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Computed Tomography of the Cervical Spine

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Computed tomography of spine was first undertaken in 1973 when large aperture scanner to accommodate the entire body was built. The axial projection offers a major advantage of the procedure over the conventional radiographic studies though computer reformations of the images are possible. Introduction of non-ionic water soluble contrast medium greatly supported the versatility and resolution of the imaging of the spinal soft tissues also. With increasing experience and improvement of techniques CT has become the primary diagnostic modality for all spinal lesions resulting in diagnostic accuracy and therapeutic effectiveness.

Localisation (scannogram, topogram) capability for preselecting the levels of sections, wide range of gantry tilt, variable slice thickness, high spatial and contrast resolution and soft-ware programmes to assist measurements of densities and distances on a matrix with smaller pixels are the optimal requirements of a modern scanner. Techniques of scanning are modified according to the clinical problems and diagnostic objectives. High spatial resolution is achieved by selecting thin slices and small pixels thus facilitating the visibility of finer bone details. High doses are required when thick sections are obtained to image the soft tissue contents of the spinal canal. Viewing the image at higher window width supplemented by intrathecal contrast medium permits display of the desired detail. Enhancement of the subarachnoid space is achieved by intrathecal administration of 2 to 5 ml of isotonic metrizamide (170mg I/ml) by lumbar or cisternal puncture. Lateral C1-2 puncture is found to be more convenient for patient positioning and pooling of the contrast medium in the cervical region. Layering of contrast medium is avoided by turning the patient around from supine to prone and again supine position. Entry of metrizamide into the cranial subarachnoid spaces is prevented by elevating the patient's head on a small pillow.

The boundaries of the cervical spine namely the craniovertebral junction and the cervico-dorsal junction flanked by the shoulder girdles pose special problems of artifacts. Dental fillings, deglutition and respiratory movements of larynx X-ray attenuations and beam-hardening cause the inherent artifacts at the lower cervical spine (cervico-dorsal junction).

Normal anatomy

The atlas in cross section is seen as a ring shaped structure with the two lateral masses joined by the anterior and posterior arches. From the lateral masses two transverse processes extend laterally on either side. Small midline tubercles are also seen on both the arches. At the plane of the atlas, the odontoid process of axis is seen lying immediately posterior to the anterior arch of atlas (Figure 1). The transverse ligament of atlas lies posterior to the dens. The synovial joint in this region is visible on high resolution images. The body of axis also has the transverse processes on either side. A large bifid spinous process projects posteriorly from the arch. Direct coronal imaging permits assessment of the atlanto-occipital and atlanto-axial joints (Figure 2). The third to seventh vertebrae have oval bodies having larger transverse diameter than the anteroposterior diameter. Impression of the basivertebral vein penetrating the vertebral bodies is appreciated on the posterior rim in axial sections. The anteromedical margins of intervertebral foramina are performed by the uncinate processes, projecting superiorly from the vertebral bodies of C3 to C7. Recognition of hypertrophy of these processes is important in the diagnosis of root compression. Posteriorly the pedicles, laminae, and spinous and transverse processes form a traingular rim to contain the cord and meninges. Demonstration of facet joints in the cervical region may not be always possible, since the joints lie obliquely between the axial and coronal planes, with respect to the rostrocaudal axis of the spine. The facet hypertrophy could not be reliably demonstrated till the advent of CT because of their oblique orientation and curved surfaces. The intervertebral disc varies in its height from 3 to 5 mm in the cervical spine. The discs are nearly circular with flat posterolateral margins adjacent to the uncinate processes and appears homogenous and more dense than the adjacent epidural fat and theca. Both nucleus and annulus have equal density. Margins of the disc do not extend beyond the vertebral margins. The epidural space in cervical spine is very small and root sheaths course as linear structures through the epidural fat. Intrathecal metrizamide penetrates the root-sheaves for better definition of the nerve-root along its course. The internal vertebral veins and retrovertebral plexus are demonstrable on intravenous contrast administration.

Axial section through atlas showing relation of odontoid process to the anterior arch and the spinal cord

Coronal section showing atlanto-occipital and atlanto-axial joints in detail

The spinal cord is a homogenous round or elliptical structure surrounded by CSF of water density. The CT attenuation values of the cord are around 30 to 40 HU. The cord is located in the centre of the cervical spinal canal and it may not be delineated well on its posterior aspect if the subarachnoid space measures less than 3 mm. The epidural fat surrounding the theca adds to the apparent hypodense ring of CSF shadow around the spinal cord. The ventral and dorsolateral sulci, dorsal nerve roots and smaller ventral nerve roots and often identified on metrazamide enhanced CT (Figure 3). Gray and white matter of spinal cord cannot be distinguished.

Metrizamide enhanced axial section reveals ventral and dorsal sulci and dorsal and ventral nerve roots

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Pathological Conditions

Until the advent of CT the spine was mainly studied in two dimensions only by conventional radiographic procedures supplemented by rare axial views obtained by conventional transaxial tomography. CT has now sufficient versatility and resolution to provide more diagnostic information and demonstrate more pathologic changes than conventional studies. In addition to safety and low radiation exposure, CT has advantages over conventional tomography, myelography and spinal; angiography or venography for evaluating spinal pathologic conditions because it effectively demonstrates spinal soft tissues, detects metastases, herniated intervertebral discs, ligamentum flavum hypertrophy and cord tumours. Tissue specific diagnosis can also be made based on the characteristic attenuation (HU) values like air, fat, blood, calcification, bone etc. It also demonstrates facet joint abnormalities, many fractures and spinal stenosis.

Intramedullary neoplasms

Enlargement and irregularity of the cord contours and infiltration of the cord with oedema are the gross pathologic changes in intramedullary neoplasms. As the cord expands in the subarachnoid space the CSF that defines the cord margins become more obscure in CT images.

The most frequent intramedullary tumours are ependymomas, astrocytomas and haemangioblastomas having similar characteristic features in CT images. Spinal cord density is homogeniously diminished possibly because of edema fluid and malignant glial cells infiltrating the cord. They are usually isodense with the normal spinal cord with indistinct margins between the tumour and normal spinal cord. The contour of the expanded cord is poorly seen except in intrathecally enhanced images.

Ependymomas are the most frequent, confined to the central portion of the cord. These tumours appear as low density areas on CT with minimal contrast enhancement. Osseous changes in the form of pressure erosion and spinal canal enlargement can also be demonstrated. Glial tumours, the next most frequent have a low attenuation and show faint patchy contrast enhancement. CT of haemangoblastomas, the least common tumours shows a tumour of irregular shape of low attenuation often showing dramatic contrast enhancement.

Intradural extramedullary neoplasms

Neurofibromas:

These are fibrous, solid and rounded arising from epineurium of nerve roots. CT shows a mass that is usually slightly more dense than the spinal cord. Intravenous contrast medium administration reveals moderate contrast enhancement. Occasionally CT displays cystic degeneration or calcification in the neurofibroma. If the mass displaces all the CSF in the dural sac the margins of the cord and tumours are not easily distinguished. In such cases intrathecal enhancement is indicated to effectively demonstrate the mass. Lateral thoracic meningoceles may also be well demonstrated if associated with neurofibromatosis.

Lipomas:

CT recognition is easy because of rounded or slightly lobulated nature having low intratumoral Hounsfield Units, (20 to 100 HU range) which varies according to the fibrous stroma within the tumour usually situated in the intradural compartment. Contrast enhancement is not evident. Intrathecal enhancement is seldom required but may be useful to show communications of subarachnoid space with an associated meningocele or to demonstrate the location of intrathecal nerve roots.

Meningiomas:

Spinal, like the intracranial meningiomas are more common in women. CT shows a mass that is more dense than the spinal cord sometimes dotted with calcification. Hyperostosis of the adjoining bone and contrast enhancement are also well demonstrated. If the subarachnoid space is entirely obliterated by a spinal meningioma intrathecal enhancement is indicated. Other tumours which are uncommonly seen are Dermoids and Epidermoids. These are benign, well encapsulated tumours cystic in nature and filled with epithelial debris, cholesterol and other fatty elements and extramedullary in location

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Epidural space neoplasms

These are usually malignant and include metastasis, sarcomas and lymphomas. CT demonstrates a soft tissue mass replacing the epidural fat often destroying the adjacent bone. Hyperostosis may also be demonstrated in lymphomas and metastasis. Contrast enhancement may be noted in some of these tumours.

Bony neoplasms

Primary tumours of the bony spine are infrequent. Vertebrae are the most frequent sites of skeletal metastasis. Myeloma, lymphoma and metastasis are characterised by bone destruction and soft tissue mass. Zone of destruction may appear sharply marginated and sclerosis may also be demonstrated.

Amongst the primary tumours of bony spine, Haemangioma shows a characteristic picture. A sharply circumscribed region dotted with dense and thick trabeculae is seen with abrupt transition between normal and abnormal bone. Contrast enhancement is usually not decided. Some expansion of the vertebral body with consequent narrowing of the spinal canal may occur.

Osteochondromas of spine is rare. CT reveals homogenous mass with the density of a cortical bone projecting from the vertebrae into the spinal canal or adjacent soft tissues. CT in osteoblastoma shows a soft tissue mass expanding and destroying the bone and its extension into paravertebral connective tissue. The sclerosis of osteoma is well demonstrated but CT fails to show the lucent nidus because of partial volume averaging. Aneurysmal bone cyst (Figure 4) also has CT picture comprising of a sharply marginated soft tissue mass expanding the bone and sometimes crossing an intervertebral disc or synovial joint.

Axial section of aneurysmal bone cyst involving laminae and spinous process

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Congenital lesions

Meningocele and Myelomeningocele:

A meningocele is an extension of the dural sac outside the confines of the normal spinal canal usually through a posterior defect. A myelomeningocele is the same abnormality with the addition of cord or nerve roots along with the theca. The typical CT finding is a structure of CSF density usually posterior to the spinal canal. The dural lining may be demonstrated as a thin rim of tissue more denser than CSF. A communication between the dural sac and the meningocele can usually be inferred but mentrizamide may be needed to confirm the communication and to demonstrate small nerve within the sac.

Chiari malformation:

In Chiari type I malformation the medulla and tonsil herniate into the cervical canal, usually without hydrocephalus, and has no spinal dysraphism. The Chiari II malformation is nearly always associated with a myelomeningocele, and most often has an accompanying hydrocephalus due to aqueductal stenosis. Posterior fossa is small. The Chiari III malformation is far less common than Chiari II and is primarily a Chiari II malformation with an occipital encephalocele. The displaced cerebellar tonsils and medulla are well demonstrated by CT myelography (Figure 5) using an intrathecal contrast medium.

Hydrocephalus and posterior fossa abnormalities can also be evaluated.

Metrizamide enhanced axial section at the level of atlas showing cerebellar tonsils dorsal to the cord

Syringomyelia:

Syringomyelia is a cavity in the spinal cord which has a wall largely composed of glial tissues. Such cavitation is occasionally detectable by conventional CT. High resolution can improve detection of both spinal contour and the intramedullary cavities (Figure 6). The detection of syringomyeliac can be further increased after intrathecal metrizamide, and obtaining delayed scans to show the contrast medium inside the cavity (Figure 7) probably due to direct diffusion across the spinal cord tissue.

Plain CT scan showing central hypodensity inside the cervical cord (syrinx cavity)

Metrizamide enhanced CT scan reveals contrast in the central cavity and in the subarachnoid space. Cord is seen as hypodense

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Odontoid dysplasia and atlanto-axial dislocation

Congenital dysplasias of the odontoid process are frequently associated with atlanto-axial instability. Dysplasias may be seen in children and less commonly in adults. Odontoid process may be absent, hypoplastic or separate from body of the axis and is frequently associated with atlanto- axial dislocation. Traumatic atlanto-axial dislocation results from a severe flexion injury in which the head is thrown forward on the neck rupturing the transverse ligaments behind the dens.

CT shows malalignment of atlas in relation to axis, displacement of inferior articular surface of atlas anterior to the superior articular surface of axis, abnormal distance between the dens and the arch of atlas and usually an asymmetric position of the dens between lateral masses of atlas. The individual ligaments cannot be identified separately from the bones or the cord and its layers.

Inflammations

CT is more effective in demonstrating erosions of vertebral endplate and multifocal destruction in the vertebral body. The soft tissue changes such as paravertebral tissue involvement and extradural collections of pus are well demonstrated even in the early stages of involvement. Intervertebral disc space infection is characterised by lytic fragmentation of adjacent vertebral bodies on CT scan.

Intervertebral disc disease:

CT differentiation of normal, bulging and herniated discs is based on the shape of disc margins since the nucleus and annulus are not differentiated in CT image. Normally conforming nearly exactly to the margins of adjacent vertebral bodies the discs may bulge symmetrically or asymmetrically beyond the vertebral margins which is easily shown by CT. In free herniations the fragment is seen as soft tissue mass obscuring a margin of a root sheath if herniated disc is laying deep in the spinal canal. In case it is adjacent to the disc, a focal abnormality of disc margin with an irregular appearance is seen. In subligamentuous herniations, CT demonstrates a focal abnormality of disc contour which is smooth and curvilinear.

In cervical degenerative disc disease hypertrophied uncinate process and osteophytes are seen along the disc margins. Since the epidural fat is nearly absent in the cervical region intrathecal metrizamide is a useful adjunct to plain CT in detecting cervical disc disorders. Because of partial volume artifacts caused by adjacent vertebral bodies 5mm or thinner slices should be taken.

Spinal stenosis:

The true shape of the spinal canal cannot be demonstrated by any conventional radiological projection. CT permits not only exploration of the bony canal and its soft tissue compartments but also an accurate assessment of the factors contributing to the narrowing. It is also possible to demonstrate the narrowing of the canal secondary to a bulging disc or a hypertrophied ligamentum flavum. Intrathecal contrast enhancement may be required especially to demonstrate a compromised cervical subarachnoid space.

Trauma:

The distinct advantages of CT over conventional radiography in spinal trauma are as follows:

1) Multiple images and projections can be obtained without changing the patient's position on the table.
2) The axial projection is optimal for assessing spinal cord compression and intraspinal bone fragment.
3) Soft tissues such as intervertebral disc, ligaments, spinal cord, and haematomas can be demonstrated.
4) Identification of foreign bodies and fracture lines, especially in the rostro caudal axis of the spine is possible.

In addition metrizamide CT can determine the exact cause of compression, if it is present. Late sequeale of injury to the spinal cord include distal atrophy and syringomyelia, again easily identified by CT examinations.

The value of CT for spinal diagnosis is generally under estimated because a sufficient number of scanners with adequate resolution and versality are not available and optimal scanning techniques for spine studies are scant. Since the recent development of high resolution - CT, sufficient experience and other technical advances it will not be too long when CT will be used routinely in evaluation of patients with spinal problems.