Fractures of the C-2 vertebral body

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Vertical C-2 body fractures are presented in 15 patients with clinical and imaging correlations that suggest the existence of a variety of mechanisms of injury. In these patients, clinical and imaging correlations were derived by: 1) defining the point of impact by clinical examination; 2) defining the point of impact by soft-tissue changes on cranial magnetic resonance (MR) imaging or computerized tomography (CT); 3) obtaining an accurate history of the mechanism of injury; and 4) spine imaging (x-ray studies, CT, and MR imaging) of the C-2 body fracture and surrounding bone and soft tissue.

The cases presented involve the region located between the dens and the pars interarticularis of the axis. Although these fractures are rarely reported, they are not uncommon. An elucidation of their pathological anatomy helps to further the understanding of the mechanistic etiology of upper cervical spine trauma.

A spectrum of mechanisms of injury causing upper cervical spine fractures was observed. The type of injury incurred is determined predominantly by the force vector applied during impact and the intrinsic strength and anatomy of C-2 and its surrounding spinal elements. From this clinical experience, two types of vertical C-2 body fractures are defined and presented: coronally oriented (Type 1) and sagittally oriented (Type 2). A third type of C-2 body fracture, the horizontal rostral C-2 fracture (Type 3), is added for completeness; this Type 3 fracture is the previously described Type III odontoid process fracture described by Anderson and D’Alonzo.

KEY WORDS • cervical spine fracture • axis • hangman’s fracture • pedicle • odontoid • pars interarticularis • dens

Although vertical C-2 body fractures are not commonly reported, they are not rare. Their elucidation and clear definition are therefore warranted. The odontoid process fracture scheme of Anderson and D’Alonzo1 defines three types of odontoid process fractures. This scheme is misleading and contributes to confusion regarding fracture location. Their Type I fracture is an avulsion of the tip of the odontoid process rather than a true odontoid process fracture. Their Type III fracture is not a fracture through the odontoid process. Instead, the fracture fault, as defined by Anderson and D’Alonzo, passes horizontally through the upper aspect of the C-2 vertebral body; it is therefore a horizontal rostral C-2 body fracture.

Fractures of the C-2 body proper occur in the region between the base of the odontoid process (dens) and the pars interarticularis (Fig. 1); they are rarely reported as such in the literature. The following is a report of 15 cases of vertical C-2 body fracture in which the mechanism of injury was established through clinical examination, pertinent medical history, and multiple imaging studies. Two types of vertical C-2 body fractures are identified and a new system for categorizing C-2 body fractures is presented. This classification system encompasses the two newly described vertical C-2 body fracture types and the horizontal rostral fracture that was defined by Anderson and D’Alonzo as a Type III odontoid process fracture.

Clinical Material and Methods

Fifteen cases of vertical C-2 body fractures were retrospectively reviewed. These patients presented to the University of New Mexico Medical Center in Albuquerque over a 3-year period ending April 30, 1993.

The mechanism of injury for each patient was established from clinical information and correlated with data acquired from imaging studies (Table 1). Multiple imaging modalities were employed to clearly define the extent of injury to spinal cord elements. Plain x-ray films provided information regarding gross structural alterations; computerized tomography (CT) detailed the bone pathology, particularly in the axial plane; and magnetic resonance (MR) imaging defined injury to the
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**TABLE 1**

*Clinical summary of 15 patients with vertical C-2 body fracture*

<table>
<thead>
<tr>
<th>Fracture Type &amp; Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Injury Mode</th>
<th>Means of Diagnosis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>coronally oriented vertical C-2 body fracture (Type 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>75, F</td>
<td>MVA</td>
<td>C</td>
<td>2 &amp; 3</td>
<td>hyperextension with axial component</td>
</tr>
<tr>
<td>2</td>
<td>28, F</td>
<td>MVA</td>
<td>C</td>
<td>2</td>
<td>hyperextension with axial component</td>
</tr>
<tr>
<td>3</td>
<td>24, M</td>
<td>skiing</td>
<td>C</td>
<td>1 &amp; 2</td>
<td>hyperextension with axial component</td>
</tr>
<tr>
<td>4</td>
<td>52, F</td>
<td>MVA</td>
<td>C</td>
<td>3</td>
<td>combination (mechanism C) and hangman's fracture (mechanism B)</td>
</tr>
<tr>
<td>5</td>
<td>30, M</td>
<td>MVA</td>
<td>C</td>
<td>1, 2, &amp; 3</td>
<td>hyperextension with axial component, accompanying C-1 arch fracture</td>
</tr>
<tr>
<td>6</td>
<td>52, M</td>
<td>fall (ladder)</td>
<td>D</td>
<td>1 &amp; 3</td>
<td>axial load with some hyperextension; MR imaging demonstrated significant ant &amp; post soft-tissue injury</td>
</tr>
<tr>
<td>7</td>
<td>35, M</td>
<td>fall (roof)</td>
<td>D</td>
<td>1 &amp; 3</td>
<td>axial load with some hyperextension; MR imaging demonstrated significant ant &amp; post soft-tissue injury</td>
</tr>
<tr>
<td>8</td>
<td>24, M</td>
<td>MVA</td>
<td>D</td>
<td>1 &amp; 2</td>
<td>axial load with dorsal component</td>
</tr>
<tr>
<td>9</td>
<td>19, M</td>
<td>MVA</td>
<td>F</td>
<td>1, 2, &amp; 3</td>
<td>axial load with dorsal component</td>
</tr>
<tr>
<td>10</td>
<td>62, M</td>
<td>MVA</td>
<td>F</td>
<td>1 &amp; 2</td>
<td>no external evidence of cranial trauma; shoulder harness-related neck abrasion</td>
</tr>
<tr>
<td>11</td>
<td>24, F</td>
<td>MVA</td>
<td>H</td>
<td>3</td>
<td>no external evidence of trauma, except sternum injury</td>
</tr>
<tr>
<td>sagittally oriented vertical C-2 body fracture (Type 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>75, F</td>
<td>MVA</td>
<td>H</td>
<td>3</td>
<td>no external evidence of trauma, except sternum injury</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fracture Type &amp; Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Injury Mode</th>
<th>Means of Diagnosis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>23, M</td>
<td>MVA</td>
<td>E</td>
<td>1 &amp; 2</td>
<td>axial load; deeply comatose, died</td>
</tr>
<tr>
<td>14</td>
<td>40, M</td>
<td>MVA</td>
<td>E</td>
<td>2</td>
<td>axial load</td>
</tr>
<tr>
<td>15</td>
<td>34, F</td>
<td>MVA</td>
<td>E</td>
<td>1 &amp; 2</td>
<td>axial load with lat component</td>
</tr>
</tbody>
</table>

*For an explanation of fracture type, see Results and Table 2. The mechanisms of injury are described and depicted in Fig. 6. MVA = motor-vehicle accident.

† The method used for defining injury is as follows: 1 = point of impact by clinical examination; 2 = point of impact by noting soft-tissue changes on computerized tomography or magnetic resonance (MR) imaging; and 3 = accurate history of the mechanism of injury.

soft tissues. Specific information obtained regarding each fracture included: 1) identification of the point of impact by clinical examination; 2) identification of the point of impact by evaluating soft-tissue changes on cranial MR imaging and CT; 3) a history of the mechanism of injury; and 4) spine imaging (x-ray studies, CT, and MR imaging) of the C-2 body fracture and surrounding bone and soft tissue.

Based on this information, the fractures were grouped according to mechanism of injury and type of fracture observed. Vertical C-2 body fractures were divided into those that were coronally oriented (Type 1) and those that were sagittally oriented (Type 2). These two new vertical fracture types with corresponding mechanisms of injury were clearly differentiated by the orientation of the fracture fault. They are defined and exemplified according to the mechanism of injury in Table 2.

**Results**

Of the 15 fractures in this series, 12 were coronally oriented and three were sagittally oriented (Table 1).

**Coronally Oriented Vertical C-2 Body Fracture (Type 1)**

Coronally oriented fractures are acquired by a variety of mechanisms. Each mechanism of injury may be associated with surprisingly similar imaging findings. Fractures with this radiographic appearance, which involves a coronally oriented vertical fracture through the posterior aspect of the C-2 vertebral body, are defined as Type 1 C-2 body fractures. These coronally oriented fractures have at least four possible mechanisms of injury.

**Extension With Axial Load.** In Cases 1 to 5 (Table 1), the mechanism of injury was extension with axial load. Slightly less capital extension than that causing traumatic spondylolisthesis of the axis, combined with a small axial load component, may result in a modi-

![Fig. 1. Drawing depicting the location of C-2 body fractures (those restricted to the C-2 vertebral body proper). This may be defined as the region located caudal to the base of the dens and the pars interarticularis of the axis (solid lines).](image-url)
TABLE 2
Fractures of the C-2 vertebral body and mechanisms of injury

<table>
<thead>
<tr>
<th>C-2 Body Fracture Type &amp; Variants</th>
<th>Mechanisms of Injury*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1: coronally oriented vertical</td>
<td>capital extension with slight axial load (C)</td>
</tr>
<tr>
<td>variants: extension teardrop &amp; hyperextension dislocation</td>
<td>axial load with slight capital extension (D)</td>
</tr>
<tr>
<td>Type 2: sagittally oriented vertical</td>
<td>axial load with slight capital flexion (F)</td>
</tr>
<tr>
<td>variant: lateral vertical</td>
<td>capital flexion with distraction (H)</td>
</tr>
<tr>
<td>Type 3: horizontal rostral</td>
<td>capital extension &amp; hyperextension</td>
</tr>
<tr>
<td></td>
<td>isolated axial load (E)</td>
</tr>
<tr>
<td></td>
<td>significant axial load with lateral component (E)</td>
</tr>
<tr>
<td></td>
<td>dorsal-to-ventral oriented blow to the head (G)</td>
</tr>
</tbody>
</table>

* Letters in parentheses indicate mechanism of injury depicted in Figs. 6 and 7.

Fig. 2. Coronally oriented vertical fracture of the posterior C-2 vertebral body caused by an extension and axial loading mechanism of injury. **Left:** Lateral cervical spine radiograph demonstrating the appearance of a “hangman’s fracture” with apparent bilateral pars interarticularis fractures. There is associated anterior displacement of C-2 on C-3. **Right:** Axial computerized tomography scan demonstrating a coronally oriented vertical fracture (arrow) of the posterior C-2 vertebral body on the right extending through the C-2 pars interarticularis on the left (double arrows). Orientation shown (inset).

Fig. 3. Lateral cervical spine radiograph (left) and axial computerized tomography scan (right) demonstrating a coronally oriented vertical fracture of the posterior C-2 vertebral body (arrows) and an anterior teardrop fracture (arrowhead) caused by hyperextension and axial loading. On the radiograph (left), anterior displacement of C-2 on C-3 can also be seen. Note the associated anterior soft-tissue swelling.

Fication of the traumatic spondylolisthesis of the axis. The fracture fault travels through the posterior C-2 vertebral body instead of the pars interarticularis of C-2 (which is typical for traumatic spondylolisthesis of the axis). It has been termed an atypical traumatic spondylolisthesis of the axis by Burke and Harris4 and Efendi, et al., and an unusual type of hangman’s fracture by Marotta, et al. However, it is neither atypical nor particularly unusual and is not a spondylolisthesis of the axis (hangman’s fracture). This fracture is characterized by a dorsally positioned vertical C-2 body fracture (Fig. 2).

Hyperextension With Axial Load. Cases 6 to 8 (Table 1) are examples of hyperextension with axial load. A force vector applied to the high forehead region results in the application of an axial load and capital hyperextension forces to the upper cervical spine. The C-2 vertebral body may fall in a similar location to that described above, but due to the direction and the magnitude of the force applied it results in disruption of the intervertebral disc and in hyperextension of the spine at the C2–3 level. This causes an opening of the anterior disc interspace and a teardrop avulsion fracture of the anterior caudal aspect of the C-2 vertebral body. The vertically oriented axial load causes significant compression of the C2–3 disc interspace, with a shearing mechanism applied to the ventral and dorsal aspects of the vertebral body because of the more rigid perimeter of the intervertebral disc (Fig. 3).

Comment. Three distinct common findings associated with these two injury mechanisms are: 1) an anterior teardrop component (most commonly associated with a significant axial load component); 2) posterior element fractures; and 3) fractures involving the foramina transversarium (Figs. 2 and 3). The first two reflect the hyperextension component of the mechanism of injury and the latter is a manifestation of the lateral extension of a C-2 body fracture. These mechanisms of injury can also result in an arch fracture of C-1 (Case 5, Table 1). The abutment of the posterior arch of C-1 onto the posterior elements of C-2 or the occiput may cause isolated disruption of the arch of C-1 in only two posterior locations (as opposed to a
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burst fracture of C-1, where four fracture faults are usually observed.

**Flexion-Axial Load.** In Cases 9 and 10 (Table 1), the mechanism of injury was flexion-axial load. The application of a dorsally applied force vector with an axial load component to the calvaria may result in opening the dorsal aspect of the C2–3 disc interspace (capital neck flexion), translating the ventral component of the C-2 complex forward on C-3 and tearing the anterior longitudinal ligament, thus causing an accompanying posterior C-2 body fracture. Since the C2–3 disc interspace is slanted ventrally and caudally, the orientation of this disc interspace is nearly in line with the applied force vector. This encourages the translational deformation of C-2 forward on C-3. The foramina transversarium are often transgressed by the fracture (Fig. 4).

**Flexion-Distraction.** Cases 11 and 12 (Table 1) demonstrated flexion-distraction. If a capital flexion injury is combined with a distraction component, usually caused by deceleration over a fulcrum (for example, the shoulder harness of a seat belt), a flexion-distraction force complex is applied. This results in a bending moment arising around the ventral caudal aspect of C-2, an opening of the disc interspace dorsally, maintenance or exaggeration of disc height, and preservation of anterior soft-tissue integrity unless excessive distraction results in anterior longitudinal ligament disruption. This fracture is virtually identical in appearance to one caused by the previously described mechanism of injury (Fig. 4).

**Sagittally Oriented Vertical C-2 Body Fracture (Type 2)**

The sagittally oriented C-2 body fracture is caused by axial loading to the point of failure. In Cases 13 to 15 (Table 1), the mechanism of injury was axial load. This fracture type is defined as a Type 2 C-2 body fracture.

Axial load applied to the vertex of the calvaria can cause several types of injury. If other spinal elements do not fail first (resulting in a Jefferson fracture or a subaxial cervical spine burst fracture), the load applied to the articular pillars of C-2 may result in a comminuted burst fracture of the C-2 body with a sagittally oriented vertical fracture fault line. Due to the sagittal nature of the fracture fault, this injury is best visualized via an anteroposterior view.

When an axial load is borne, the lateral masses of C-2 accept the load. Since no structural support exists immediately below the superior articulating process of C-2, a fracture fault through the vertebral body junction with the pedicle is created and the vertebral body bursts. The C-2 body fails along the lateral aspect of the vertebral body in the region of the pedicle’s junction with the vertebral body. Because the posterior wall of the C-2 vertebral body (in part) is thrust into the spinal canal by virtue of the predominant axial load applied, it is a burst fracture as defined by Denis (Fig. 5).

A lateral variant of the Type 2 C-2 body fracture can occur if there is a slight lateral orientation of the applied force vector (Case 15, Table 1). This fracture variant is oriented vertically through the lamina facets and foramina transversarium (Fig. 5d and e).

**Discussion**

In most cases of a C-2 body fracture, the mechanism of injury is either unknown or not clearly established. The 15 cases described here are unique in that the mechanism of injury was clearly established in every patient. Each case involved vertically oriented fractures of the C-2 vertebral body.

**Mechanisms of Injury**

The fracture fault lines of the dens fracture (Type II odontoid process fracture of Anderson and D’Alonzo) and traumatic spondylolisthesis of the axis
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Fig. 5. a, b, and c: Sagittally oriented vertical C-2 pedicle burst fracture. a: Sagittal computerized tomography (CT) reconstruction demonstrating the sagittally oriented vertical fracture of the C-2 vertebral body (arrows). Note the lack of a tear drop component, the violation of the spinal canal by retrophused bone fragments (burst fracture), and the maintenance of the C2–3 disc interspace height. b: Axial CT scan demonstrating the sagittal orientation of the vertical C-2 body fracture and the retrophusion of the bone into the spinal canal. c: Coronal CT reconstruction demonstrating the right lateral mass of C-1 compressed into the body of C-2 (arrows). d and e: Sagittally oriented lateral vertical C-2 body fracture (Type 2, lateral variant). d: Coronal CT reconstruction demonstrating a more lateral Type 2 fracture (arrow) resulting from axial load transmitted through the left lateral mass of C-1. e: Axial CT scan showing lateral and posterior extensions of the fracture line into the left lamina (arrows).

border the C-2 vertebral body proper (Fig. 1). Biomechanical and clinical studies suggest that the horizontal rostral C-2 body fracture (Type III odontoid process fracture of Anderson and D’Alonzo) is most commonly caused by a flexion injury and the dens fracture is caused by a laterally applied and medially directed force vector.4,12 Traumatic spondylolisthesis of the axis, on the other hand, is caused by a hyperextension injury, usually the result of a blow to the forehead or face.5,13 Other mechanisms of injury such as judicial hanging,2,10,11 transverse ligament of the atlas rupture,7,12 and atlantoaxial dislocation10 have also been described. Variants of C-2 body fractures have even been described.4 Specific information, however, regarding fractures situated in the C-2 vertebral body is less abundant.4,11

This and previous reports indicate that most upper cervical spine injuries are the result of blows to the head.1,5,6,8,10,11 Exceptions exist, however, as illustrated by Cases 11 and 12 (Table 1). In these cases deceleration of the torso, combined with a restriction of movement of the chest, created a flexion-distraction force that resulted in a bending moment at the ventral caudal aspect of the C-2 vertebral body.

The kinetic energy imparted to the upper cervical spine is, in most cases, directed via the dens. The direction (orientation) of the force vector predominantly dictates the location of the fracture fault line as shown in Fig. 2. The location of the fault line, however, is also dictated by the intrinsic strengths and weaknesses of C-2 and the surrounding bone and soft-tissue elements.

An exception to the forces applied through the dens is the true axial load injury where the superior articulating process (lateral mass) of C-2 accepts the entire load. In this case, due to the fact that the underside of the lateral mass is not supported, a fault line characteristic of a Type 2 C-2 body fracture is created. No direct force is applied to the dens in this case.

A variety of injury mechanisms are involved with upper cervical spine injuries, as defined by existing laboratory and clinical data. Figure 6 illustrates the complexity of the relationship between the mechanism of injury and the injury type. It also depicts the relationship of the mechanisms of injuries of vertical C-2 body fractures with other upper cervical spine injuries. The location of the fault lines of upper cervical bone injuries is depicted in Fig. 7. An understanding of the relationship between mechanism of injury and the bone fault is facilitated by correlating Figs. 6 and 7.

Anatomy of the Cervical Spine

A clear knowledge of the anatomy assists in the understanding of the mechanism of injury. The C-2 pedicle is located more ventrally and medially than the pedicle at lower spinal levels. Essentially, it forms a posterolateral extension of the vertebral body, connecting it with its superior articulating process (lateral mass). The pars interarticularis of C-2 (not to be confused with the C-2 pedicle) has a more horizontal orientation than at more caudal spinal levels. This affects the manner in which an axial load is transmitted through the spine and the type of injury sustained when the load limit is exceeded.
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![Diagram of C-2 vertebral body fractures](image)

**Fig. 6.** Schematic diagrams of the most probable mechanisms involved with upper cervical spine injuries, sagittal plane (left) and coronal plane (right). The moment arm (m) applied by the force vector (arrows) is depicted for each mechanism of injury (A through J). A: Judicial hangman’s fracture; B: traumatic spondylolisthesis of the axis (hangman’s fracture); C: coronally oriented vertical fracture of the posterior C-2 vertebral body (Type 1 C-2 body fracture) with C2-3 hyperextension-subluxation and an anterior teardrop; D: coronally oriented vertical fracture of the posterior C-2 vertebral body (Type 1 C-2 body fracture) with C2-3 hyperextension-subluxation and its lateral variant, or a C-1 burst fracture (Jefferson fracture); E: sagittally oriented vertical C-2 pedicle burst fracture (Type 2 C-2 body fracture), its lateral variant, or a C-1 burst fracture (Jefferson fracture); F: coronally oriented vertical fracture of the posterior C-2 vertebral body (Type 1 C-2 body fracture) with C2-3 flexion-subluxation and an anterior teardrop; G: Type 3 C-2 body fracture (formerly the Type III odontoid process fracture of Anderson and D’Alonzo) or rupture of transverse ligament of the atlas; H: coronally oriented vertical fracture of the posterior C-2 vertebral body (Type 1 C-2 body fracture) with C2-3 flexion-distraction; I: dens fracture (formerly Anderson and D’Alonzo Type II odontoid process fracture); and J: atlanto-occipital dislocation.

**Horizontal Rostral C-2 Body Fracture (Type 3)**

One additional type of C-2 body fracture exists. The previously defined Type III odontoid process fracture of Anderson and D’Alonzo is not an odontoid process fracture but a horizontal rostral C-2 body fracture. Its mechanism of injury has previously been described as resulting from a dorsal blow to the head.

**Body Fracture Types of the Cervical Spine**

The information provided here allows the definition of three types of C-2 body fracture; two vertical and one horizontal in orientation (Table 2). Vertical fractures are either coronally oriented (Type 1) or sagittally oriented (Type 2) fractures. The horizontal fracture (Type 3) is rostrally located in the C-2 body and is the same injury as the previously described Type III odontoid process fracture of Anderson and D’Alonzo.

**Conclusions**

This description of types of C-2 body fracture illustrates that through clinical and imaging correlations, the relationships between mechanisms of injury and injury anatomy can be established. Anatomical classification of these fractures helps to unify concepts of injury mechanisms and biomechanical principles. This correlation may assist in the clinical management of patients and facilitate future laboratory and clinical research in this area.

It is emphasized that C-2 body fracture types can rarely be differentiated on the basis of a single imaging
modality. A combination of plain x-ray studies, CT, and MR imaging in association with a clinical correlation is often necessary to accurately establish the specific fracture type. The choice of management schemes may depend on fracture type and mechanism of injury. A clear understanding of injuries to this region of the spine allows for the most appropriate management algorithms.

It is recommended that the previously described odontoid process fracture scheme of Anderson and D’Alonzo be abandoned. Their Type I fracture should be simply considered a dens avulsion fracture; their Type III odontoid process fracture is not an odontoid process fracture and is included in the C-2 body fracture scheme introduced here. Finally, their Type II fracture is more appropriately described via its anatomical location, that is, a dens fracture.

References


Manuscript received August 20, 1993.
Accepted in final form November 3, 1993.
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