Fractures of the craniovertebral junction associated with other fractures of the spine: overlooked entity?

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AJNR Am J Neuroradiol 1984, 5 (6) 775-781
http://www.ajnr.org/content/5/6/775

Fractures of the Craniovertebral Junction Associated with Other Fractures of the Spine:

Overlooked Entity?

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In a review of 155 craniovertebral fractures (occiput–C1–C2), 40 of these had associated fractures and/or dislocations or subluxations elsewhere in the spine. This rather common occurrence, one of four, has not been emphasized in the recent literature, indicating that the radiologic examination should not stop after the craniovertebral fracture is identified. Furthermore, in 13 patients, neurologic deficits were encountered that in all instances were from associated lower-level fracture. From this experience it was believed that a minimum of anteroposterior and lateral views of the entire spine should be obtained in patients in whom a craniovertebral fracture is found, especially if neurologic deficits are present. The other sites of injury were in the lower cervical spine in 17 patients, in the thoracic spine in five, in the lumbar spine in two, and in the sacrococcygeal spine in two patients. Eight patients had three or more levels of fracture.

Craniovertebral fractures are a unique category of spinal fractures involving the occipital bone, atlas, and axis. In 1939 Plaut [1] reported the largest series of atlas fractures, 99 cases, of which 59 involved both the atlas and the other sites in the cervical spine. Thirty-three of these 59 were confined just to the C1 and C2 levels, and the other cases involved the atlas and the rest of the lower cervical spine. Since that time there have been other reports about craniovertebral fractures occurring in combination with other fractures of the spine [2–8], but none have stressed how often this combination occurs. Having observed a number of craniovertebral fractures associated with other fractures of the spine, we decided to review our experiences with craniovertebral fractures to determine the incidence of combined fractures.

Materials and Methods

We reviewed 458 cervical spine fracture patients admitted to the Northwestern University Medical Center from 1975 to 1981. One hundred one fractures involved the craniovertebral junction (occiput–C1–C2). Of these, 26 were found to have multiple levels of fractures. We also reviewed all 189 cervical spine fracture patients admitted to the University of Kentucky Medical Center from 1977 to 1982. Of these, there were 54 craniovertebral fractures, and 14 fractures had multiple levels of injury. The incidence of combination craniovertebral fractures was compared between the two institutions. Plain radiographs, tomograms, and computed tomographic (CT) scans were reviewed, and the patterns of fractures as well as the neurologic findings of each patient were recorded. The craniovertebral fracture was considered to be the primary injury in the classification of the data.

Results

A total of 40 craniovertebral fractures were associated with other fractures of the spine in both institutions combined. The various types of craniovertebral fractures encountered at the C1 level included 15 posterior arch fractures, two anterior arch fractures, and three avulsion fractures of the medial aspect of the

Received December 21, 1983; accepted after revision April 9, 1984.

Presented at the annual meeting of the American Roentgen Ray Society, Atlanta, April 1983.

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AJNR 5:775–781, November/December 1984
0195-6108/84/0506-0775

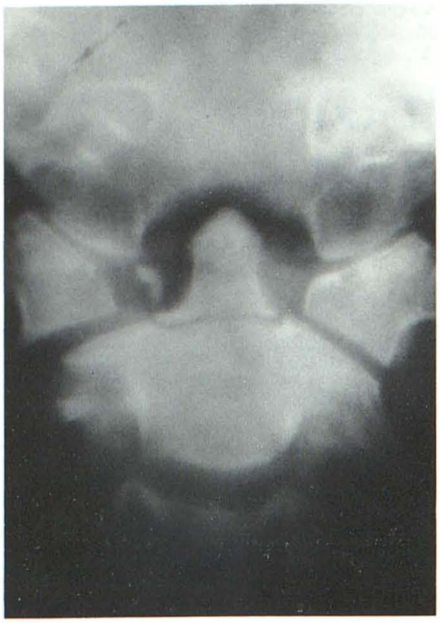

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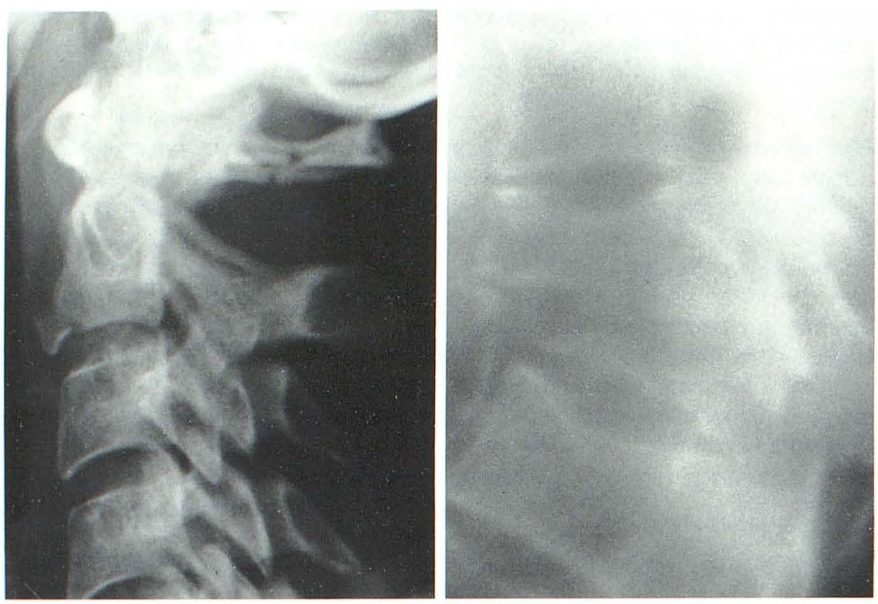
Fig. 1.—Fracture at base of dens with fracture of medial aspect of right C1 lateral mass produced by avulsion of transverse ligament. Posterior arch fracture (not shown) allows lateral displacement of right C1 lateral mass.

Fig. 2.—Bilateral posterior arch of C1 fracture plus C2 hangman fracture extending into and involving posterior inferior corner of C2 body.



A B

Fig. 3.—**A**, Bilateral posterior arch of C1 fracture with C2 anterior inferior corner fracture. **B**, Associated compression fractures of T4 and T5 and posterior element disruption.

Fig. 4.—Bilateral posterior arch of C1 fracture with C2 dens fracture. Posterior offset of dens suggests extension mechanism.

lateral mass. We distinguish fractures of the medial aspect of the C1 lateral mass from other fractures of the C1 lateral mass. In the former, the injury is the result of avulsion of the transverse ligament from the medial tubercle of the C1 lateral mass (fig. 1). This is a potentially unstable injury, since subluxation can occur between the dens and the atlas. The other lateral mass fractures involved either the facet or the lateral-most aspect of the C1 lateral mass. At the C2 level, there were 15 hangman fractures, seven anterior inferior corner fractures, and 13 dens fractures. One case of a fracture of the medial aspect of the occipital condyle was found. There were three or more levels of fracture or dislocation in 13 cases.

The largest group of fractures had a C1 fracture plus

TABLE 1: **Other Spine Injuries Associated with 19 C1 Fractures**

Associated Fracture: Type	Total No.	No. of Associated Neurologic Deficits
C2:		
Dens	9	0
Hangman	4	0
Anterior inferior chip	2	0
Lateral mass	4	0
Subtotal	19	0
Others:		
C3–C7	7	3
Thoracic	4	1
Lumbar	0	...
Subtotal	11	4
Subluxation/dislocation:		
C3–C7	5	3
Thoracic	1	1
Lumbar	0	...
Subtotal	6	4
None	16	...

Note.—C1 fractures were of the posterior arch (14 fractures), anterior arch (two), avulsion of medial aspect of lateral mass (three), and lateral mass (two) ($n = 19$).

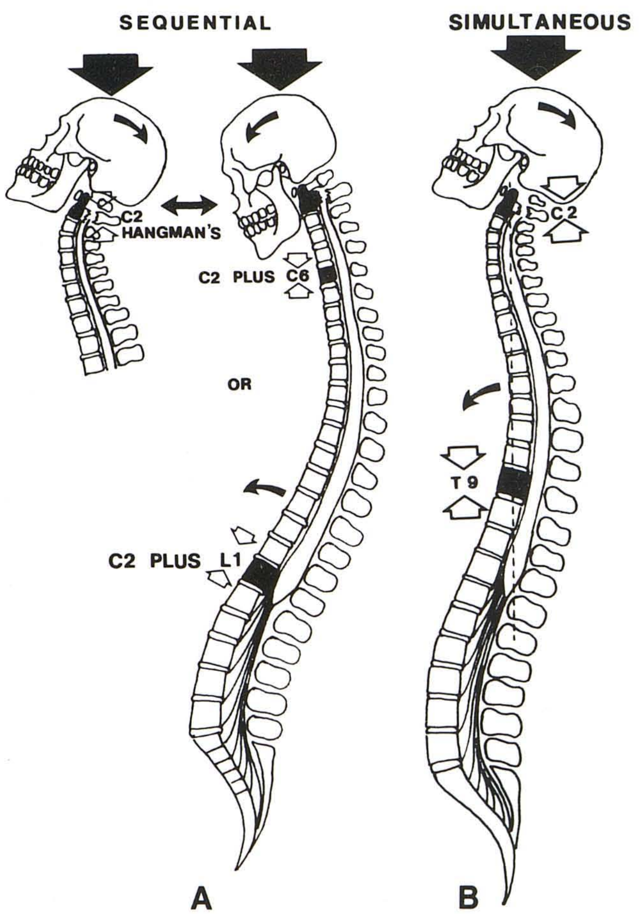


Fig. 5.—**A**, Sequential fracture mechanism. Either extension and flexion occurs first followed by flexion or extension. Either two fractures of cervical spine (C2 plus C6) or fracture of cervical spine and rest of spine (C2 plus L1) may occur. **B**, Simultaneous fracture mechanism. With neck extended and normal kyphosis of thoracic spine, single, axial, compressive force will produce fractures at C2 and T9.

TABLE 2: **Other Spine Injuries (Except C1 Fractures) Associated with 11 Hangman Fractures**

Associated Fracture: Type	Total No.	No. of Associated Neurologic Deficits
C2:		
Anterior inferior chip	2	0
Lateral mass	1	0
Subtotal	3	0
Other levels:		
Cervical (C3–C7)	9	2
Thoracic	0	...
Lumbar	0	...
Coccyx	1	0
Subtotal	10	2
Subluxations:		
Cervical (C3–C7)	5	3
Thoracic	0	...
Lumbar	0	...
Subtotal	5	3

another fracture elsewhere in the spine (fig. 2). Fourteen of the total 19 involved just the C1 and C2 levels. None of these patients had neurologic deficits. Each of the other five C1 fractures had two or more levels of other fractures involving the cervical region (C3–C7), plus the thoracic region in two (fig. 3). All these patients had severe neurologic deficits at a level corresponding to the level of the lower spinal injury (tables 1–4). In the entire group there were five subluxations or dislocations, with four occurring in the five cases of C1 fracture plus two or more levels of injury, which probably contributed to the spinal cord injury.

In eight there was a combination of C1 posterior arch fracture plus a C2 dens fracture (fig. 4). A hyperextension mechanism produced the C1 posterior arch fracture and the C2 dens fracture in six of the cases. However, the dens was displaced anteriorly in the other three, indicating a flexion mechanism. This would imply a combination flexion-extension mechanism, which has been described as being uncommon [2]. There were also three other cases of C1 fractures for which the lower injury was from a flexion injury manifested as either an anterior wedge deformity of the body or a teardrop fracture. In the other cases with a C2 fracture, 12 had a lower fracture produced by a flexion mechanism.

The mechanism of flexion and extension can be likened to a severe form of whiplash with sequential extension and then flexion of the spine (or vice versa) (fig. 5A). Alternatively the injury may be a single force with simultaneous extension of the head and flexion of the lower spine (fig. 5B). This mechanism may explain why the upper cervical injury tended to be the extension type, and the lower injury tended to be the flexion type.

The next largest group encountered was the hangman fracture (bilateral posterior arch fracture at pedicle or lamina) with 11 cases. The most common other associated injury was a C2–C3 subluxation/dislocation (fig. 6) in five cases, of which one had a C3–C4 subluxation also. Other associated injuries included lower cervical teardrop fractures in two,

Fig. 6.—Hangman fracture with C2 anterior inferior corner fracture and bilateral C2/C3 facet lock.

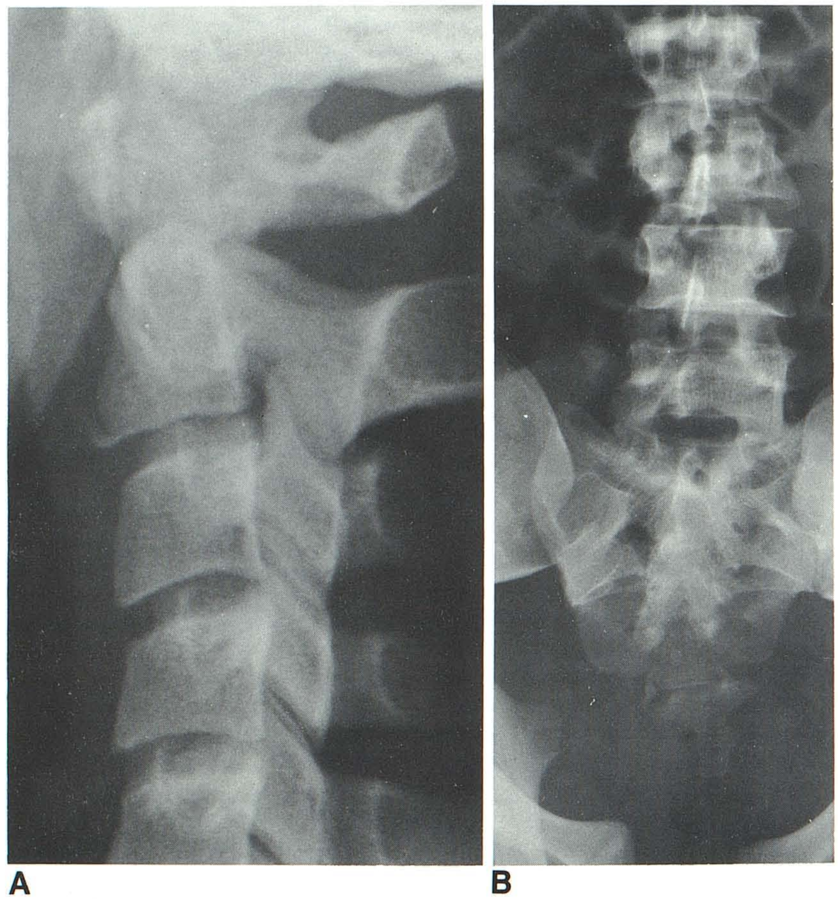


Fig. 7.—**A**, C2 anterior inferior chip fracture. **B**, L3 burst fracture, coccyx fracture, and pelvic ring fracture.

TABLE 3: **Other Spine Injuries (Except C1 Fractures and C2 Hangman Fracture) Associated with Four C2 Anterior Inferior Chip Fractures**

Associated Fracture: Type	Total No.	No. of Associated Neurologic Deficits
Other fractures:		
Cervical	1	0
Thoracic	2	1
Lumbar	1	1
Subtotal	4	2
Subluxation/dislocation:		
Cervical (C3–C7)	1	1
Thoracic	0	...
Lumbar	1	1
Subtotal	2	2

TABLE 4: **Other Spine Injuries (Except C1 or C2) Associated with Five C2 Dens Fractures**

Associated Fracture: Type	Total No.	No. of Associated Neurologic Deficits
Other fractures:		
Cervical (C3–C7)	2	1
Thoracic	1	0
Lumbar	1	0
Coccyx	1	0
Subtotal	5	1
Subluxation/dislocation:		
Cervical (C1–C2)	1	0
Cervical (C3–C7)	2	2
Thoracic	0	...
Lumbar	0	...
Subtotal	3	2

anterior inferior corner avulsion fracture of the body of C2 in two, an anterior superior corner chip fracture of the C3 body in three (fig. 6), facet fractures in two, and an associated coccyx fracture in one. Significant neurologic deficits were present in three cases, with the lower-level injury being responsible for the clinical symptoms.

There were four C2 anterior inferior corner chip or avulsion fractures, of which three had associated thoracolumbar fractures (fig. 7). The other case had a lower cervical unilateral facet lock. One had minimal neurologic deficits, and two had severe cord injury. Again, the lower-level fracture was responsible for the neurologic deficit.

Five dens fractures were associated with other spinal fractures except C1. Four were of the extension type, and one was of the flexion type (fig. 8). The other injuries were facet locks in the lower cervical spine in three (of which one also had a thoracic burst fracture plus a coccyx fracture), a lower cervical lamina fracture, and a lumbar burst fracture. Only two had neurologic deficits, the result of the lower-level spinal

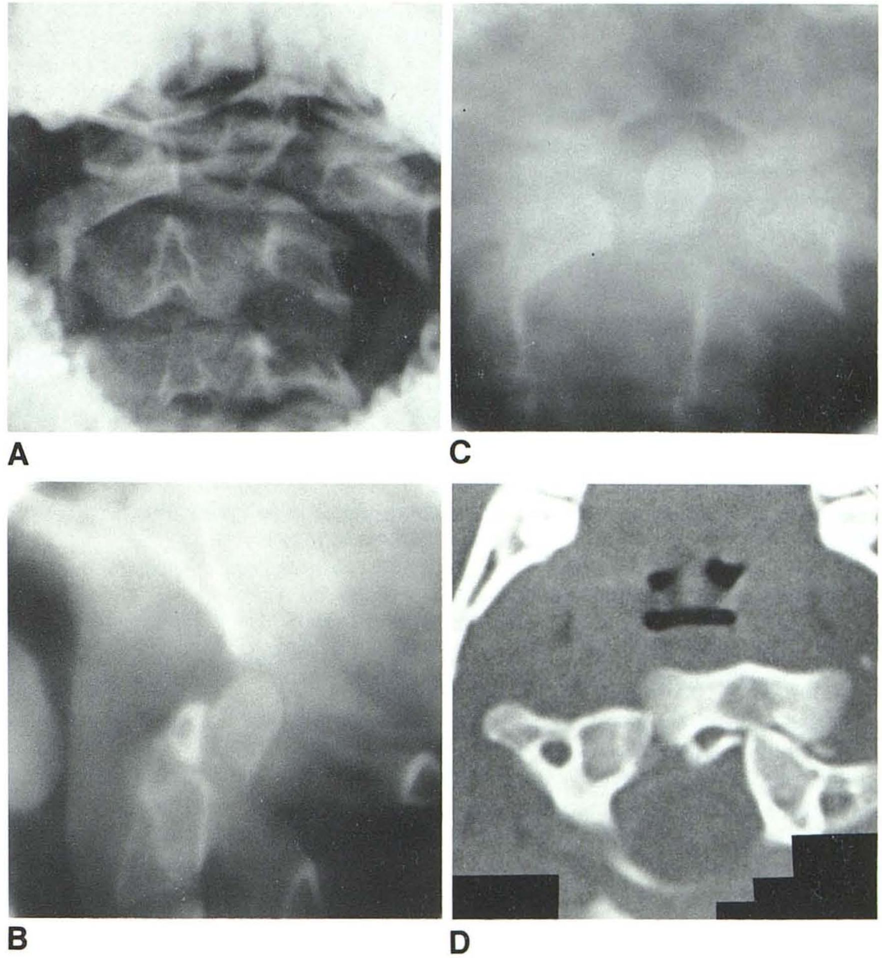


Fig. 8.—**A**, Fracture of dens, tilted to left, and lateral displacement of C1 to left with respect to C2. **B**, Lateral tomogram. Posterior displacement of C1 such that it impinges on base of C2 dens, also displaced posteriorly. **C**, Anteroposterior tomogram shows cause of displacement to be from locking right C1 lateral mass with C2 lateral mass, better seen on CT (**D**).

injury. The coccyx fracture was probably from direct trauma to the lower back rather than being a part of the cervical and thoracic fractures.

Both institutions had a similar incidence of 26% of all craniovertebral fractures having another associated spinal injury. All but one of the patients with neurologic injuries were from the Northwestern group, reflecting the fact that it is an acute spinal cord trauma center for which one of the admitting criteria is cord injury.

Discussion

Craniovertebral fractures represent 8% [2] to 27% [3] of all cervical spine fractures. Although associated neurologic deficits are seldom described [3–13], Plaut [1] found severe cord injuries and death in his review of atlas fractures. Several autopsy series on victims of motor vehicle accidents discuss the fatality of craniovertebral fractures and difficulty in making a radiographic diagnosis. Twenty-four cervical spine fractures or dislocations in 100 fatal traffic accidents were reported by Bucholz et al. [14]. Twelve of these were missed radiographically, and eight of these missed fractures were atlantooccipital dislocations. In addition, ligamentous tears were found quite often, which would be missed radiographically [14, 15]. The craniovertebral junction was the most common site of injury as well in those traffic death victims with cervical spine injuries [15, 16]. From this information it appears that craniovertebral fractures are either fatal or else the patients survive with few or no neurologic injuries.

Craniovertebral fractures occur with other fractures of the spine [1], with reports of 1%–5% per series [3–9]. Miller et al. [2] reported that 24% of all craniovertebral fractures (33 total) had associated fractures of the spine elsewhere. This agrees with the incidences we found at Northwestern and Kentucky. Very few neurologic injuries have been found with these combination craniovertebral fractures [2–8].

However, in our series almost one-third (13 of 40) had neurologic deficits. These deficits were produced by the lower-level spinal fracture rather than by the craniovertebral fracture. In three patients there were no deficits initially. Under these circumstances the lower fracture will be overlooked. In fact, in one patient with an unsuspected thoracic fracture, excessive manipulation moving the patient onto the radiographic table resulted in paraplegia.

The most common combination of craniovertebral fractures that we encountered was a C1 and a C2 fracture, which Plaut [1] also found. This association is not surprising since the atlas and axis act together as a functional unit; injury to one may also injure the other. Specifically, a C1 posterior arch fracture plus a C2 dens fracture was the most common combination in our series (22.5%) as well as in that of Plaut (23.8%). The concept of a flexion and extension fracture mechanism has also been suggested by Davis et al. [15],

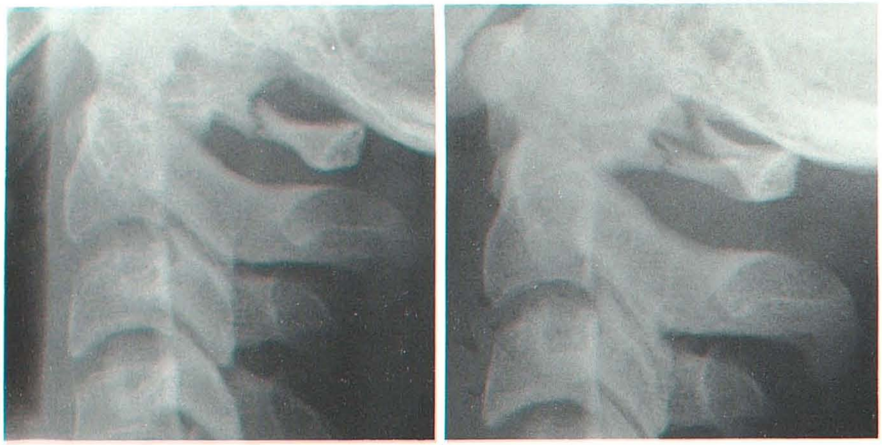


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Fig. 9.—Off-lateral views show posterior arch of C1 fracture (A) to be bilateral (B). Off-lateral view separates two laminae.

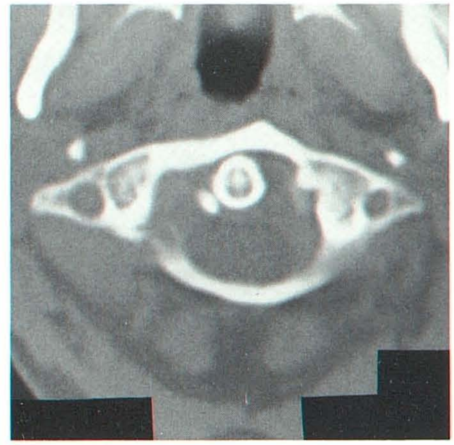

Fig. 10.—CT scan of avulsed medial aspect of C1 lateral mass (tubercle to which transverse ligament attaches). Right C1 laminar fracture and offset of C1 to left with respect to dens.

who found combination anterior and posterior ligamentous disruption to be common in their autopsy series.

Another C1 and C2 combination that we encountered was a C1 posterior arch fracture plus a hangman fracture. This combination was the most common one reported in the recent literature [2–8], but was uncommon in the review of Plaut, occurring in three (5%) of 60 cases. Of the two anterior arch C1 fractures, one was associated with a hangman fracture and the other with a C5–C6 subluxation. These patterns were not encountered by Stewart et al. [8] in their review of nine cases. They did show that these anterior arch C1 fractures occurred with other spinal injuries, with the most commonly encountered fracture elsewhere being a dens fracture in four cases.

The avulsion fracture of the medial aspect of the C1 lateral mass is a unique injury and may be overlooked. Its presence indicates disruption of the transverse ligament and thus C1–C2 instability. Barker et al. [12] described these as isolated fractures. However, we encountered three cases associated with another fracture at the C2 level (two were dens fractures and the other a C2 anterior inferior corner chip).

Hangman fractures were prominent, with the more commonly associated spinal injuries being either subluxation or facet lock in five or chip fracture from the anterior inferior corner of the C2 body in two. Martinez et al. [17] described hangman fractures with unilateral or bilateral facet lock. Both Martinez et al. [17]and Elliott et al. [5] described the association of hangman fracture with the C2 body chip fracture. The chip fracture is not always present, and probably results from ligamentous avulsion.

A total of 11 C2 anterior inferior corner chip fractures were encountered at both institutions. Five of these from Northwestern were isolated fractures and were excluded from this series. Six C2 chip fractures had fractures at another level or a hangman fracture; and in most (four of six) neurologic deficits were present corresponding to the level of the other fracture. Therefore, the C2 anterior inferior chip fracture should not be regarded as an isolated injury, especially if neurologic deficits are present.

Technically poor films were responsible for misdiagnosis initially. The lower fracture was also overlooked once the craniovertebral fracture had been identified, and no further studies were performed. Correlation of the bony injury with clinical level of injury will ensure that the other fracture will not be overlooked. An off-lateral radiograph will demonstrate the posterior arches better, since the laminae no longer overlie each other. Unilateral fractures can be differentiated from bilateral fractures (fig. 9). The axial orientation of CT is ideal for evaluating the posterior arches of C1 and C2 [18].

The horizontal anterior arch fracture of C1 is best demonstrated on plain radiographs or tomograms. A horizontal split of the anterior arch of C1 separating it into two halves and extending the entire length of the anterior arch of C1 is seen on tomography. Differentiation of this fracture from an accessory ossicle is simple. The ossicle appears ovoid on the anteroposterior tomograms, and it has smooth corticated margins in contrast to the fracture. Because of the axial orientation of the CT, this fracture may be missed.

The fracture of the medial aspect of the C1 lateral mass is best seen in an anteroposterior open-mouth view. However, this may be difficult to obtain, in which case CT or tomography should be used. Care should be taken in the positioning of the patient for tomograms, since a slight degree of rotation can mimic this fracture. If there is any question, CT should be used (fig. 10).

In summary, if a craniovertebral fracture is seen, a minimal radiographic examination should include an anteroposterior and lateral of the entire spine, not just the cervical spine alone. Even if multiple-level cervical fractures are seen, the rest of the spine should be radiographed. Multiple-level cervical fractures were associated with other fractures of the rest of the spine in six of our 11 cases. Most other spinal fractures occur in the lower cervical spine. CT or tomography must visualize at least the entire cervical spine. If a questionable fracture is seen on the routine radiographs or neurologic injury is present, CT or tomography should be used with attention to the level of neurologic injury. The occurrence of craniovertebral fractures with other fractures of the spine is quite common, with an incidence of one in four in one reported series [2] and in our two combined series. Neurologic injury is not common with the craniovertebral fracture itself. It is the other associated fracture that produces symptoms.

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