in one patient, there were



A B

Fig 2. *A*, Axial CT scan shows vertical fracture through dens (*closed arrow*) with gap between fracture fragments. Note fractures involving anterior (*open arrow*) and posterior (*curved arrow*) arches on left side of C-1, compatible with a unilateral Jefferson-type injury.

B, Midsagittal reformation from CT scans shows vertical (*straight arrows*) and type 2 (*curved arrow*) fractures. Note that anterior arch of C-1 (*open arrow*) is in normal relationship to the dens and that the atlantodental space is preserved.

Fig 3. Axial CT scan shows vertical fracture (*arrow*). The distance between the right lateral mass of C-1 and the dens is increased because of tilting of the head.

also fractures involving the arches of C-1 (Jefferson-type injury). This differs somewhat from the findings in our patients, in whom all vertical fractures were seen in the presence of type 2 dens fractures. One of our patients also had a concomitant Jefferson fracture.

Odontoid fractures are believed to be due to abnormal hyperextension, hyperflexion, and rotation. Pure vertical dens fractures may be the result of axial loading on the anterior lip of the foramen magnum striking the apex of the dens (4). This then induces a vertical shearing force resulting in a fracture. Other forces that may play a role in the development of vertical dens fractures are hyperflexion and slight hyperextension in combination with axial loading, leading to a chisel-type fracture (4, 5). In one reported case, axial loading was considered responsible for the findings, since the patient's injury occurred after striking the head on a tree while diving for a football (2). The mechanism of injury was similar in our patient who was struck on the top of the head by a large slab of falling ice. Therefore, there is evidence to suggest that axial loading plays an important role in the development of vertical dens fractures. Pure axial loading would also result in the force being transmitted from the vertex of the skull to the occipital condyles and through the lateral masses of C-1, producing a Jefferson-type fracture. Indeed, in one reported case (4) and in one of our patients, the vertical dens fractures were accompanied by fractures of the arches of C-1, supporting axial loading as a mechanism of injury. However, in order to produce a vertical dens fracture, there also has to be slight tilting of the head posteriorly (extension) so that the lip of the basion aligns precisely with the tip of the dens. Then, the mechanism responsible for vertical dens fractures is probably a combination of slight extension and axial loading.

Two reported patients (4, 5) and two of our patients were involved in high-speed motor vehicle accidents, and therefore it is not possible to determine clearly the exact mechanism of injury. The presence of synchronous type 2 dens fractures in all of our patients supports the theory that extension also plays an important role. Vertical dens fractures do not appear to have damaged the transverse ligament in our patients or in those reported patients, since they all had normal atlantodental spaces. The incidence of vertical dens fractures is unknown. In our hospital, we have seen approximately 30 patients with fractures involving C-1 during the period in which these three cases of vertical dens fractures were collected.

The imaging evaluation of suspected dens fractures begins with plain radiography in the emergency department. Plain radiography is important for demonstrating indirect signs (such as prevertebral soft-tissue swelling) rather than the fracture itself (6). CT with thin contiguous sections (1 to 3 mm), particularly with sagittal and coronal reformations, is the imaging method of choice. Linear tomography, although helpful, is not commonly used. In our cases, we were not able to identify the vertical fractures on plain radiographs, but these were clearly seen on CT scans. CT may potentially miss fractures oriented in the plane of scanning, which has been a potential pitfall in the evaluation of transverse dens fractures, particularly of type 2. This problem is easily solved by obtaining orthogonal reformations, especially in the sagittal plane. Since vertical dens fractures are oriented perpendicular to the axial scanning plane, none should be missed on axial scans. Vertical dens fractures may be hard to identify on coronal reformations, because they are oriented in the same plane. Because they are perpendicular to the sagittal plane, vertical dens fractures are clearly seen on this projection. Generally, the atlantoodontoid distance is preserved in all dens fractures owing to preservation of the integrity of the transverse ligament.

Treatment of dens fractures is initially noninvasive (providing there are no neurologic deficits or no significant displacement of fracture fragments) and is accomplished by external immobilization. Type 1 dens fractures may be treated with a rigid cervical orthosis. All types of dens fractures may also be immobilized by a halo vest (7). Because the rates of nonunion vary from 60% for type 2 fractures to 10% to 15% for type 3 fractures, many prefer internal fixation as the treatment of choice (7). In patients with acute fractures or those in whom there is nonunion, internal fixation may be accomplished from a posterior or an anterior approach. Type 2 fractures may be fixed posteriorly provided there is no displacement of the dens or epidural hematoma. Posterior internal fixation is generally done by attaching the occipital bones to C-1 and C-2 via plates, rods, cables, or wires (8). In addition, bilateral transarticular screws at C1–2 provide stabilization with greater mobility than do other posterior approaches (R. Toselli, personal communication, May 1996). A significantly displaced dens may be resected transorally after posterior immobilization. Anterior internal fixation (transorally) may be done for acute fractures and for nonunion, provided there is no significant compromise of the spinal canal diameter (9). This fixation involves placement of a screw anteriorly through the body of C-2 into the dens and is believed to provide a high rate of fusion with good mobility of the cervical spine. A vertical fracture of the dens may prevent the placement of the latter type of screw, as the dens would offer suboptimal purchase.

In conclusion, vertical fractures are a fourth but uncommon type of fracture affecting the odontoid process. Of six cases reported in the literature (including the three described here), four have been accompanied by other fractures at either C-2 or C-1. In our experience, vertical dens fractures were not identified on plain radiographs, an observation that supports the need to obtain CT scans in all patients with suspected fractures of C-2.

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