CT in the Evaluation of Spine Trauma

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Fifteen patients admitted for spine trauma in an 8 month period were studied with computed tomography (CT). All the patients had initial routine plain film screening, and 10 of 15 were also examined with conventional tomography. Five patients sustained vertical fall, axial-load injuries in the thoracolumbar junction region; two others suffered missile injury to the spine. CT provided more information than plain films in all these patients due to its superior imaging of bony detail and its ability to assess soft-tissue damage. In four of these patients, conventional tomography was done but contributed no additional information. Eight other patients sustained complex fractures of the cervical spine. In all but one, the combination of plain films and CT allowed complete evaluation of the injury. In one patient, conventional tomography showed an additional linear fracture one vertebral level below the main region of injury. Plain films and CT allow complete, safe, rapid, easily interpretable evaluation of spine trauma patients in the acute setting. Conventional tomography yields no additional clinically vital information in the acute evaluation of spine trauma, when plain films are abnormal. Its current ability to show finer bony detail than CT can be reserved for evaluating equivocal plain film and CT findings or more complete evaluation (if indicated) after the patient is clinically stable.

CT scanning for evaluation of spine trauma has received modest and mostly anecdotal attention in the literature [1-5]. This communication describes the initial 8 month experience of a major urban trauma center using CT for the assessment of spinal injuries. The aim of this report is to better define the role of CT in the radiographic evaluation of acute spine injuries.

Subjects and Methods

Fifteen patients with acute spine trauma admitted to our institution over an 8 month period had CT evaluation as part of their diagnostic work-up. No conscious selection process was used by the clinicians in requesting CT scans. The clinical and radiographic records of these patients were reviewed. Conventional radiographs were obtained in all cases before CT. All CT scans were performed using a GE 8800 unit; scan time was 9.6 sec, and nonoverlapping 5 mm axial slices were obtained using the infant body calibration. A preliminary radiograph with longitudinally superimposed catheters was used for localization. Several vertebrae above and below the level of injury were included in the scan sequence, so that there was adequate longitudinal perspective for sagittal and coronal reconstruction images. Of the 15 patients, 10 were also evaluated with pluridirectional tomography.

Results

The 15 patients whose data constitute the body of this report are summarized in table 1. The first group of five patients sustained axial-load injuries to a lower thoracic or lumbar vertebral body after a vertical fall. Initial plain films revealed

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TABLE 1: **CT for Spine Trauma**

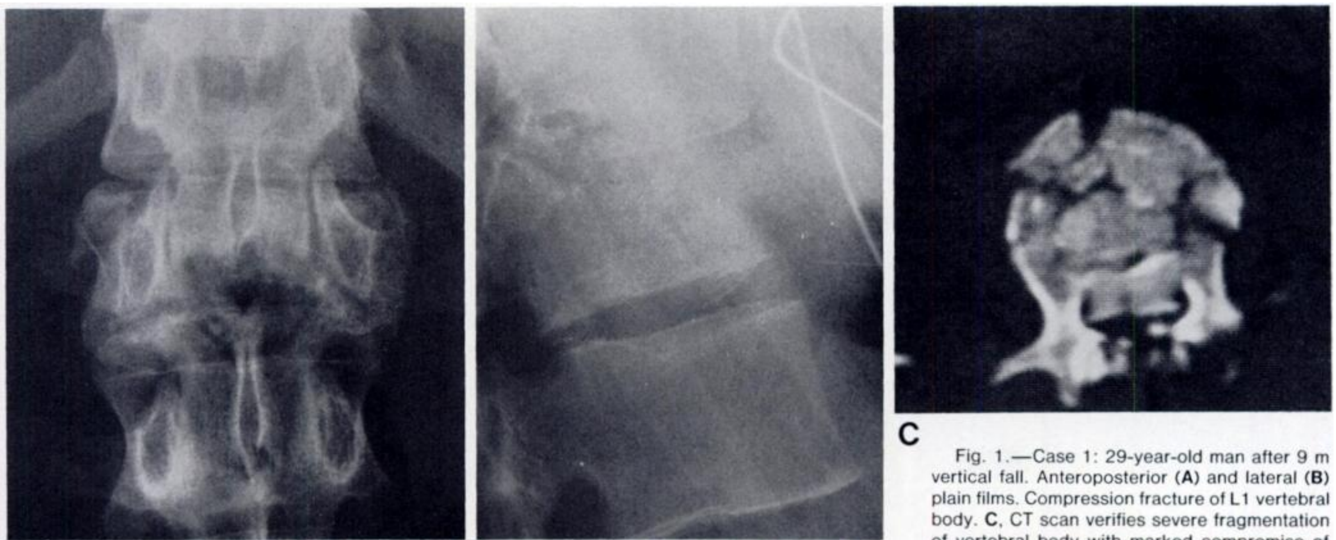
Case No. (age, gender)	Mechanism of Injury	Neurologic Signs	Plain Film Findings	Salient CT Findings
1 (29, M)	Vertical fall, axial load	Yes	Burst L1	Burst L1; marked compromise of spinal canal
2 (18, M)	Vertical fall, axial load	Yes	Wedge fracture L1	Midsagittal cleavage of L1; marked spinal cord compromise
3 (28, F)	Vertical fall, axial load	Yes	Comminuted fracture L1	Fragmented L1, body and lamina; spinal canal about 50% compromised by bone fragments
4 (46, M)	Vertical fall, axial load	No	T12 fracture	Marked comminution of T12 body; minimal compromise of spinal cord
5 (20, M)	Vertical fall, axial load	No	Fractured L4	Comminuted fracture L4; minimal spinal canal encroachment
6 (15, M)	Gunshot wound	No	Bullet, left C1 lateral mass	Bullet disrupting C1 lateral mass; mild spinal canal impingement; severe upper airway compression
7 (24, F)	Gunshot wound	Yes	No definite fracture	Fragmentation of T12 lamina; fragments compromising spinal canal
8 (47, M)	Vertical fall, extension	Yes	C6–C7 subluxation; "locked" facets	Fractured C6 lamina; angular deformity of spinal canal on sagittal reconstruction
9 (42, F)	Motor vehicle accident, flexion-rotation	No	Fracture and anterior subluxation C2; ?C3 fracture	Oblique C2 body fracture; C2 right lamina fracture; slight rotation of dorsal fragment; no definite C3 fracture
10 (50, F)	Axial load with flexion; fall after previous motor vehicle accident	No	Anterior subluxation C1 on C2; odontoid fracture	Jefferson fracture C1; odontoid fracture not totally appreciated; spinal canal intact
11 (43, M)	Motor vehicle accident, axial load in extension	No	Anterior subluxation of C2 on C3 with bipedicular C2 fractures (hangman)	Hangman fracture confirmed, bilateral pedicle fractures; neural canal intact
12 (29, F)	Motor vehicle accident, axial load with flexion	No	Odontoid fracture, posterior arch C1 fracture	Anterior arch and lamina fractures C1; sagittal reconstruction showed angulation of odontoid suggestive of fracture
13 (19, M)	Motor vehicle accident, axial load	No	C4, C7 fracture	Linear fracture through body of C4; comminuted fracture body of C7 with moderate encroachment on neural canal
14 (18, M)	Motor vehicle accident, extension, rotation	No	Rotatory subluxation C3–C4 on C5; no definite fracture seen	Fracture of lamina and lateral mass of C5; no significant spinal canal compromise
15 (89, F)	Fall down stairs	No	Marked osteopenia; C6 fracture suspected	Linear nondisplaced fracture of lateral mass C6

Note.—Pluridirectional tomography was done in cases 3–5, 7, 8, 10, 11, and 13 (no additional information); case 9 (linear nondisplaced fracture of C3 lamina on right); and case 12 (somewhat better definition of C1 fracture).

varying degrees of vertebral compression fracture. Subsequent CT evaluation defined the degree of fragmentation and fragment location, and gave vital information regarding the status of the spinal canal and its contents in all instances (fig. 1). Integrity of the posterior elements was much easier to assess with CT. In all three patients with neurologic signs, CT demonstrated encroachment on the spinal canal by bone fragments. Conventional tomograms were performed in three patients and yielded no additional information; in fact, the status of the bony spinal canal was more difficult to evaluate than on CT. This limitation was partly due to the fact that conventional tomography was often limited in quality in acutely injured or paralyzed patients due to difficulties (and hazards) with patient positioning [1].

The next group comprised two patients with missile (bullet) injuries to the cervical and thoracic spine, respectively. Again, CT defined bony damage more adequately than the plain films, showing the location and extent of bone disruption (table 1). Vital soft-tissue damage unsuspected before CT was also demonstrated in both instances. In the first case, extreme compromise of the upper airway was seen, leading to emergency tracheostomy. Also, the bullet demonstrated in the lateral mass of C1 was seen to encroach slightly on the spinal canal, and its localization necessitated investigation of the vertebral artery. Subsequent arteriography defined vertebral artery patency (fig. 2). In the second case, the initial plain films showed no bone disruption. CT demonstrated cord damage at the T12 level caused by fragmentation of the T12 lamina, which explained the patient's paraplegia. Conventional tomograms yielded no additional information.

The last group comprised eight patients with complex



A B C

Fig. 1.—Case 1: 29-year-old man after 9 m vertical fall. Anteroposterior (**A**) and lateral (**B**) plain films. Compression fracture of L1 vertebral body. **C**, CT scan verifies severe fragmentation of vertebral body with marked compromise of neural canal.

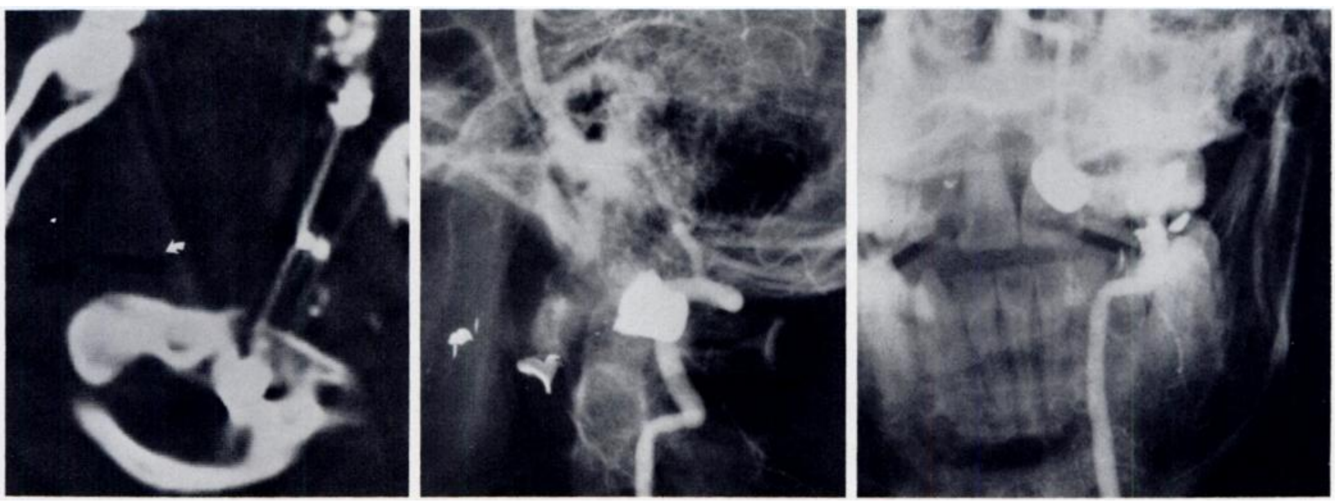


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Fig. 2.—Case 6: 15-year-old boy with self-inflicted gunshot wound. **A**, CT. Bullet lodged in fragmented left lateral mass of C1. Only minimal encroachment on spinal canal. Extreme narrowing of oropharyngeal airway at this level (*arrow*) prompted emergency tracheostomy. **B** and **C**, Selected films from vertebral arteriogram document patency of vertebral artery. Subtractions showed compression of vertebral artery.

cervical spine injuries. Six of these patients had conventional tomography in addition to plain films and CT. In all but one case, the combination of plain films and CT allowed complete evaluation of the injury. In the one exception, conventional tomography showed an incidental fracture one vertebral level below the main region of injury demonstrated on plain films and CT (case 9, fig. 3). In two other cases, CT failed to demonstrate odontoid fractures evident on plain films and conventional tomography (cases 10 and 12, fig. 4), although in one instance sagittal reconstruction did reveal abnormal angulation of the dens. In the other five patients in this group, CT was superior to plain film evaluation of the spine. As can be seen in table 1, the diagnosis and localization of fractures (especially in the posterior elements) was much easier with CT, as was assessment of the spinal canal.

In five of the 15 patients, CT showed fractures when plain films did not; in three of these, subluxation on plain films strongly suggested fracture but failed to completely define it (cases 8, 10, and 14, figs. 4 and 5). The last case showed a fracture with CT when plain films were equivocal due to marked osteopenia (case 15). Overall, the combination of CT and plain films yielded all the information necessary for acute management of these patients. Decisions regarding (surgical vs. mechanical) stabilization of the spine, need for cord decompression, and management of soft-tissue damage were helped by the CT scan findings in every case. In at least three cases (1, 6, and 8), the CT scan yielded information that led to acute intervention that clearly affected the patient's clinical outcome. It did so with minimal excess motion of the patient, in a short interval, and yielding images that were easily interpretable.

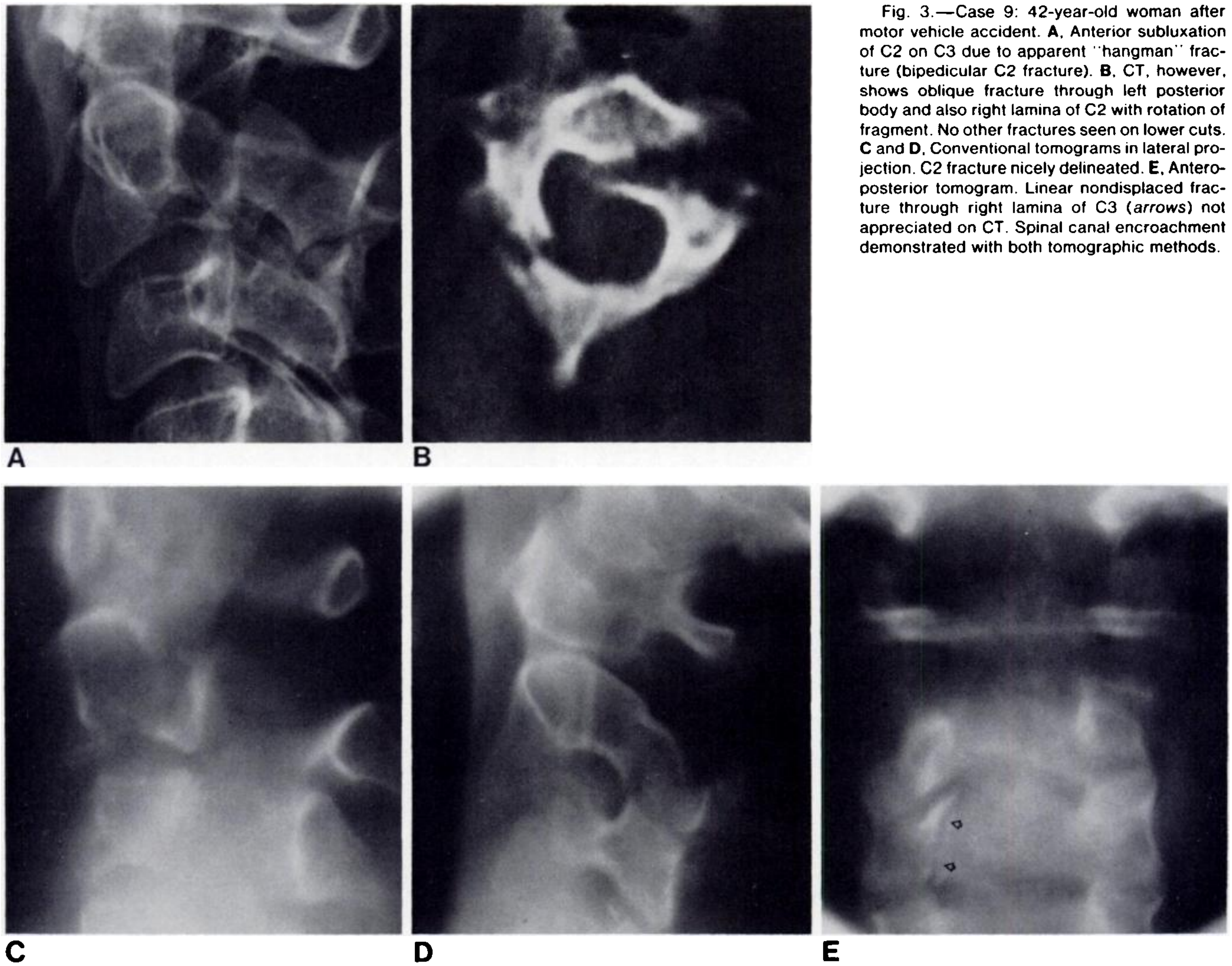

Fig. 3.—Case 9: 42-year-old woman after motor vehicle accident. **A**, Anterior subluxation of C2 on C3 due to apparent "hangman" fracture (bipedicular C2 fracture). **B**, CT, however, shows oblique fracture through left posterior body and also right lamina of C2 with rotation of fragment. No other fractures seen on lower cuts. **C** and **D**, Conventional tomograms in lateral projection. C2 fracture nicely delineated. **E**, Anteroposterior tomogram. Linear nondisplaced fracture through right lamina of C3 (*arrows*) not appreciated on CT. Spinal canal encroachment demonstrated with both tomographic methods.

Representative Case Reports

Case 1

A 29-year-old man fell 9 m. He was admitted complaining of back and heel pain. Neurologic examination on admission revealed bilateral lower extremity paresis and decreased sensation in the left leg. Screening plain films (figs. 1A and 1B) revealed a burst fracture of the L1 vertebral body and calcaneal fractures. CT scan was obtained for progressive lower extremity paresis. This verified severe comminution of the vertebral body with marked compromise of the neural canal by extruded bony fragments (fig. 1C). Emergency decompressive laminectomy and Harrington rod fixation were performed, with resulting improvement in the neurologic signs.

Case 6

A 15-year-old boy suffered a self-inflicted gunshot injury to the oropharynx and upper neck. He was awake, alert, and neurologically intact on admission. Anteroposterior and lateral plain films showed the bullet superimposed on the left lateral mass of C1. A CT scan (fig. 2A) revealed fragmentation of the left lateral mass of C1 and slight compromise of the bony neural canal. In addition, the oropharyngeal airway was severely compromised by soft-tissue swelling. This prompted an emergency tracheostomy. A vertebral arteriogram (figs. 2B and 2C) also demonstrated compression, but no disruption of the left vertebral artery. The patient remained neurologically intact and made an uneventful recovery.

Case 8

A 47-year-old man fell 9 m from a tree striking the back of his head and neck. On admission, mild bilateral upper extremity weakness was noted. Admission plain films (fig. 5A) demonstrated anterior subluxation of the upper cervical spine on C7 with "locked" facets. CT (fig. 5B) disclosed a laminar C6 fracture not seen on the plain films. Sagittal reconstructions (fig. 5C) delineated the angular deformity of the neural canal. Multiple bony fragments were likewise seen in the C6 region. Surgical C6–C7 bone graft fusion was performed after removal of bone fragments. The patient made an uneventful recovery.

Case 9

A 42-year-old woman's automobile was hit broadside by another vehicle. On admission she complained of neck pain, but no neuro-

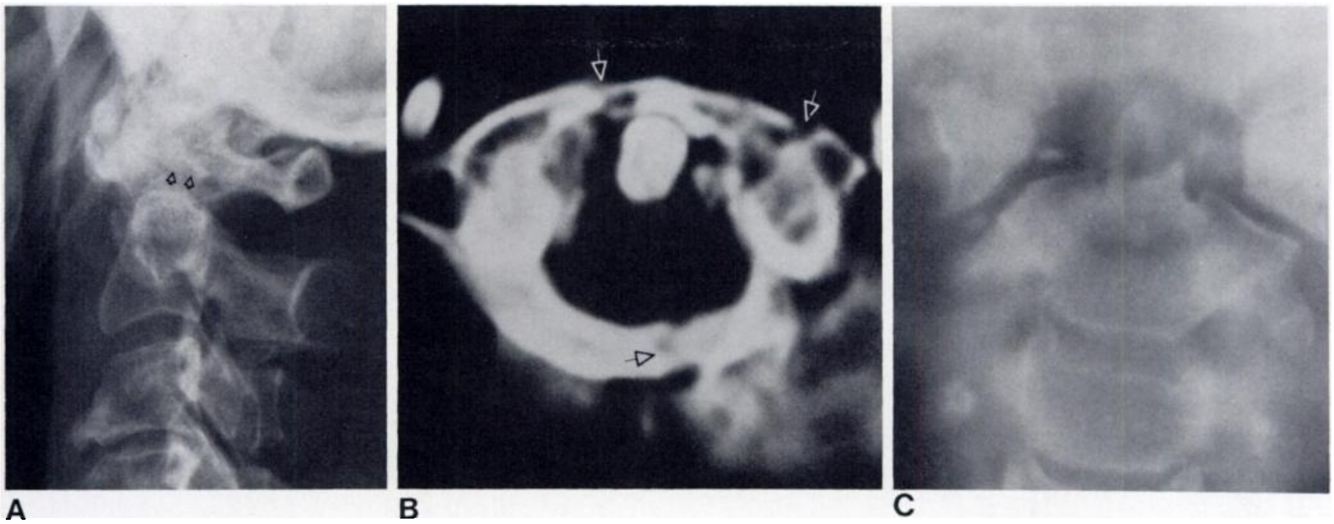

Fig. 4.—Case 10: 50-year-old woman who fell 4 months after automobile accident. **A**, Lateral film. Anterior subluxation of C1 on C2 with displacement of odontoid. Loss of bony integrity (*arrows*) suggested posterior C1 arch fracture as well. **B**, CT scan nicely defined Jefferson fracture component of this injury (*arrows*). However, base of dense fracture was not appreciated. Anteroposterior (**C**) and lateral (**D**) conventional tomograms verified plain film and CT findings.

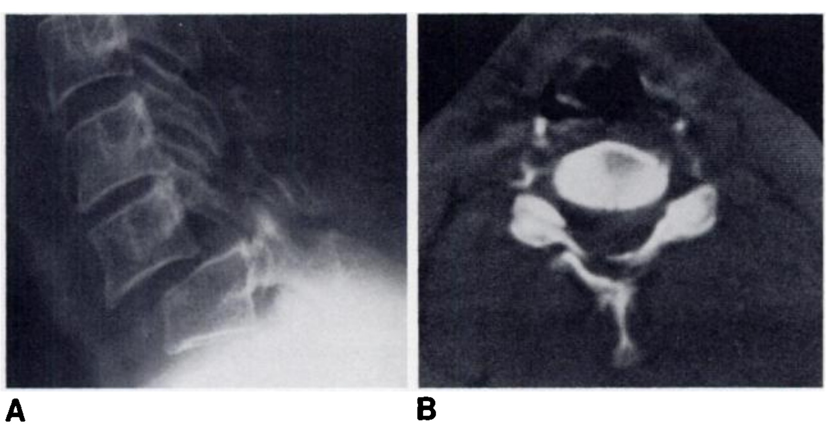

Fig. 5.—Case 8: 47-year-old man after 9 m fall from tree. **A**, Lateral film. Anterior subluxation of C6 on C7 with "locked" facets. **B**, CT. Laminar C6 fractures. Marked anteroposterior separation of C6 and C7 vertebral elements seen on axial cuts at slightly lower level (not shown). **C**, Midsaggital reconstruction. Severe angular deformity of spinal canal. Conventional tomography simply verified plain film and CT findings.

logic deficits were noted. Initial plain films (fig. 3A) disclosed anterior subluxation of C2 on C3 and suggested bipedicle C2 fractures (hangman). However, the subsequent CT scan (fig. 3B) showed an oblique fracture through the left posterior body and also right lamina of C2 with posterior displacement and slight clockwise rotation of the dorsal fragment. Conventional tomograms in the anteroposterior and lateral projection (figs. 3C–3E) delineated this fracture as well, but in addition showed a linear, nondisplaced fracture through the right lamina of C3. The patient was treated with halo traction and she remained neurologically intact.

Case 10

A 50-year-old woman was admitted with complaints of left hand weakness about 4 months after an automobile accident. She had suffered a recent fall with loss of consciousness. She noted weakness in both arms on awakening. Neurologic examination at admission revealed no significant abnormalities. Initial plain radiographs (fig. 4A) demonstrated anterior subluxation of C1 on C2 with a fracture through the odontoid waist. Lateral displacement of the C1 lateral masses was also seen indicating a Jefferson fracture. The subsequent CT scan (fig. 4B) fully defined the components of the Jefferson fracture, that is, multiple C1 arch fractures. The odontoid fracture itself was not seen on CT; follow-up pluridirectional tomograms (figs. 4C and 4D) showed both the odontoid and the Jefferson fracture. The patient remained neurologically intact; however, subsequent tomograms suggested nonunion of the odontoid fragment.

Discussion

Computed tomography has added an important new dimension to the workup of the spine-injured patient at our institution. Our initial 8 month experience has shown that CT provides vital information about spinal injuries not always available on plain films or conventional tomography, and does this in a rapid and safe manner.

Specifically, in instances of crush injuries to vertebral bodies in the lower thoracic or lumbar area, CT demonstrated the fractures to better advantage than plain films and, in addition, provided vital information regarding the integrity of the spinal canal itself. Thus, the role of plain films in this setting is mainly for screening; conventional tomography could be done when plain films are equivocal and no localizing neurologic signs exist. If, however, plain films show definite evidence of bony damage or if localizing neurologic signs exist, CT of the region evaluates the injury thoroughly, obviating conventional tomography. Thus CT allows more expeditious intervention and, in some cases, dictates the type of intervention necessary.

In cases of focal missile injury to the spine, CT delineates the relation of the missile to vital structures and permits a more thorough evaluation of soft-tissue damage. Since missile injuries are not subtle, there is no need for conventional tomography in this setting.

Traumatic injuries of the cervical spine are more complicated. Yet, even here, as seen from our data, the combination of plain films and CT allowed a thorough and efficient evaluation. In only one case did conventional tomography delineate a fracture not detected with the other two methods, and the clinical significance of this additional fracture was minimal.

Plain film screening of cervical spine injury allows early recognition of spinal malalignment. The transverse orientation of CT images makes subtle malalignment difficult to interpret, but sagittal image reconstruction gives CT this capability as well. The localizing digital radiograph modification of CT software improves this capability even further, and perhaps could eventually replace plain film screening.

The CT evaluation of bony integrity was superior to plain films in our material, with the possible exception of transversely oriented fractures, such as those of the odontoid. In our experience, odontoid fractures are well seen on plain films.

CT did miss one sagittally oriented fracture subsequently demonstrated with conventional tomography. We speculate that the location of this fracture in a region of dense bone (just beyond the pedicle) and its subtle nondisplaced nature point to the partial voluming problem as one that may still leave conventional tomography a role in delineating subtle bone detail. Yet, even in this case, the primary site of injury was thoroughly evaluated by CT, and this additional fracture one vertebral level below was of little clinical significance. No alteration of therapy was necessary. Thus, no clinically significant information was missed in our cases when the combination of plain films and CT was used for the evaluation of cervical spine injury.

Overall, CT scans of the spine are, at least subjectively, easier to interpret than conventional tomograms. This is in part due to the superior contrast resolution of CT, the ability to vary the gray scale allowing soft-tissue evaluation, the ability to delineate bony fragments and orient them in a three-dimensional space, and finally the capacity for manipulating images via sagittal and coronal reconstruction. Conventional tomography requires some mental gymnastics in reconstructing the image in a three-dimensional way. Of course, the ability to discern nondisplaced fractures is important, and conventional tomography may still be the method of choice in cases where the plain films are negative or equivocal in the presence of significant trauma to the spine. However, when plain films do show an abnormality, CT allows more efficient evaluation without loss of clinically significant information necessary for emergent therapy.

Replacing conventional tomography with CT in the acute spine trauma setting is desirable from several other vantage points. First, most spine CT examinations are completed within 30 min. Moreover, the only patient movement required for the examination is to and from the scanner couch. Minimizing motion of these patients while expediting their diagnosis is thus a major advantage of this method. Conventional tomography usually requires at least an hour to complete and requires decubitus positioning for the lateral view, a potentially hazardous maneuver in this clinical setting. This factor and the limited ability of traumatized patients to cooperate with the technician usually limits the quality of conventional tomographic images.

Another advantage of CT over conventional tomography is decreased patient radiation. On our scanner, the dose for a lumbar CT scan is 4–7 rad (0.04–0.07 Gy) per section, depending on patient size (data supplied by GE). Since the beam is well collimated and the sections contiguous, the total dose to any part of the region examined is not significantly greater than this 7 rad (0.07 Gy) maximum. However, in contrast to CT, conventional tomograms deliver radiation to the same area with each slice. Thus, although the exposure per section is about 1 rad (0.01 Gy), the total dose increases almost arithmetically with each slice [6]. Hence, a typical spine series (eight frontal and eight lateral exposures at 5 mm intervals) could deliver a dose in the range of 16 rad (0.16 Gy). This does not include preliminary control views. Axial CT sections of a similar area would not deliver much more than 7 rad (0.07 Gy) to any tissue in this same region.

At first glance, the higher cost of CT relative to conventional tomography may be construed as a disadvantage of CT. A recent survey of several major hospitals in San Francisco disclosed that the average cost of a conventional tomographic series was $154.00 vs. $271.00 for 10 CT sections of the spine. Yet when one considers the speed, safety, and information content of the spine CT, this difference in dollars wanes in significance. This is especially true when one considers technician time and effort spent in preliminary conventional tomographic slices, repeat cuts prompted by patient motion or discomfort, and the quality of images obtained.

At our institution, CT is now considered the key diagnostic test in the evaluation of severe spine trauma after the plain film examination. Conventional tomography is reserved for cases where screening plain films are equivocal and no neurologic deficit exists. Also if evidence of cervical spinal ligament damage is seen on plain films without fracture and CT reveals no fracture at the suspected level, conventional tomography is done to rule out a subtle nondisplaced fracture which might have been missed with CT. Yet the therapy of such an injury would probably not be affected even if such a fracture were found.

When malalignment is evident on plain films, sagittal reformation of the CT images is routinely performed. Conventional tomography is still used in evaluating spinal stability after recuperation from ligamentous damage or after surgical fusion. Only lateral view cuts in flexion and extension are then performed.

We believe the addition of digital radiographic localization and the attendant ability to increase collimation to 1.5 mm will improve bone detail resolution even further and will enhance greatly the quality of multiplanar reformation. We are currently planning a prospective study using this refinement of our CT equipment.

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