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Multiplanar Spinal Anatomy: Comparison of CT and Cryomicrotomy in Postmortem Specimens

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Good anatomic knowledge is a prerequisite for correct interpretation of computed tomographic (CT) scans. To elucidate the complex CT anatomy of the spine, autopsy specimens from various spinal regions were frozen in situ to preserve the undistorted topographic anatomy. The frozen specimens were examined by CT in axial, sagittal, and coronal planes and sectioned by cryomicrotomy along the scanning planes. Photography of the section surfaces yielded detailed anatomic images that were accurately correlated with the CT scans.

The high resolution of modern computed tomographic (CT) scanners and the possibilities of multiplanar image reformation create a demand for good anatomic knowledge of complex structures such as the spine. Technical limitations and individual variations in the normal anatomy contribute to difficulties in interpreting CT scans. Accurate comparisons of CT scans with anatomic sections are therefore required.

This report describes the application of a correlative CT-cryosectional method [1, 2] in the examination of spinal autopsy specimens. Various normal anatomic and a few pathologic structures were analyzed and compared.

Materials and Methods

Two of a total of 40 spinal autopsy specimens were selected for detailed presentation.

Preparation of Specimens

To prevent drainage of cerebrospinal fluid and blood from the specimens and to preserve the topographical relation between the soft tissues and contiguous skeletal structures, spinal segments of interest in fresh cadavers were deep-frozen in situ by local application of liquid nitrogen. When the segment was frozen solid, specimens were cut out en bloc with an oscillating air-pressure saw. Under fluoroscopic control specimens were then accurately positioned in plane-parallel rectangular boxes and embedded in a semiliquid solution of carboxymethyl cellulose gel. This was then frozen, giving firm support to the specimens.

Computed Tomography

CT was performed in axial, coronal, and sagittal planes. All CT scans of the two presented specimens were obtained on a rotating detector scanner, the Somatom DR2 (Siemens). To obtain the highest possible image quality, the following scan data were chosen: 125 kV; scan time, 14 sec; 1,440 projections; x-ray tube load, 1,036 mAs. Specimens were scanned with a slice thickness of 2 mm and a table increment distance of 2 mm, except in the outer part of the scanned region, where a 4 mm slice thickness was used. Image reconstructions were carried out with the latest available software package, version BØ, which is supplied with a high-resolution reconstructive algorithm for working on raw data. A standard reconstruction program was used for the multiplanar reformation. Because of the small size of the specimens and for greater ease in visualization, a zoom factor of 4–6 was used in the reconstruction procedure. Since the CT scanner employed is equipped with an image matrix size of 256 × 256, the pixel size varied from 0.3 to 0.5 mm. The maximum spatial resolution specified for the Somatom DR2 is 0.7 mm.

The box containing the specimen was carefully centered in the scan aperture. The light beam indicator and the marks made on the box during fluoroscopy were used to align the specimen parallel to the scanning plane. To guarantee accurate correspondence between the planes and levels of scanning and those of subsequent cryosectioning, the scanning planes were marked on the outer wall of the box, using the light beam indicator.

Cryomicrotomy

The frozen specimens, embedded in carboxymethyl cellulose gel, were sectioned along the indicated CT scanning planes by a sledge cryomicrotome (LKB 2250, Bromma, Sweden). Slices varied in thickness from 25 to 40 μm. Macrophotographic images of the sections were obtained at 1 mm intervals equidistant from the cut surfaces, using Kodachrome 25 as a color reversal film.

Specimen Presentations

Specimen 1

A young woman sustained severe head and cervical spine injuries in a traffic accident. At hospital admission she was unconscious. Plain radiographs of the cervical spine revealed a right-sided pedicular fracture of C5. The patient died of extensive brain damage.

CT scans of the cervical spinal autopsy specimen showed not only the pedicular fracture of C5 but also a right-sided arch fracture and fractures of the superior articular facets of C6 and C7 (fig. 1).

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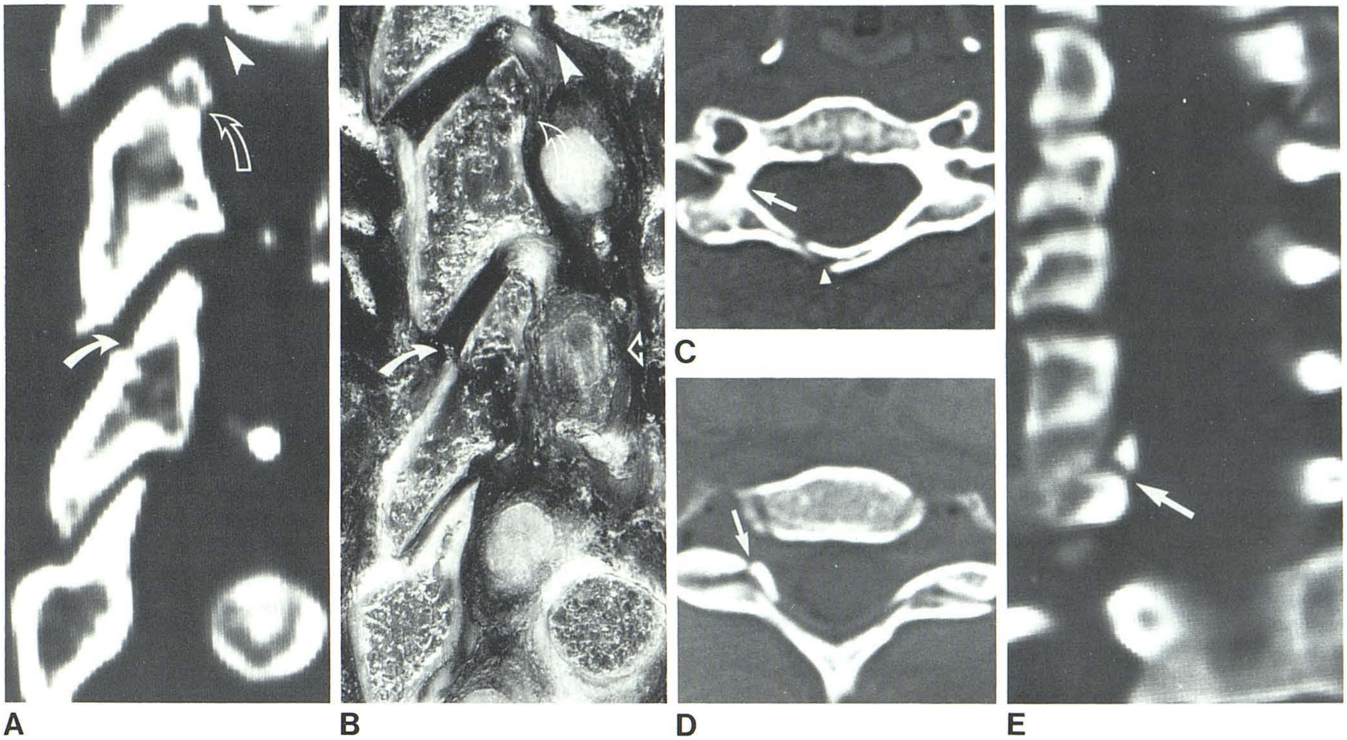

Fig. 1.—Specimen 1. Sagittal CT scan (**A**) and corresponding cryosectional photograph (**B**) of articular facets of C5–T1. Pedicular fracture of C5 (*solid arrowheads*) and fractures of superior articular facet of C6 (*curved open arrows*) and C7 (*curved solid arrows*). Joint spaces C5–C6 and C6–C7 are widened. In **B**, intra- and periganglionic extravasation of blood at level of C7 (*open arrowhead*). **C**, Axial CT scan through pedicular (*arrow*) and arcn (*arrowhead*) fractures of C5. **D**, Axial CT scan at midforaminal level of C6–C7. Articular facet fracture of C7 (*arrow*). **E**, Coronal CT scan at level of articular facet fracture of C7 (*arrow*).

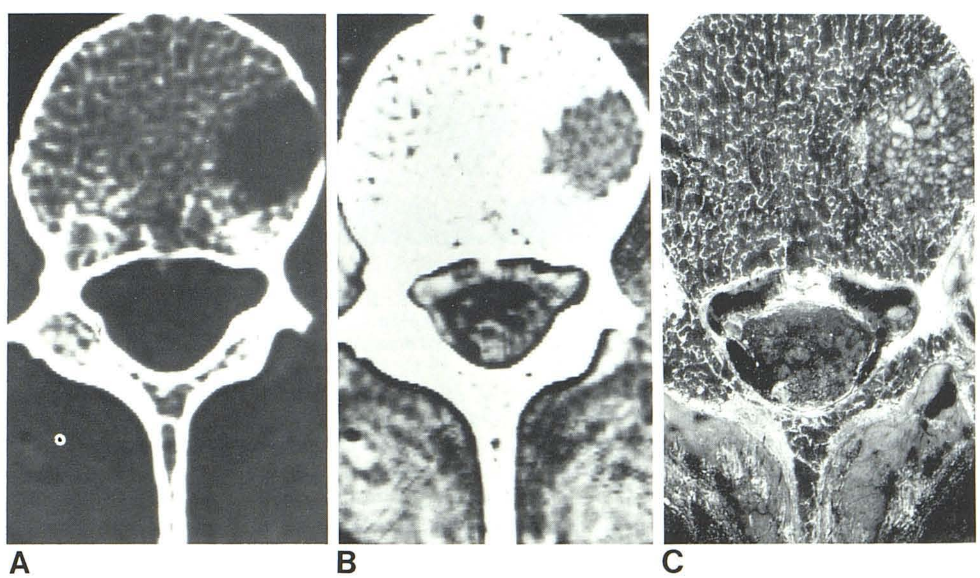

Fig. 2.—Specimen 2. Axial CT scans (**A**, skeletal image; **B**, soft-tissue image) at lower pedicular level of L3. Metastasis in left part of L3 vertebra. Corresponding cryosectional photograph (**C**) shows honeycomb pattern of metastasis.

These fractures were also observed on polytomography of the specimen. They could not be demonstrated on reformatted CT images of the three different planes, however. The cryosectional photographic image corresponding anatomically to the CT image in the sagittal plane (fig. 1A) is shown in figure 1B.

Specimen 2

A middle-aged man had squamous carcinoma of the lung diagnosed by fine-needle biopsy and exfoliative cytology. He had received a combination of radiation and cytostatic therapy (bleomycin). Autopsy confirmed the pathologic diagnosis. Metastases were found in the left kidney, the thyroid, and the third lumbar vertebra.

A plain film of a specimen of the lumbar spine showed a questionable lytic lesion in L3, whereas CT scans and cryosectional photographs demonstrated a definite metastasis (fig. 2).

Discussion

The 40 autopsy specimens comprising our study material were randomly selected and did not represent a particular clinical problem or special population. The material was used primarily for further development of the correlative CT-cryosectional method of studying anatomic structures and their CT representation. The detailed knowledge acquired has been of value in the examination and documentation of pathologic changes.

The multiplanar method correlating CT images of autopsy specimens with cryosectional photographic images provides ideal opportunities for determining whether and to what degree the anatomic morphology can be visualized by CT. Any differences between the scanning planes can be observed, and motion artifacts do not enter the picture. The latter factor is particularly important when comparisons are made between direct and reformatted scans obtained in different planes.

Photographic reproduction of a section surface in a specimen always implies a two-dimensional image of three-dimensional object. Possible variation in the third dimension of the object, perpendicular to the photographed plane, does not contribute any information to the image. In contrast, CT uses an x-ray beam which also has some extension perpendicular to the imaging plane. This means that every image element (pixel) in the CT image is actually represented by a volume element (voxel), the height of which depends on the detector collimation of the x-ray beam. The ability to reproduce small differences in contrast depends in part on the slice thickness. With thinner slices the influence of the structures contiguous to the cryosectional image plane will be reduced. However, with a reduction in slice thickness, there will be an increase in noise in the CT image resulting from a decrease in the number of detected photons. Increased noise impairs the resolution of the CT image.

From a series of consecutive CT images, the appearance of the object in other, optional planes can be calculated. The quality of the reformatted image will always be poorer than the original images of the individual slices. The reason for this is that the thickness of the slice far exceeds the size of the pixel; therefore, the reformatted image has different degrees of resolution in these two dimensions. This explains why narrow fractures in the small skeletal objects in our specimens could not be visualized on reformatted images.

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