Imaging the spine

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Abstract

The spine is a complex structure composed of different tissues with a wide range of clinical pathologies. There are multiple imaging modalities available at our disposal to image the spine. This article will present several common pathologies and how different imaging modalities have their respective roles in clinching the right diagnosis and aiding subsequent management.

Keywords Metastatic compression fracture; mimics; osteoporotic compression fracture; seronegative spondyloarthropathy; spine; spondylodiscitis

Introduction

The spine is an extremely complex structure encompassing bones, joints, muscles and discs, all working together to allow a wide range of movement while protecting the underlying neural and vascular structures. The spine can be imaged in a multitude of ways, but ultimately the imaging method is guided by the clinical presentation and clinical queries that need to be answered. This article does not attempt to be an exhaustive reference to all spinal pathologies, but aims to introduce the imaging modalities at our disposal and discuss several pathologies that are frequently encountered in our department including infection, spondyloarthropathy and non-traumatic compression fracture. This article will also present several pathologies that can mimic infection.

Choosing the right imaging modality

The plethora of imaging modalities can sometimes present a conundrum for clinicians wanting to know the optimal modality for the investigation of a spinal pathology. The Royal College of Radiologists (RCR) has published iRefer (formerly *Making the Best Use of a Department of Clinical Radiology*), which is a set of referral guidelines principally aimed at primary care and emergency services. It is designed to help clinicians choose the most appropriate imaging investigation for specific clinical diagnostic problems. This aims to obviate any unwarranted radiation exposure, and reduce delay in instituting optimal management for the patients.

Plain radiography

Plain radiography is often considered a first-line imaging modality because it is easily available in all departments and is the least expensive. Plain radiography also provides one of the highest spatial resolution images, with a limiting resolution of three line pairs per millimetre (compared to computed tomography's limiting resolution of 0.7 line pairs per millimetre).[1] However, plain radiography is limited by its poor contrast resolution, and is not suited for defining subtle soft tissue changes. Its efficacy is further hindered by the inability to obtain satisfactory views of the upper thoracic spine. Plain radiography is increasingly being displaced by other cross-sectional modalities, but is still indicated in certain clinical conditions including trauma, spondylolisthesis in young adults and osteoporotic fractures in the elderly.

Ultrasonography

Ultrasonography has very little to offer in adult spine imaging. Its value lies in imaging newborns or infants whose spinal arches are still incompletely ossified and mainly cartilaginous, providing an acoustic window for the ultrasound beam. Its use is limited beyond 3 months of age as the posterior elements begin to ossify. Ultrasonography is useful in diagnosing congenital abnormalities such as myelomeningocele, spinal lipoma and diastematomyelia. Real-time scanning with ultrasonography allows visualization of reduced pulsatile cord movement to aid diagnosis of tethered cord. Ultrasonography can also be used to assess acquired intraspinal diseases from birth trauma, such as spinal cord injury and intraspinal haematoma.

Computed tomography (CT)

The first CT scan was performed in the early 1970s and has revolutionized medical imaging. It is becoming progressively accessible, with more than 4.6 million CTs performed in England in 2016/17.[2] CT is currently the workhorse in everyday clinical imaging of the spine, especially in trauma. Its ability to obtain thin sections at 0.625 mm and perform multiplanar reconstruction more than compensates for its low contrast resolution. Furthermore, with the use of intravenous iodinated contrast, the inherently small differences in soft tissue contrast can be augmented, making differentiation of normal tissue from adjacent pathology easier. Since its first clinical introduction, there has been immense headway in dose reduction techniques with current modulation, bowtie filter, and complex iterative reconstruction algorithm. There are also techniques to reduce metallic artefacts on CT by using metal artefact reduction algorithms, dual-energy CT, or a combination of both.

Magnetic resonance imaging (MRI)

MRI is an imaging modality that uses strong magnetic fields and radiofrequency pulses to produce diagnostic images without involving ionizing radiation. Through its wide variety of pulse sequences, it is able to provide superior contrast resolution to allow different soft tissues to be distinguished with ease. The most commonly utilized MRI sequences include T1-weighted imaging (T1WI), T2-weighted imaging (T2WI), and short tau inversion recovery (STIR).

T1WI provides excellent soft tissue contrast and is useful in delineating anatomical structures including nerve roots, discs, tendons and ligaments. Fluids, fibrous tissues, bone and air are of low signal intensity on T1WI. Muscles appear as low to intermediate signal intensity, whereas fat appears as high signal

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intensity. The high signal fat around a nerve root at the neural foramen provides an interface which would be obliterated if compressed by pathologies such as disc herniation. T1WI can be used in conjunction with gadolinium contrast to assess and delineate underlying lesions. However, as both fat and gadolinium contrast enhancement are of high signal intensities, a fat suppression technique is usually employed to accentuate the visualization of contrast enhancement.

Pathologies including infection, inflammation and neoplasm generally have high fluid content and will be hyperintense on T2WI, allowing for easy detection of underlying abnormalities. Fat will also appear hyperintense on T2WI, though to a lesser extent than on T1WI.

STIR is a T2-weighted sequence with applied fat suppression. STIR suppresses the high signal from fat and greatly accentuates the signal from fluid and oedema. This sequence is widely utilized in musculoskeletal imaging and proves to be a sensitive tool in detecting a vast majority of soft tissue and marrow pathologies.

There has been increasing interest in the use of whole-body MRI (WB-MRI) in several pathologies, including multiple myeloma, lymphoma and metastatic prostate adenocarcinoma. WB-MRI is gaining traction in the diagnosis and assessment of multiple myeloma given its high sensitivity for early detection of marrow infiltration, and is recommended by the National Institute for Health and Care Excellence as first-line imaging for the investigation of myeloma.[3]

Beyond structural imaging, MRI is also capable of providing functional imaging with techniques such as diffusion-weighted imaging (DWI). DWI maps the diffusion process of water molecules within a tissue, reflecting its cellularity or degree of swelling. It is widely used in neuroimaging and is routinely used in investigations of stroke. Pathologies such as ischaemic stroke or a highly cellular tumour will show restricted diffusion. DWI is the simplest form of diffusion imaging, and there are more complex techniques such as diffusion tensor imaging, q-ball imaging and diffusion spectrum imaging. In addition, there are advanced techniques such as magnetic resonance spectroscopy which provides biochemical information by estimating the concentration of metabolites. MR spectroscopy has a wide range of clinical applications, such as estimating the grade of a glioma, prognosticating and monitoring multiple sclerosis, and assessing the aggressiveness of vertebral haemangioma-like lesions.

The main disadvantage of MRI is the length of time required to perform a scan; for example, a standard protocol for a lumbar MRI scan takes up to 20 minutes, compared to a few seconds with a CT scan. Therefore, MRI may not be suitable in the context of a clinically unstable patient. In addition, certain pacemakers or aneurysm clips are not compatible with MRI, therefore precluding these patients from this modality. However, it remains the modality of choice in stable patients in many clinical conditions.

Nuclear medicine

Nuclear medicine techniques use a variety of radioisotopes to allow metabolic and functional imaging. Bone scintigraphy (bone scan) is one of the most applied nuclear medicine techniques. It uses radiopharmaceutical technetium-99m-methyl diphosphonate (^{99m}Tc-MDP), where the MDP moiety selectively seeks out bone and concentrates in areas with increased osteoblastic activity, thereby identifying the presence and extent of skeletal infection or metastases in patients with known primary tumours. However, it is a modality that assesses osteoblastic activity and not tumour proliferation, hence it can be falsely negative in a predominantly osteoclastic deposit (such as renal cell carcinoma), or it can be falsely positive in a benign lesion (such as fibrous dysplasia).

Single photon emission CT (SPECT) uses the same radiopharmaceutical ^{99m}Tc-MDP. In contrast to the planar acquisition of bone scintigraphy, the images in SPECT are acquired in a cross-sectional fashion. This allows more precise anatomical localization of an abnormal tracer uptake in the body.

Positron emission tomography (PET) is an increasingly utilized modality especially in oncology. It identifies abnormally high metabolic activity in a tumour by using radiopharmaceutical 18F-fluorodeoxyglucose (^{18}F-FDG). PET also provides quantitative metabolic information by way of revealing a lesion's maximum standardized uptake value (SUV_{max}). This not only provides diagnostic information, but allows assessment of the degree of response following oncological treatment. In addition, hybrid imaging with PET/CT is now commonly performed, allowing accurate anatomical localization of a metabolically active lesion.

Infective spondylodiscitis

Spinal infection can lead to significant neural compromise, structural deformity and result in severe morbidity and mortality. It encompasses infection of the vertebral body, intervertebral disc, or the adjacent paravertebral soft tissue including the epidural space. Spondylodiscitis can result from haematogenous spread from a distant site (e.g. endocarditis), direct inoculation (from trauma or surgery) or contiguous contamination from an infected adjacent soft tissue (such as abscess or infected aortic graft).

Infective spondylodiscitis can be pyogenic, granulomatous, parasitic or fungal. Pyogenic infection is the most common, with the most frequently implicated organisms being *Staphylococcus aureus*, *Escherichia coli* and *Streptococcus pyogenes*.[4] Patients with sickle cell anaemia are known to have increased incidence of *Salmonella* infection, whereas spine infections in intravenous drug users are more likely to be due to *Pseudomonas*. Use of immunosuppressive treatment for chronic conditions such as rheumatoid arthritis predisposes patients to infection from uncommon organisms such as candida or atypical mycobacteria. Other predisposing factors for spinal infection include HIV infection, diabetes mellitus, long-term steroid use, and renal or liver failure.

Imaging

Plain radiograph in spondylodiscitis has limited sensitivity and specificity. There may be erosions of the vertebral endplates and progressive loss of disc height. These changes may not be present in the first 2–3 weeks of the disease, and will not be evident until more than 30% of bone destruction has occurred.[5] A normal plain radiograph should not reassure the clinician if infective spondylodiscitis is suspected clinically; instead a more sensitive imaging modality should be requested.

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