Unstable Jefferson variant atlas fractures: an unrecognized cervical injury.

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AJNR Am J Neuroradiol 1991, 12 (6) 1105-1110
http://www.ajnr.org/content/12/6/1105

Unstable Jefferson Variant Atlas Fractures: An Unrecognized Cervical Injury

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We retrospectively reviewed the plain films and CT scans of 11 unstable atlas fractures from a series of 72 atlas fractures to better characterize these injuries and to determine if the correct diagnosis could have been made. These 11 atlas fractures were unstable because either the anterior bony ring was disrupted (six cases), the posterior longitudinal ligament was torn (one case), or both the anterior bony ring and the posterior longitudinal ligament were disrupted (four cases), allowing C1–C2 subluxation to occur. Although all the fractures were potentially unstable, only eight demonstrated subluxation on the lateral radiograph. Despite the abnormal open mouth view in all cases, the plain films showed minimal abnormalities, requiring CT for definitive diagnosis. Less than half (five of 11) of the patients had other levels of spine injury or associated transverse ligament tear. Three of the 11 patients were quadriplegic, and two died as a result of their spinal cord injury.

These unstable atlas fractures were similar to the classical Jefferson fracture in appearance and mechanism, except that they had fewer than four breaks in the atlas ring and were associated with severe neurologic injury and lower level spine injuries. The pattern of bilateral anterior arch fractures was associated more often with neurologic injury. Because of these differences, we chose to refer to them as Jefferson variant fractures to distinguish them from the classical Jefferson fracture and to emphasize the seriousness of this injury.

AJNR **12:1105–1110, November/December 1991;** ***AJR*** **158: January 1992**

In 1920 Jefferson [1] proposed a mechanism by which atlas fractures occur. He did not personally report the fracture that was later named for him, but rather described potential fracture sites with four breaks in the atlas ring. In his review of 46 previously reported atlas fractures he found eight cases with four breaks in the atlas ring, one case with three breaks, 13 with two breaks (of which eight were bilateral anterior and five were bilateral posterior arch fractures), and 22 cases with one break of the posterior arch.

We have encountered one classical Jefferson atlas fracture and 71 cases with less than four breaks of the atlas ring, of which 11 were found to be unstable. Because three of these 11 had quadriplegia and the other eight had a potential for subluxation and neurologic injury, we chose to refer to this type of injury as the unstable Jefferson variant fracture.

By describing and defining the unstable Jefferson variant fracture as a distinct clinical and radiologic entity, we hoped to emphasize its significance as well as to contrast it against the classic Jefferson fracture, which has not been reported to be associated with permanent neurologic injury [1–4]. It is the purpose of this article to describe the unstable Jefferson variant fracture of the atlas, its radiologic findings, and its clinical significance.

Materials and Methods

Seventy-two atlas fractures from a series of 479 cervical fractures or dislocations were reviewed retrospectively between 1982 and 1990. All were studied by plain radiographs and

Received February 27, 1991; revision requested April 16, 1991; revision received June 14, 1991; accepted June 17, 1991.

Presented in part at the annual meeting of the American Roentgen Ray Society, Boston, May 1991.

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0195-6108/91/1206-1105

CT scans, and 14 were additionally studied by polytomography. One case was the classic Jefferson fracture, 11 were the unstable Jefferson variant fracture, and 60 were either isolated unilateral (31) or bilateral (29) posterior arch fractures. Because the 60 patients with isolated posterior arch fractures were neurologically intact and stable, they were excluded from this review.

Instability of the spine was determined on the basis of the patterns of fracture from the CT scans and not from the radiographs. In fact, instability was not suspected on the initial examination, and the true significance of these Jefferson variant fractures was not recognized until CT studies had been obtained.

Anterior subluxation was defined by a greater than 3-mm widening of the predental space, indicating tear (or laxity) of the transverse ligament. Posterior subluxation was defined by a posterior displacement of the C1 spinolamina line with respect to the spinolamina line of C2, occurring with the anterior ½ Jefferson variant fractures (bilateral anterior arch fractures). Lateral subluxation was defined by a unilateral offset of the C1 lateral mass with respect to the C2 lateral mass without a corresponding inward displacement of the opposite C1 lateral mass, occurring with the hemi-ring pattern of Jefferson variant fractures.

Disruption of the spinolamina line was evaluated on the lateral radiograph. The spinolamina line has been described as a smooth, curving line joining the bases of the posterior spinous process (junction of the spinous process with the lamina) and extending to the posterior lip of the foramen magnum or opisthion [5–8].

Since the atlas ring lateral masses should line up with the lateral mass of the axis, any outward displacement should indicate widening of the atlas ring. Lateral offset of one or both lateral masses exceeding 6.9 mm on the anteroposterior radiograph should indicate transverse ligament tear [3, 9].

The degree of displacement of the atlas lateral mass with respect to the axis lateral mass, and the atlas lateral mass to the dens spaces bilaterally was measured from the anteroposterior radiograph. The clinical charts were reviewed to correlate the atlas injuries with the neurologic injuries. Autopsy was performed on one patient.

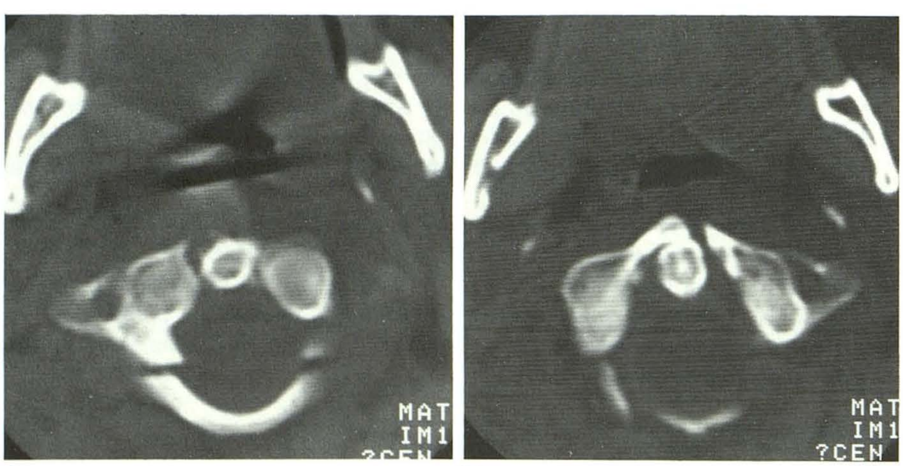
Results

Among the 11 cases of unstable Jefferson variant fractures, the following patterns occurred. One patient had three breaks of the C1 ring (Fig. 1), consisting of bilateral posterior arch fractures plus a third anterior arch fracture. Eight patients had two breaks, consisting of three subpatterns: (1) four cases of bilateral anterior arch fractures (Fig. 2) of which one had an associated transverse ligament tear; (2) three cases of an ipsilateral hemi-ring pattern (Fig. 3) with a break in the anterior and posterior ring on the same side, of which all three had associated transverse ligament tear; and (3) one case of a contralateral hemi-ring pattern. One patient had a single break, consisting of a posterior arch fracture plus a transverse ligament tear. And one patient had a traumatic separation of the anterior arch synchondrosis plus a posterior spina bifida (Fig. 4). We also referred to these patterns of ring breaks as ¾ Jefferson, anterior ½ Jefferson, and hemi-ring Jefferson (ipsilateral and contralateral) variant fractures (Table 1).

In seven patients, the offset of the C1 lateral masses with respect to the C2 lateral masses was unilateral, varying from 1 to 7.5 mm on the open mouth view. In the other four patients, the offset was bilateral, varying from 3 to 8 mm (Table 2). Asymmetry of the spaces between the C1 and dens on the open mouth view was present in 10 patients, varying from 1 to 14 mm (Figs. 2 and 4). Bilateral offset of the C1 lateral masses with respect to the C2 lateral masses was present in the 11th case. The greatest degree of offset occurred with transverse ligament tears. In addition, the greatest degree of asymmetric widening of the spaces between the dens and the medial margin of the C1 lateral mass occurred with transverse ligament tears (Table 2). This would be expected, since a tear of the ligament would allow ring widening to occur.

The lateral radiographs in eight patients demonstrated anterior displacement of the spinolaminal line at C1 (Fig. 2) in five patients with transverse ligament tears, and posterior displacement in three patients, of whom two had bilateral anterior arch fractures and one had an extension type II dens fracture, which may have contributed to the C1–C2 subluxation.

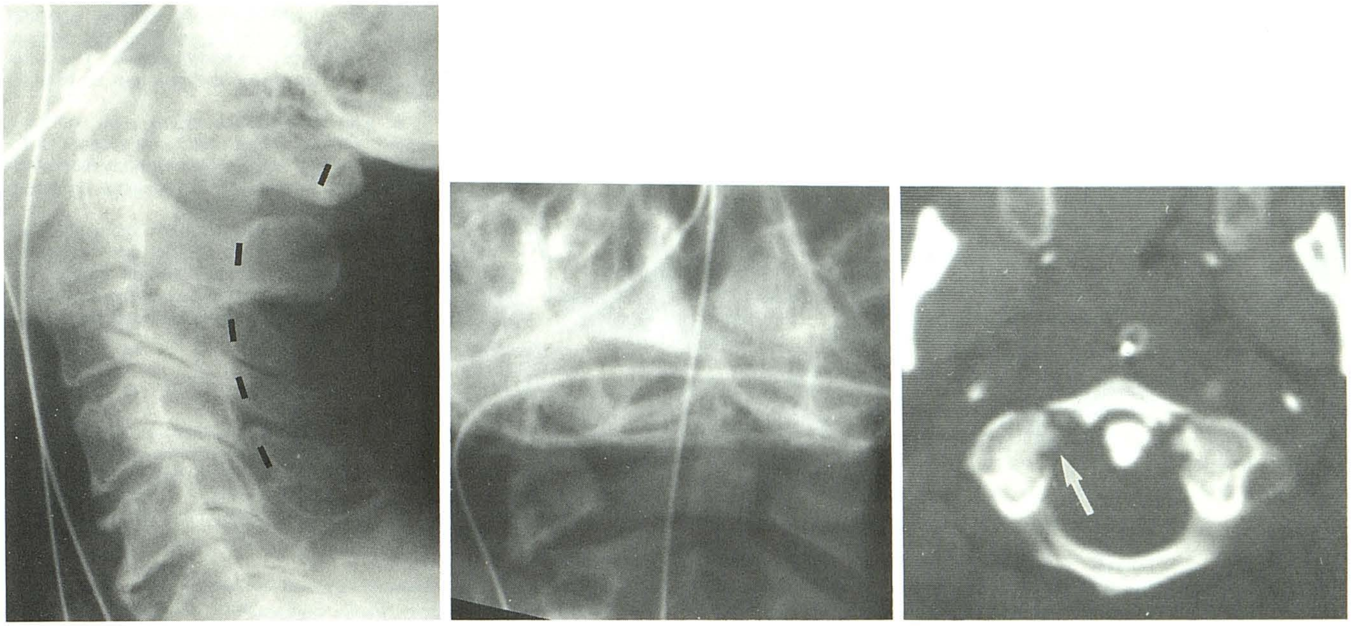
Of the unstable Jefferson variant fractures, three (27%) of the 11 patients were quadriplegic. In one of these patients, autopsy showed the spinal cord to be subtotally transected, and there was hypermobility at the C1–C2 level because of the anterior ½ Jefferson variant fracture. We also found extensive soft-tissue and ligamentous disruption and, most notably, tear of the transverse ligament. Another quadriplegic



A B

Fig. 1.—Case 1: 58-year-old woman who had been in a motor vehicle accident was neurologically intact but had severe neck pain.

A and *B*, CT scans show example of ¾ Jefferson variant fracture, with bilateral posterior arch fracture (*A*) and unilateral anterior arch fracture (*B*).



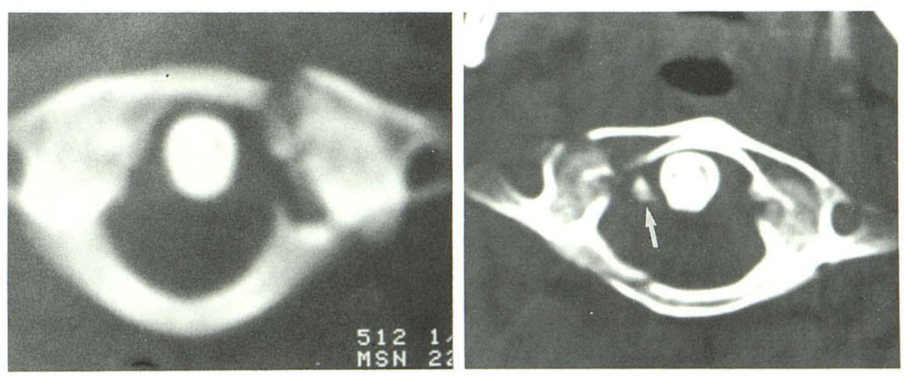
A B C

Fig. 2.—Case 2: 84-year-old man who had been in a motor vehicle accident was found to be unresponsive without respirations and his head twisted to one side at the scene of the accident. Autopsy demonstrated near transection of spinal cord.

***A*, Lateral radiograph shows example of anterior ½ Jefferson variant fracture, with marked posterior displacement of the cranium and posterior arch of C1 with respect to C2. C1 ring is markedly widened, and anterior arch of C1 remains in normal relation to the C2 dens. C1 spinolaminal line is displaced posteriorly (*dashes*).**

***B*, Open mouth view of dens shows marked asymmetry between dens and lateral masses of C1. There is marked overhang of right side of C1 with respect to lateral mass of C2.**

***C*, CT scan shows bilateral anterior arch fractures and marked asymmetry between dens and lateral masses of C1. There is also a tear of the transverse ligament. Note that C1 tubercle on right (*arrow*) has lost its sharp cortical margin as compared with the left. The avulsed fragment is seen better on a lower CT section (*not included*).**



A B

Fig. 3.—Two examples of the hemi-ring fracture pattern.

***A*, Case 6: 25-year-old man who had been in a motor vehicle accident was neurologically intact but had neck pain. CT scan shows ipsilateral form with both fractures on left side.**

***B*, Case 8: 35-year-old woman who had been in a motor vehicle accident was neurologically intact but had neck pain and difficulty turning her head due to pain. This is another example of ipsilateral form on the right side but with an associated transverse ligament tear. The C1 tubercle (*arrow*) has been avulsed.**

patient with an anterior ½ Jefferson variant fracture was flaccid and comatose and eventually died. Although this patient also had a C5 teardrop fracture, the clinical level of injury was at the brainstem (cervicomedullary) level related to the C1–C2 subluxation rather than to the teardrop fracture. In the third case of quadriplegia, this condition was most likely related to the teardrop fracture of C5 as well as to lateral dislocation of C5 with respect to C6. With the exception of the one case of bilateral anterior arch fracture with associated transverse ligament tear, none of the cases of transverse ligament tear were associated with neurologic injury even though instability was demonstrated on radiographs.

Five (45%) of the 11 patients had other associated spinal fractures, and in three of these more than two levels of injury were involved (Table 1). Of the five cases, only one associated spinal fracture other than the Jefferson variant fracture was responsible for cord injury. The other four patients did not have cord injury related to the associated lower spinal fracture.

Discussion

The Jefferson variant fracture of the atlas is characterized by less than four breaks (vertically oriented) of the atlas ring,

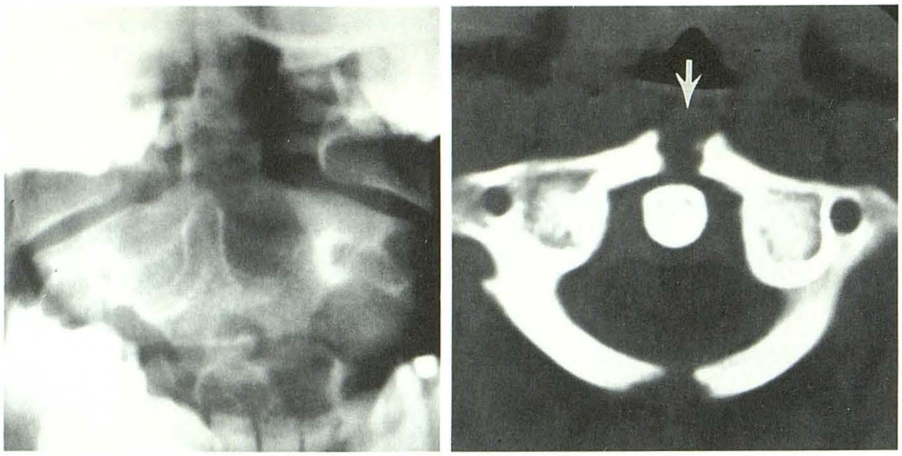


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Fig. 4.—Case 10: 13-year-old boy who had been in a motor vehicle accident was without neurologic deficit but had neck pain. This is an example of traumatic separation of an anterior arch synchondrosis.

***A,* Radiograph, open mouth view, of dens shows bilateral offset of C1 with respect to C2 lateral masses. The initial emergency room evaluation was interpreted as possible Jefferson bursting fracture of the atlas.**

***B,* CT scan shows posterior spina bifida as well as separation of anterior arch synchondrosis. Even on the bone window setting, hematoma can be seen as a rounded soft-tissue density related to the synchondrosis (*arrow*).**

TABLE 1: Fracture Type and Clinical Findings in 11 Patients

Case No.	Age (yr)	Type of Fracture	Anterior		Posterior		Neurologic Findings; Other Fractures
			Unilat.	Bilat.	Unilat.	Bilat.	
1	58	3/4 Jefferson	X			X	No neurologic deficit; dens and C5–C6 lamina Fx
2	84	Anterior 1/2		X			Quadriplegia and death; transverse ligament tear
3	29	Anterior 1/2		X			Quadriplegia and death; C5 teardrop Fx
4	43	Anterior 1/2		X			No neurologic deficit; T7, T8, T9 compression Fx, Le Fort II facial Fx
5	47	Anterior 1/2		X			No neurologic deficit; C7–T1 Fx dislocation
6	25	Ipsilateral hemi-ring	X		X		No neurologic deficit
7	27	Ipsilateral hemi-ring	X		X		C5 level quadriplegia; C5 teardrop fracture and lateral C5–C6 dislocation; C2 hangman's fracture; transverse ligament tear
8	35	Ipsilateral hemi-ring	X		X		No neurologic deficit; transverse ligament tear
9	78	Contralateral hemi-ring	X		X		No neurologic deficit; transverse ligament tear
10	13	Anterior synchondrosis Fx	X				No neurologic deficit; posterior arch bifida
11	22	Unilateral arch Fx			X		No neurologic deficit; transverse ligament tear

Note.—Fx = fracture.

and transverse ligament tear is a significant associated injury. The fractures occur in the same four sites as those encountered with the classical Jefferson fracture—at the junctions of the anterior and posterior arches with the lateral masses, the thinnest portions of the atlas ring [1]. Jefferson variant fractures probably occur by the same bursting mechanism as the classical Jefferson fracture. Transverse ligament tear likewise is an injury associated with the classical Jefferson fracture.

Atlas instability occurs if the anterior bony ring or the posterior ligamentous ring is disrupted. In the former (bilateral anterior arch fractures), posterior dislocation of the head may occur, and in the latter (transverse ligament tear) anterior dislocation may occur. Isolated unilateral and bilateral posterior arch fractures are not clinically significant, since only the posterior bony ring and not the posterior ligamentous ring is involved. In fact, the posterior ring may even be aplastic without causing instability at the C1–C2 level.

Until CT evaluation of cervical spine trauma became routine, only the unilateral and bilateral posterior arch fractures of the atlas had been recognized. More recently, the bilateral anterior arch fractures [2, 10], the ¾ Jefferson variant [11, 12],

TABLE 2: Lateral Mass Offset Measurements

Case No.	OMV Widening (mm) Right	OMV Widening (mm) Left	C1–C2 Lateral Offset (mm) Right	C1–C2 Lateral Offset (mm) Left	Type of Fracture	Transverse Ligament Tear
1	3	5	—	1	3/4 Jefferson	
2	17	3	7	—	Anterior 1/2	Yes
3	5	6	1	—	Anterior 1/2	
4	5	3	3	—	Anterior 1/2	
5	5	8	4	—	Anterior 1/2	
6	4	8	—	4	Hemi-ring	
7	9	14	4	5	Hemi-ring	Yes
8	9	8	3	3	Hemi-ring	Yes
9	19	9	7.5	7.5	Hemi-ring	Yes
10	7	7	3	3	Synchondrosis	
11	14	8	3	3	Unilateral posterior	Yes

Note.—OMV widening = space between the dens and the medial margin of the C1 lateral mass on the open mouth view; C1–C2 lateral offset = outward or lateral overhang of the C1 with respect to the C2 lateral mass on the open mouth view; type of fracture = see Table 1 for full description.

and the hemi-ring Jefferson variant patterns have also been reported [4, 12–15].

The most unstable Jefferson variant fracture has a pattern of bilateral anterior arch fractures that allows posterior C1–C2 dislocation to occur. Severe cord injury occurred in two of our patients, with autopsy documentation of near cord transection in one. Of the previously reported cases of bilateral anterior arch fractures only two of eight were neurologically intact [2, 10], one died, two were monoplegic, one was dysphagic, one had severe occipital neuralgia but no neurologic symptoms, and the clinical status in one was not known.

This is in contrast to the classic Jefferson fracture, in which no neurologic injuries have been reported in cases where the Jefferson fracture is the only injury [1–4]. Jefferson's review of eight atlas fractures of the classical Jefferson type revealed no neurologic injury in four cases, but the clinical status was not known in the fifth case. In the other three cases, two patients had monoplegia, most likely resulting from associated dens fractures, and one patient had a C6 quadriplegia resulting from an associated C6 body fracture. Plaut [16] also added an additional four cases of the classic Jefferson type, of which two patients had quadriplegia and eventually died, most likely consequent to associated dens fractures, and the other two had no neurologic deficits.

Another pattern with potential instability is the hemi-ring type that occurs with fractures of the anterior and posterior arches. The majority of cases that we encountered with this pattern (three of four) had associated transverse ligament tears, which is a recognized, unstable injury. This pattern results from lateral spread of the two halves of the bony ring by trauma. Other reports of the hemi-ring pattern of atlas fractures describe bilateral, outward offset of the C1 lateral masses [12–15, 17], which would suggest ring widening and possibly transverse ligament tear. However, none of these cases was reported to have neurologic injury.

Tear of the transverse ligament was first suggested by Spence et al. [3] as an associated component of the classical Jefferson fracture, and probably occurs with the hemi-ring Jefferson variant fracture as well. The injuring forces produce outward propulsion of the bony fragments in a centrifugal fashion, widening the atlas ring. Spence et al. demonstrated on cadaver spines that ring widening of greater than 5.7 mm occurred in the Jefferson fracture. Fielding et al. [9] demonstrated that if the ring widening exceeded 6.9 mm, tear of the transverse ligament would occur.

It is difficult to determine the frequency of transverse ligament tear occurring with the classical Jefferson fracture. As Fielding pointed out, the majority of mechanically induced transverse ligament tears on cadavers occur within the body of the ligament, and less often fracture the transverse ligament tubercle [9]. Unless flexion-extension radiographs document widening of the predental space, there is no reason to suspect transverse ligament tear if there is no bony avulsion.

Jefferson did not discuss the presence of transverse ligament tear in his review of atlas fractures. Gehweiler et al. [2] reported three of seven classic Jefferson fractures with associated transverse ligament tear. Baumgarten et al. [4] also reported one case of a classic Jefferson fracture with a transverse ligament tear. Our one case of a Jefferson fracture also had a transverse ligament tear.

It is even more difficult to determine the frequency of transverse ligament tears associated with the Jefferson variant fractures, since none of the reports of such cases comment about the transverse ligament. From our small series it would appear that transverse ligament tear is common and occurs more often with the hemi-ring pattern.

The isolated single and bilateral posterior arch Jefferson variant fractures are stable and are not associated with neurologic injury. Our case of a ¾ Jefferson variant fracture was also stable, since there was only one break in the anterior arch. The bilateral posterior arch breaks were not significant. However, the pattern of bilateral anterior arch plus a unilateral posterior arch fracture in a ¾ Jefferson variant fracture would most likely be unstable and have the same significance as the anterior ½ pattern.

All the Jefferson variant fractures demonstrated either unilateral or bilateral offset of the C1 with respect to the C2 lateral masses on the open mouth view of the dens. Bilateral offset and a greater than 4-mm difference between the dens and C1 lateral mass spaces on the open mouth view occurred most often with the hemi-ring pattern with associated transverse ligament tear.

On the lateral radiographs, the pattern of C1 spinolaminal line displacement separated the bilateral anterior arch fracture pattern from those with transverse ligament tears. With the bilateral anterior arch fractures there is posterior dislocation of the cranium and posterior arch of C1 with respect to C2, and therefore, of the spinolaminal line. However, there is no displacement of the anterior arch with respect to the dens (Fig. 2). With transverse ligament tears the spinolaminal line is displaced anteriorly as are the cranium and atlas with respect to C2.

Identification of a posterior arch fracture of C1 on the plain radiographs does not mean that no further radiologic studies are needed, since it may be associated with other injuries of C1 that are not readily visible. Asymmetry on the open mouth view of the dens is a nonspecific finding and can occur without cervical injury.

In summary, the unstable Jefferson variant fracture has fewer than four breaks in the atlas ring and probably occurs by the same fracture mechanism as the classic Jefferson fracture. It may occur with transverse ligament tear, and the anterior ½ (bilateral anterior arch fracture) pattern has the most potential for severe cord injury. In contrast to the classical Jefferson fracture, the unstable Jefferson variant fracture is more often associated with neurologic injury. It may also be associated with other, multiple-level spinal injuries. The plain radiographs are often unremarkable, and the diagnosis can only be made with certainty on CT.

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