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AJNR Am J Neuroradiol 1982, 3 (5) 561-565
<http://www.ajnr.org/content/3/5/561>

This information is current as
of August 26, 2025.

Dynamic CT Scanning of Spinal Column Trauma

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Dynamic sequential computed tomographic scanning with automatic table incrementation uses low milliamper-second technique to eliminate tube cooling delays between scanning slices and, thus, markedly shortens examination times. A total of 25 patients with spinal column trauma involving 28 levels were studied with dynamic scans and retrospectively reviewed. Dynamic studies were considerably faster than conventional spine examinations and yielded reliable diagnoses. Bone disruption and subluxation was accurately evaluated, and the use of intrathecal metrizamide in low doses allowed direct visualization of spinal cord or radicular compromise. Multiplanar image reformation was aided by the dynamic incrementation technique, since motion between slices (and the resulting misregistration artifact on image reformation) was minimized. A phantom was devised to test spatial resolution of computed tomography for objects 1–3 mm in size and disclosed minimal differences for dynamic and conventional computed tomographic techniques in resolving medium-to-high-contrast objects.

Dynamic sequential computed tomographic (CT) scanning with automatic table incrementation uses low milliamper-second technique to minimize the net heat gain of an x-ray tube during CT scanning. This reduction in heat load obviates the tube cooling delays required between consecutive CT slices when conventional exposure factors are used. Dynamic incrementation thus affords a much shorter examination time per patient. Although image reconstruction time remains constant, the elimination of tube cooling delays allows more rapid back-to-back examinations since image reconstruction can occur while one patient is released from the room and the next is being positioned.

Several CT manufacturers offer scanners capable of performing rapid sequential scans. Dynamic incrementation provides a means for markedly shortening standard examination times on the G.E. 8800 scanner. Reese et al. [1] recently reported a significant decrease in overall scan times (on a G.E. 8800 scanner) for 10 slice cranial CT examinations from 400 sec using standard 320 mAs to 160 sec using 200 mAs dynamic incrementation. These authors noted that low milliamper-second techniques resulted in increased quantum noise, which in turn led to a modest decrease in resolution of low-contrast object on CT scans of a standard head phantom. The spatial resolution of high-contrast objects remained notably unaffected on dynamic incrementation head scans.

Our recent experience with spinal CT examinations in trauma victims indicated that the attenuation properties of both the bony vertebral column and contrast-enhanced thecal sac offered sufficiently high contrast relative to soft-tissue background (>15%) to be studied by dynamic incrementation CT scanning techniques, with no significant loss of resolution. A reduction in scanning time over standard examinations minimized patient discomfort while permitting more rapid completion of emergency spinal trauma studies. An added advantage was the improved quality of multiplanar image reformations, since shorter study time reduces misregistration artifacts on reformatted images caused by patient motion

This article appears in the September/October 1982 issue of *AJNR* and the December 1982 issue of *AJR*.

Received December 30, 1981; accepted after revision April 27, 1982.

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AJNR 3:561–565, September/October 1982
0195–6108/82/0305-0561 \$00.00
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between slices. A retrospective review of our initial experience with dynamic incrementation CT scanning in spinal column trauma patients is presented. Also, phantom scan data are offered to support the clinical use of this technique.

Materials and Methods

All spine scans were obtained on a G.E. 8800 CT/T scanner using a 9.6 sec scan time, 576 pulse width code, 1.1 msec pulse time, and 120 kVp. Scans of the thoracolumbar spine as well as the C4–C7 region of the cervical spine involved serial 5-mm-thick slices spaced every 3 mm over the region of interest for a maximum of 45 slices over 13.5 cm of vertical extension. Scans of the upper cervical spine between C1 and C3 used contiguous 1.5-mm-thick sections. Dynamic sequential scans of the thoracolumbar spine as well as the lower cervical spine were obtained at 158 mAs while dynamic scans of the upper cervical spine were obtained at 190 mAs. All dynamic scans involved a 2.1 sec delay for table incrementation but no additional tube cooling delay between slices. Multiplanar reformations were obtained in both sagittal and coronal planes as clinically indicated using a prototype software package provided by G.E. (Arrange, G.E. Medical Systems Div., Milwaukee, Wis.).

A total of 25 patients were evaluated with dynamic CT scanning for a variety of suspected spinal column traumatic lesions during a 6 month period. Trauma patients in traction were always scanned with traction devices in position in order to assess the impact of these devices on spinal column configuration. Patients with neurologic deficits routinely received intrathecal metrizamide immediately before scanning. Metrizamide CT studies used 5 ml of metrizamide at a concentration of 170–190 mg/dl to delineate possible cord or cauda equina compression or dural tears.

To assess the impact of low milliamperage dynamic incrementation on the image resolution characteristics of spine CT scans, a phantom was devised to test the resolution of high-contrast objects with CT. This Lucite phantom was drilled to yield nine rows of holes, each row containing a series of equal size tubes. The rows were arranged in order of increasing diameter size by 0.25 mm increments. Hole diameters ranged from 1 mm for the first row to 3 mm for the ninth row with hole centers spaced two diameters apart (fig. 1).

The tubes were then filled on five separate occasions with varying dilutions of iodinated contrast (60% Hypaque M) to yield five object-to-background levels varying from 13% (130 Hounsfield units [H]) to 74% (740 H). Five-millimeter-thick CT scans of this phantom at the five separate contrast levels were then obtained at settings of 158, 190, 238, 475, 608, and 760 mAs. Only the lowest contrast level ("worst case") was scanned at all six milliamperage settings. The 158 mAs phantom scan settings corresponded to the minimum used for clinical dynamic incrementation scans in our institution, although a recent update of our equipment has raised this minimum to 190 mAs for most cases.

Minimal spatial resolution was then assessed in terms of the smallest hole diameter that could be clearly resolved as separate holes on a given row (table 1). All assessments were made on hard copies of CT scans of the phantom for various contrast and milliamperage settings. Photography was performed at standard bone window and level settings as employed in our clinical spine CT cases (based on a nonextended CT scale of –1,000 to +1,000 H).

Results

Vertebral body fracture was the most common abnormality encountered in all regions of the spine (fig. 2). Of the 18

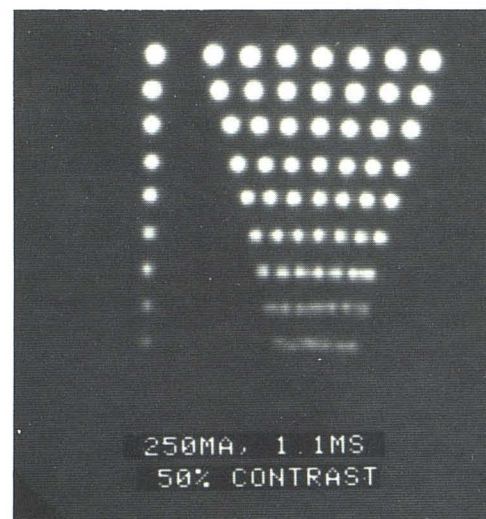


Fig. 1.—Resolving power phantom scanned at 158 mAs with iodinated contrast solution providing object-to-background contrast ratio of 50%. (A spectrum of object-to-background ratios was studied—see text.) Holes vary from 1 to 3 mm in 0.25 mm increments.

TABLE 1: Minimal Diameter of Holes in a Test Phantom Resolvable with CT at Varying Contrast Levels

mAs	Minimal Hole Diameter (mm)				
	Contrast Level (%)				
	13	18	33	50	75
158	1.50*	NS	NS	1.25	NS
190	1.25	NS	NS	1.25	NS
238	1.25	NS	1.25	NS	NS
475	1.25	1.25	1.25	1.25	1.25
608	1.25	NS	1.25	NS	NS
760	1.25	1.25	1.25	1.25	1.25

Note.—mAs = milliamperage-second; NS = not scanned.

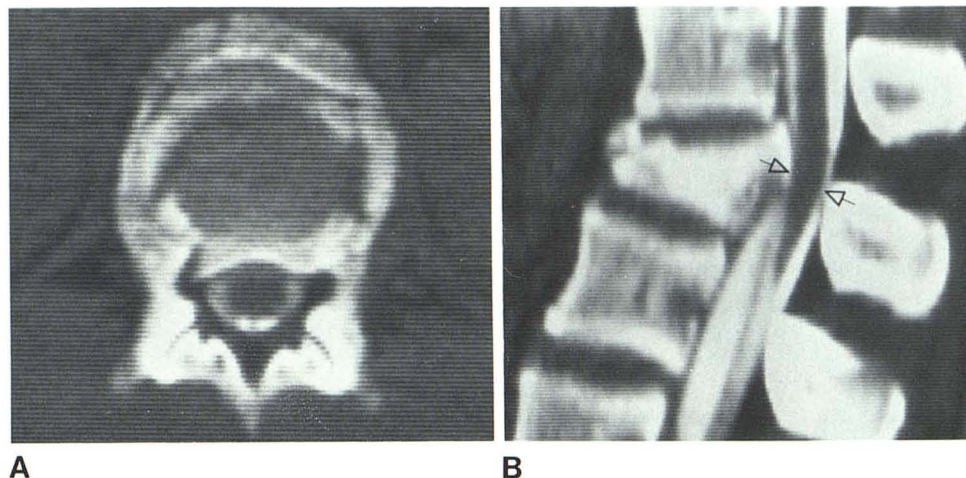
* Minimal hole diameter was between 1.50 and 1.75 mm.

vertebral body fractures in our series, 10 involved the thoracolumbar junction (T11–L2). Thoracic vertebral body fractures involved T12 in four of nine cases, while virtually all lumbar vertebral body fractures (six of seven cases) were confined to L1 and L2.

Spinal canal compromise due to malalignment or free bony fragments was the second most common abnormality in our series. Intrathecal metrizamide was necessary for directly visualizing impingement on the thecal sac and spinal cord in cases with canal compromise (fig. 2), and in one case disclosed a dural tear. Other findings that were seen occasionally at all three levels of the spine included posterior element fractures and jumped or perched facets (fig. 3).

A variety of other spinal abnormalities were also detected using dynamic incrementation CT in selected cases of spinal trauma. Cervical abnormalities included vertebral body subluxation, C1 arch fracture, base of dens fracture (fig. 4), and atlanto-occipital fusion. Thoracic abnormalities included vertebral body subluxation, transverse process fracture, rib

Fig. 2.—26-year-old man developed L4–L5 nerve root signs after 9 m jump. **A**, Axial section. L1 vertebral body fracture with retropulsed bony fragment. Minimal compromise of metrizamide-filled subarachnoid space. **B**, Midsagittal reformation. More ominous compromise of spinal canal in off-axial (arrows) plane not recognized with original axial sections.



dislocation, blood in the subarachnoid space, and cord transection by bullet fragments. A single case of focal disk protrusion in the lumbar spine was also noted on a dynamic incrementation CT scan. All of the abnormalities enumerated above involved visualization of mid-to-high-contrast structures (i.e., bone and/or the thecal sac filled with metrizamide) and were readily imaged using low milliamperage dynamic incrementation techniques on spine CT scans. Clinical and/or surgical follow-up corroborated the CT findings in all cases. Representative dynamic incrementation CT findings on cervical, thoracic, and lumbar spinal trauma scans are illustrated in figures 2–4.

Results of high-contrast resolving power phantom CT scans are presented in table 1. For high-contrast settings of 18%, 33%, 50%, and 74%, minimal spatial resolution remained fixed at 1.25 mm for both low and high milliamperage-second settings. Only at the medium contrast setting (13%) did spatial resolution show a slight decrement (from 1.25 to between 1.50 and 1.75 mm) when scanned at the lowest setting (158 mAs).

Discussion

The utility of CT in the evaluation of spinal trauma is becoming more recognized [2–7]. Dynamic incrementation offers substantial advantages in evaluating potentially unstable, acute vertebral column fractures by virtue of a substantially shortened examination time. A complete 45 slice dynamic incrementation spinal CT examination requires about 8–9 min (45 slices at 11.7 sec/slice) compared with at least 25–30 min for a comparable conventional examination. Spinal trauma patients are often in considerable pain and, thus, are difficult to immobilize during lengthy conventional spinal CT examinations. Short dynamic incrementation examinations minimize patient pain and discomfort and decrease motion blurring of multiplanar reformations (caused by misregistration of axial slices). Prompt diagnosis of unstable fractures also serves to alert hospital staff to the need for precautions in moving the patient and may facilitate selection of patients for early fusion.

Despite the advantages of significantly shortened CT examination times in patients with spinal column trauma, it is

also important to avoid sacrificing diagnostic accuracy for the sake of expediency. Therefore, it is reassuring that for the range of expected contrast differences (15%–70%) between bone and soft tissue as well as between metrizamide and soft tissue in the spine, no loss of spatial resolution was appreciated in our clinical material due to the use of low milliamperage-second dynamic incrementation scanning. Scans of our CT phantom showed that only the lowest contrast level tested had a slight decrease in spatial resolution at the lowest milliamperage setting.

The use of intrathecal metrizamide and multiplanar reconstruction serves an important function in dynamic incrementation CT scans of spinal trauma patients with spinal canal compromise and neurologic deficits [2, 3]. Spinal canal compromise may be due to posterior element fractures, bony fragments in the canal, or subluxation due to jumped facets. Intrathecal metrizamide permits more direct evaluation of impingement on the dural sac and its enclosed spinal cord and nerve roots by bony fragments or subluxed vertebral elements. Posterior element fractures and perched facets may occasionally be appreciated only on sagittal reformations. Such reformations more accurately assess the degree of canal compromise.

Neurologic deficits in spinal column trauma are usually due to: (1) transection of the cord or cauda equina (a permanent injury); (2) cord or nerve root compression; and (3) nerve root contusion. Nerve root contusion, though undetectable by CT, often resolves spontaneously without treatment. Cord and nerve root compression or transections can be detected on dynamic incrementation CT scans with intrathecal metrizamide and multiplanar reformations. Nerve root entrapment outside the dura may be suggested by metrizamide dynamic incrementation CT scans disclosing dural tears with contrast extravasation. Surgical decompression of the cord or nerve roots may aid neurologic recovery in those patients with incomplete neurologic deficits, hence, early accurate diagnosis on spinal CT scans is essential. Detection of unstable bony and/or ligamentous injury guides appropriate stabilization as well. In both these areas, high-resolution CT is useful, especially if performed promptly and efficiently.

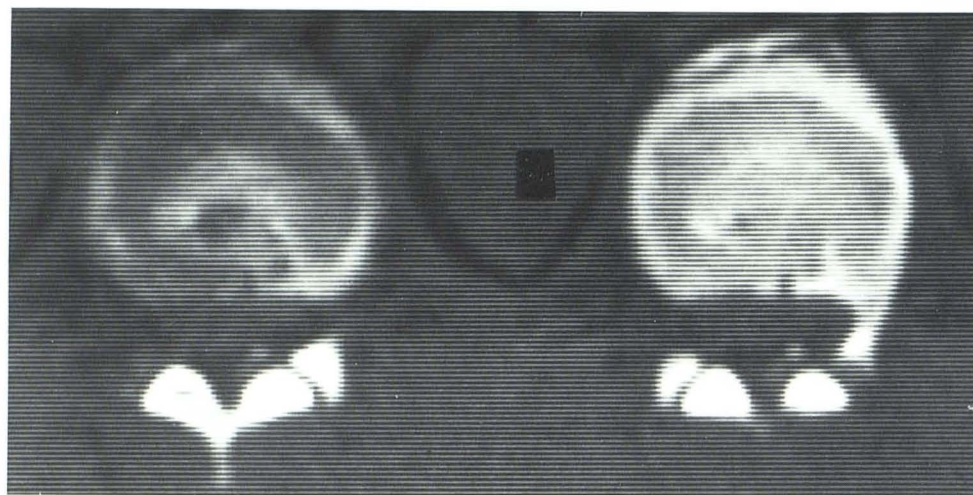
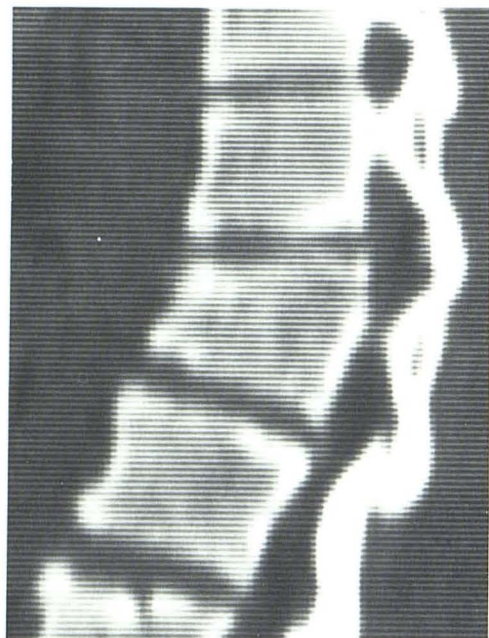
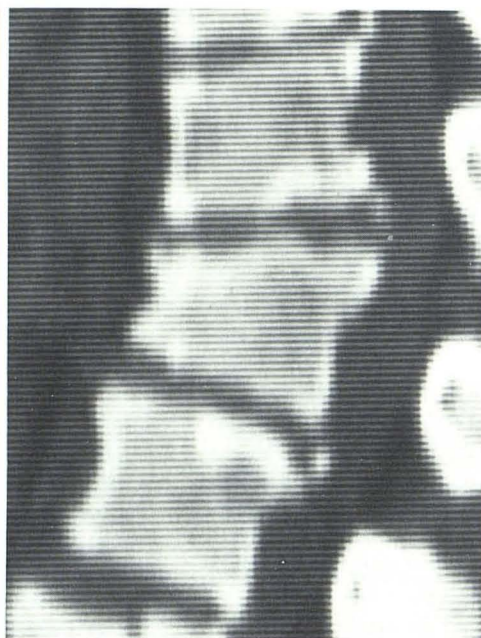
**A****B****C**

Fig. 3.—26-year-old woman fell three stories. **A**, Two contiguous 5 mm axial sections at T12-L1 level suggest traumatic disk herniation into end plate, but no other abnormality. **B**, Sagittal reformation. Perched T12-L1 facets indicating unstable injury. **C**, Midsagittal reformation verifies impaction of multiple end plates.

**A****B**

Fig. 4.—52-year-old woman with cervical spine trauma was scanned with contiguous 1.5 mm sections through the upper cervical spine. Multiplanar reconstructions were in coronal and sagittal planes. **A**, Axial section. Fracture in plateau of C2. **B**, Coronal reconstruction localizes fracture to base of dens.

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