How to interpret computed tomography of the lumbar spine

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ABSTRACT

Computed tomography (CT) of the spine has remained an important tool in the investigation of spinal pathology. This article helps to explain the basics of CT of the lumbar spine to allow the clinician better use of this diagnostic tool.

KEYWORDS

Computed tomography – Lumbar spine – Fractures – Trauma

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Computed tomography (CT) is used commonly for investigating spinal pathology. However, many clinicians lack an understanding and appreciation of it. This article aims to cover the basics of CT including its mechanism, indications and contraindications. We also review the basic interpretation of lumbar spine CT. This article is not intended to replace expert opinion but instead aims to help demystify CT of the spine, thereby allowing clinicians to make well informed decisions regarding the use of their CT service.

Background of CT

It was as early as the 1900s when Vallebona, an Italian radiologist, proposed a method to represent on radiographic film a single slice of the body known as tomography.¹ With the advent of mini-computers in the 1970s, Hounsfield and Cormack developed the method of computed tomography. The first commercial CT scanner was developed by EMI and the first imaging performed on 1 October 1971. It has been claimed that EMI, well known in the music industry, was able to fund the development of CT for medical purposes thanks to the success of The Beatles.²

Basic physics of clinical CT

CT is the process of creating two-dimensional (2D) images from three-dimensional (3D) anatomy, using a mathematical technique called reconstruction. CT involves using an x-ray tube that rotates around the patient generating x-ray

slice data. When x-ray radiation travels through a patient, it is attenuated by the anatomical structure through which it passes. Differences in attenuation help to differentiate structures. Conventional radiography uses a film-screen system as the primary image receptor to collect the attenuated x-ray. The CT process differs in that it collects the attenuated photon energy and converts it to an electrical signal, which is then converted to a digital signal for computer reconstruction.

The modern detector for CT is the gas chamber. This is made of a ceramic material, containing thin tungsten submerged in xenon gas. These long, thin tungsten plates act as electron collection plates. When exposed to x-ray, ionisation occurs in the chamber, producing an electrical current detected by the tungsten plates, which is converted to a digital signal to contribute to the image. These signals vary depending on how much the x-ray has been attenuated by the tissue through which it has passed. The attenuation of each x-ray is termed a 'ray sum'. A complete set of ray sums is referred to as a 'view' or 'projection'. It takes many views to create a CT image. Obtaining a single view does not give the entire perspective. These raw data are collected together, processed using tomographic reconstruction to give a 3D reconstruction of the desired image.³

Indications for spinal CT

CT is often used to image fractures, ligament injuries and dislocations, which can be recognised easily with a 0.2mm resolution. It can eliminate superimposition of structures outside

the area of interest. CT has a much higher contrast resolution than normal x-rays, with the ability to distinguish between tissues that differ in physical density by less than 1%.

As CT uses x-ray radiation, it is good for visualising tissue composed of elements of a higher atomic number than its surrounding tissue, such as bone and calcified tissue. Magnetic resonance imaging (MRI) uses non-ionising radiofrequencies to acquire images and is best suited for soft tissue. CT is the preferred method for imaging solid tumour lesions in the chest and abdomen. It is also used when MRI may be contraindicated, for instance when non-MRI compatible cardiac pacemakers are in situ. CT is therefore indicated to assess bony pathology, seen on plain radiography, or when plain radiography is not clear, such as in patients with ankylosing spondylitis.

Disadvantages of CT

CT uses ionising radiation and has the potential to cause cellular injury secondary to irreversible damage of deoxyribonucleic acid. It should therefore only be conducted if necessary and the risks should be explained to the patient. It is contraindicated in pregnant patients, patients who are unable to keep still or follow instructions and patients who are unable to fit in the scanner, such as the morbidly obese. Care must be taken when administering contrast in patients with renal impairment and monitoring for allergic reactions to the contrast agent is prudent. MRI is preferable to CT when imaging soft tissue in situations that may require multiple scans, for tumours in certain parts of the body such as the brain, and to image the spinal cord and neural elements.

Basics of lumbar spine CT interpretation

Step 1: Check demographics and previous imaging

First, note the name, date of birth and history of the patient. A good CT request should include pertinent positive and negative findings in the history and examination, and the specific reason why the clinician has requested the imaging. Check the system for previous x-rays and imaging, and compare the findings of the current CT with the previous imaging.

Step 2: Know your tools

Windows: CT can be manipulated in order to demonstrate body structures by detecting their ability to block the x-ray beam. This process is called 'windowing'. The windows include bone, soft tissue, liver and other windows (Table 1). It is important when reviewing a body structure that the correct window is being used. For example, the bone window should be used to inspect the bony vertebral column and the soft tissue window when inspecting the musculature surrounding the vertebral column. The lumbar spine CT should be reviewed in both the bone and soft tissue windows.

Hounsfield units: A Hounsfield unit is a unit of x-ray attenuation used in the generation of CT images.⁴ It characterises the relative density of tissues in the body. Its values range from -1,000 to +1,000 (Table 1). Measuring

Table 1 Hounsfield units of various structures. Note this is a range; the closer the measured Hounsfield units are to the respective value, the more likely it is that structure.

Structure	Hounsfield units
Air	-1,000
Fat	-50
Water	0
Soft tissue such as muscle	+40
Calculus	+100 to +400
Bone	+1,000

the average Hounsfield units of a structure can be useful when characterising lesions, for example when differentiating a haematoma from other fluid.

Planes: Traditionally, CT was restricted to axial views of the lumbar spine. Nowadays, advanced imaging technology including acquisition of isotropic volumes and the ability to 'stack' slices on top of each other allows the generation of different views such as in multiplanar reconstruction. After axial images are acquired, they are stacked and the software can slice through the constructed image at different angles to give coronal and sagittal views. By reformatting the images, one can quickly assess vertebral body alignment. A useful view is the 3D reconstruction of the spine, which allows the physician to get a more 'real life' overview of the spine and can produce useful information to further assess the area of interest. It is also a useful tool to educate and inform the patient in clinic.

Step 3: General review

A general rapid review of all the images is useful to look for any abnormalities that are obvious, before a systematic review. In particular, a review of the scout and sagittal views is mandatory. We recommend using the following sequence for both the general and systematic review. First, review the scout image or topogram, followed by the sagittal views, the coronal views, the axial views and, finally, special views if available, such as 3D reconstructions.

Step 4: Systematic review

A CT study is a 3D reconstruction composed of 2D images. As only one slice of the scan can be viewed at a time, identifying abnormalities requires scrolling through each slice to build a mental picture of the anatomy. This may involve repetitive scrolling through the images with comparison of a targeted viewing area of the scan with similar areas above and below. For example, after the initial overview, the eye of the reviewer should be focused on the vertebra only as he or she scrolls through the images.

Abnormalities can be detected in all views by using the following sequence, represented by the mnemonic 'ABCS':

1. Adequacy of image and alignment

Assess spinal alignment on the scout and midsagittal images. The normal lumbar spine has a smooth lordosis.

Figure 1 Kyphosis due to vertebral collapse of L3

ALL = anterior longitudinal line; PVL = posterior vertebral line; SLL = spinolaminar line; PSL = posterior spinal line

Figure 2 Lines of alignment that can be checked on scout or sagittal segments of the computed tomography

Relative lumbar kyphosis may be due to degenerative disc disease or anterior vertebral collapse (Fig 1).

Review the sagittal views using similar principles to evaluating the cervical spine. Ensure the anterior vertebral line, the posterior vertebral line, the spinolaminar line and the spinous process line are smooth and intact (Fig 2).

Spondylolisthesis refers to the displacement of one vertebra over another. Forward displacement is termed anterolisthesis (Fig 3) and is most commonly due to degenerative disc/facet disease (degenerative spondylolisthesis) or pars defects (lytic spondylolisthesis). Backward or posterior displacement of a vertebral body over the vertebra below is termed retrolisthesis (Fig 4) and is usually degenerative in origin although it may also suggest relative instability in that motion segment.

Review the coronal views for alignment of the vertebral bodies, ensuring that there is a smooth line running through the lateral edge of the vertebral body and the transverse processes. Note that the transverse processes become slightly longer as one descends the vertebral column and they are usually longest at L3. Coronal plane deformity may be evident on the coronal scout view or when a dedicated coronal sequence has been reconstructed.

2. Bone

For the anterior elements, review each vertebral body in the bone window, scrolling down the vertebral column. Ensure that the cortex is intact and that the trabecular

Figure 3 Anterolisthesis of L4 over L5 due to degeneration

Figure 4 Mild retrolisthesis of L4/L5 and L5/S1

pattern is uniform. Look for changes in bone density. Abnormalities to look for include fractures, cancer (lytic or sclerotic lesions) and degenerative changes including osteophytes and sclerosis. On the scout and midsagittal views, ensure the vertebral body is square and of similar height to the adjacent vertebrae. A difference in anterior and posterior vertebral body height may suggest a fracture.

For the posterior elements, inspect the facets, pedicles, lamina and spinous processes systematically for abnormalities.

3. Cartilage

Review the intervertebral disc in the soft tissue window. It may be difficult to discern normal from abnormal, particularly as degenerative change is fairly common and there may be evidence of disc bulge or herniation, which may in itself not represent recent injury. On the scout and sagittal views, ensure that there is no loss of disc height, as compared with adjacent levels, and look for endplate fractures or abnormalities (Fig 5). Displacement of the disc can be difficult to see on CT. Further MRI can be requested if there is any clinical suspicion.

4. Soft tissue and spinal canal

Review the soft tissue, comparing one side with the other. In general, the tissues should be uniform. Evidence of previous surgery such as decompression may make interpretation of soft tissue and bony structures difficult. Look in the spinal canal, particularly in the axial and sagittal views, to

Figure 5 Anterolisthesis and anterior disc protrusion due to herniation and degeneration

detect any abnormalities such as retropulsed bone fragments from burst fractures (Fig 6).

Assessing stability

Sagittal views can be helpful when assessing whether an injury is stable. Proponents of both the two-column and Denis' three-column theory will find the sagittal views useful when assessing the number of columns likely to have been affected in an injury. These columns should be intact in the normal patient.

Figure 6 Burst fracture with retropulsion into the spinal canal. Spinal cord injury should be suspected and further imaging such as magnetic resonance imaging may be required.

The three-column theory divides the spine into: a) the anterior column including the anterior longitudinal ligament and the anterior half of the vertebral body and disc; b) the middle column including the posterior half of the vertebral body and disc and the posterior longitudinal ligament; and c) the posterior column composed of the transverse processes, spinous processes/pedicles/lamina, interspinous ligament, supraspinous ligament and ligamentum flavum (Fig 7). Denis' three-column theory suggests injuries to be unstable when two or more columns are disrupted or when there is an isolated posterior column injury. Generally speaking, anterior or middle column injury alone is considered a stable injury. A loss of height of more than 50% of a vertebra would also be considered unstable.

Compression fractures

When a heavy force exceeds the physiological load bearing capacity of a vertebral body, this may result in crushing of the vertebral body. This often occurs in hyperflexion injuries associated with axial loading. A wedge compression fracture results when only the anterior column is injured (Fig 8). If the entire vertebral body is injured, this is considered a burst fracture with anterior and middle column disruption as well as resulting instability (Fig 6). The typical appearance of a burst fracture involves retropulsion of the posterior part of the vertebral body into the spinal canal (Fig 6). There is the potential for neurological injury to the conus medullaris or cauda equina, depending on injury level, as the spinal cord ends at L1/L2 normally.

Chance fractures

A Chance fracture occurs through a different mechanism and results in a three-column injury with failure of the

columns in tension rather than compression (Fig 9). A horizontal fracture line is often seen extending through the three columns. Seatbelt injuries may result in Chance fractures and a high index of suspicion may be needed to diagnose such fractures as radiography may be insufficient. It is important to note that primarily discoligamentous

Figure 9 Chance fracture: This occurs in the upper lumbar spine, usually owing to lap belt injury, and is common in children. It consists of a compression injury to the anterior portion of the vertebral body and a transverse fracture through the posterior elements of the vertebra and posterior portion of the vertebral body. The pedicles can split in two.

rupture may still result in a three-column injury although it is more common to have either bony only or mixed bony/ligamentous Chance fractures.

Conclusions

CT of the lumbar spine is a viable and useful imaging modality, and may be considered in a wide range of clinical scenarios, especially when other modalities such as MRI may be contraindicated. A knowledge of lumbar spine anatomy and a systematic approach are required to assess CT sequences in a reliable and reproducible manner.

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