B. Normal variants and pitfalls

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Learning objectives

MRI of the lumbar spine is one of the commonest MRI examinations. Normal variants, borderline lesions and pitfalls can cause problems in the differential diagnosis and are discussed here.

The discussion is centred around the subjects of the paediatric spine, segmentation anomalies, intra- and extraosseous lesions.
The paediatric spine

At birth the normal spine is completely segmented, discs have formed between all vertebrae. Failure of segmentation leads to block vertebrae. At birth the vertebral body consists of cartilage with usually 3 ossification centres, 1 in the vertebral body and one each in each posterior element. Coronal clefts in the vertebral body due to a ventral and a dorsal ossification centre are a recognized normal variant until the age of 4y.

Bony union of the vertebral body with the posterior arch occurs from 3-6 years, complete fusion of the posterior arch at all vertebral levels usually occurs around 12y of age. Until then an incomplete bony ring is not abnormal, however an incomplete cartilaginous ring is and indicates dysraphism. Dysraphism of the posterior vertebral ring is common in the lumbosacral junction area and usually without clinical significance.

A large myelomeningocele should be identified on antenatal ultrasound or after birth and is obvious. However care must be taken to identify lesser but potentially clinically significant anomalies such as dysraphism associated with tethering of the cord or cauda and developmental anomalies giving rise to scoliosis and/or neurological anomalies (1). Bony abnormalities are more easily appreciated on radiographs or CT, neural abnormalities however are best assessed with MR imaging (figure 1).

At birth the vertebrae appear somewhat rounded, with increasing age and growth the vertebral bodies become more rectangular, the vertebral body height increases compared with the disc space. The initially thick, cartilaginous endplates become thinner and ossified ring apophyses appear at the margins of the endplates. These do not necessarily appear simultaneously and this can cause diagnostic problems particularly in radiographic trauma imaging. MRI is usually diagnostic in these circumstances, the absence of soft tissue or bone marrow oedema rules out recent injury. However the ring apophyses are areas of weakness and therefore target areas for acute injury and chronic stress lesions. The avulsion of a ring apophysis represents a Salter Harris I injury and can lead to deformity (figure 2).

Disc herniations into the endplate adjacent to the ring apophysis can also occur due to trauma or chronic stress, this should be differentiated from more centrally located Schmorl's nodes. Schmorl's nodes can be regarded as normal variants and should be asymptomatic. They are discussed in more detail in the paragraph on intravertebral lesions.

In childhood the intervertebral discs demonstrate a slightly flattened spheroid appearance with high water signal of the nucleus pulposus. The endplates are often bowed. With
age the discs loose water signal and a central low signal area can occur in the disc. The endplate loose their bowing with possible exception of the lumbosacral junction area (figure 3) (1, 2).

The neurocentral synchondroses between the posterior elements and the vertebral body close between 4-16y. They should close simultaneously and asymmetry is therefore abnormal (1, 3). Unusual, acute or chronic (stress) traumatic lesions can occur at the root of the pedicles. These are very rare, abnormal sclerosis (stress lesion) or oedema are again markers of abnormality.

Segmentation anomalies

Segmentation anomalies frequently lead to transitional lumbosacral vertebrae (figure 4). These are usually asymptomatic though some authors report an increased incidence of backpain and even neurological problems. Bertolotti described a specific subtype of transitional lumbosacral vertebrae with uni- or bilateral hyperplastic transverse processes articulating with the sacrum or iliac bone. The significance of transitional vertebrae is subject to an ongoing debate (1, 2, 4). Either way the presence of a transitional vertebra can be relevant for treatment and diagnosis of low back pain or neurological symptoms and an increased incidence of degenerative change at adjacent levels has been noted (1, 4).

It can be difficult to label a transitional vertebra if not the entire spine is imaged (in which case the vertebrae can be numbered beginning at the ooccipitocervical junction) and even in cases where the entire spine is visualised numbering can be difficult.

It is important to identify an unequivocal landmark and to clearly communicate this as reference point for the report. This ensures that anybody looking at the images is clear about the levels. Obviously this is highly relevant for any future intervention. If possible cross-referencing with plain radiographs should be undertaken and again levels should be clearly communicated.

At the author's institution the lumbar spine is regarded as always having 5 vertebrae as this allows identifying 5 levels of lumbar nerves. This avoids having an L6 root or an S1 root following on an L4 root. However persons with anomalous bony segmentation often also have an anomalous anatomy of the lumbosacral plexus which can make the planning of spinal intervention difficult (5).

Helpful markers for the determination are the right renal artery which usually is located at the L1/2 disc level and the iliolumbar ligament, which identifies the L5 vertebra (1, 4, 6).

Intraosseous lesions
Intraosseous lesions mainly affect the vertebral body. The commonest lesions encountered are Schmorl's nodes and haemangiomas.

Schmorl's nodes are disc herniations into vertebral body endplates. They are common and usually asymptomatic normal variants without clinical relevance (figure 5). However they can be due to trauma, stress and abnormally low bone strength. MRI is very well suited to assess the clinical relevance of intravertebral disc herniations. The presence of bone marrow oedema adjacent to the herniations is abnormal and often associated with pain (figure 6). Excessive bowing of the adjacent endplate can indicate abnormally weak bone such as in osteoporosis. In acute traumatic intravertebral disc herniation there are often further abnormalities in adjacent vertebrae and soft tissues.

If Schmorl's nodes are associated with wedging of multiple vertebrae in the lower thoracic spine and extensive endplate irregularities, Scheuermann's disease has to be considered. Scheuermann's disease is defined as the presence of at least 3 consecutive vertebrae wedged by at least 5°. This is associated with endplate irregularities with disc herniations into the adjacent endplates leading to loss of disc height. Scheuermann's disease presents with a painful kyphosis. Single, asymptomatic wedged vertebrae in the thoracolumbar junction area are normal and can be disregarded (1).

The commonest truly intraosseous lesions are haemangiomas. They mostly but not exclusively occur in the vertebral body. They have a preference for the lumbar and lower thoracic spine. They usually contain fatty tissue and often also demonstrate fluid signal from low flow blood vessels. As long as there is a significant amount of fat shown (high signal in T1w, low signal in fat suppression techniques) there should be no concern (figure 7). Rarefaction of bony trabecles leads to hypertrophy of the persisting trabecles leading to the typical corduroy (also called polka dot pattern) or honeycomb appearance on transverse cross sectional imaging and vertical striations on sagittal or coronal imaging and on radiographs (7). The cortex is not usually involved (1).

Atypical appearances can be difficult to differentiate from other osseous lesions in particular metastatic disease. Atypical features are lack of fat signal, oedema like signal, posterior element and soft tissue involvement. Soft tissue involvement is quite unusual but extension into the spinal canal with cord and cauda compression is well described (figure 8) (7). Benign and malignant bone marrow lesions are the main differential diagnoses and decision making can be difficult. Corduroy bone changes are good indicators for the benign nature of the lesion. The extraosseous part of the lesion might demonstrate all the typical features of a soft tissue vascular malformation in which cases the diagnosis is not difficult. The features are often unspecific though.

Haemangiomas occur often in multiple locations. The differential diagnosis to malignant infiltration can be difficult. Malignant infiltration is often multifocal and shows more frequent involvement of the posterior elements and often bone destruction. Malignant infiltration does extremely rarely show intralesional fat signal.
Not all lesions can be radiologically classified and follow up imaging investigations or biopsy will then be necessary (1).

Haemangiomas can be sclerotic and bone islands might have to be considered in the differential diagnosis. These are not common in the spine. The typical slightly spiculated outline is sometimes well seen with MRI but generally a single sclerotic lesion (low signal in all sequences) is better assessed with CT. Haemangiomas do not demonstrate dense sclerosis.

In rare cases haemangiomas are locally aggressive and can cause bone collapse due to excessive destruction, the bigger and the more osteodestructive the lesion, the higher the risk. Even if large and filling the vertebral body, vertebral collapse is rare.

Extraosseous lesions

Nerve root sleeve cysts are very common findings and usually without relevance. They can cause marked bone erosion and still remain completely asymptomatic (figure 9).

The differential diagnosis comprises neural tumours, especially nerve sheath tumours, and more rarely meningeal ectasia and meningoceles.

High quality MRI might demonstrate nerve roots surrounded by fluid signal indicative of nerve root sleeve cysts. However if the nerve roots are plastered against the wall of the sleeve cyst a definite diagnosis is not possible. Contrast medium enhancement is the most reliable way to differentiate between a soft tissue lesion and fluid (CSF). Meningeal ectasia and posterior scalloping of vertebral bodies is seen in a number of conditions and neurofibromatosis, tumours in the spinal canal, achondroplasia, syringomyelia, severe chronic hydrocephalus and syndromes such as Ehlers-Danlos, Marfan, Hurler and Morquio might be considered.

Facet joint cysts are usually easily identified as such. Sometimes they can have no obvious connection with the facet joint or can protrude into a lateral recess or foramen (figure 10). If doubt persists contrast medium injection into the facet joint can help to establish the correct diagnosis (8).

Normal nerve root sleeve cysts are very common and can lead to a disregard for all peripheral spinal fluid signal lesions. However in rare cases apparent simple sleeve cysts will turn out to be something more significant like ie a neurofibroma.

Features raising suspicion are inhomogeneity of lesions, a signal intensity different from CSF, adjacent bone or soft tissue oedema and bone destruction rather than erosion (though of course nerve sheath tumours such as neurofibromas typically also cause bone erosion and not destruction).
Other normal structures that can cause diagnostic problems are blood vessels and nerve roots. Prominent veins in the spinal canal can have a mass like appearance and tumour or disc herniations might be considered if focal (figure 11). Assessment of the entire imaged spine usually shows the tubular vascular structures in continuity and allows the correct diagnosis, rarely contrast medium enhancement and angiography sequences are necessary and help to prove the vascular nature of an apparent "abnormality".

Conjoined nerve roots present with an abnormal course of the nerve roots which can be confused with disc herniations. Diligent examination of the entire imaged area usually leads to the correct diagnosis. Image acquisition as block rather than as a few slices centred on the discs is particularly helpful here as are 3d sequences.

Conclusion

A rough understanding of the changing imaging appearance of the lumbar spine in childhood can help avoid diagnostic difficulties. Segmentation anomalies and in particular transitional lumbosacral vertebrae are common, clear identification of levels is important for communication with other colleagues. Schmorl's nodes and haemangiomas are common intraosseous normal variants. Pathological features are oedema and vertebral collapse. Nerve root sleeve cysts are extremely common, the differentiation from the rare mimickers can be difficult. Prominent epidural veins and conjoined nerve roots can be mimickers of disc herniations.
Fig. 0: Figure 1a Patient with dysraphism of the lumbosacral spine, presenting as back pain. The MRI (shown here sagittal T2w, fig a, axial T1w fig b and axial T2w fig c) show dysraphism with pars defects but attentive observation is required. An ap radiograph (fig d) shows the obvious dysraphism, a CT (fig e) best demonstrates the bony abnormalities. However the assessment of neural anomalies relies on MRI.

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**Fig. 0:** Figure 1b Patient with dysraphism of the lumbosacral spine, presenting as back pain. The MRI (shown here sagittal T2w, fig a, axial T1w fig b and axial T2w fig c) show dysraphism with pars defects but attentive observation is required. An ap radiograph (fig d) shows the obvious dysraphism, a CT (fig e) best demonstrates the bony abnormalities. However the assessment of neural anomalies relies on MRI.

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Fig. 0: Figure 2a 29 year old man with a non-united ring apophysis. Premature degenerative change. Damage to the ring apophysis can lead to an increased ap diameter of the spine. Sagittal T1w (fig a) and lateral radiograph (fig b). Note that the separation of the ring apophysis from the vertebral body is not radiographically visible due to superimposition.

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**Fig. 0:** Figure 3 7 year old boy with premature degeneration of the lower lumbar spine. The vertebral body and disc shapes on this T2w image (fig a) are normal for age and not for example sign of abnormal softness of the vertebral bodies.

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**Fig. 0:** Figure 4a 24 year old female with low back pain and disc disease. On the sagittal images (shown sag T2w fig a) the presence of a transitional lumbosacral vertebra could be easily overlooked. The transitional vertebra is best appreciated on the ap radiograph (fig b).

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**Fig. 0:** Figure 5a Multiple Schmorl's nodes and transitional lumbosacral vertebra (sagittal T2 and T1w images, fig a, b). The Schmorl's nodes appear innocuous, there is no oedema or endplate bowing and can be considered a normal variant. A transitional lumbosacral vertebra with an incomplete bone bar across is incidentally noted.

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**Fig. 0:** Figure 6a: 57 year old patient with back pain and known hyperparathyroidism. The MRI demonstrates an abnormal bone marrow signal pattern and a disc herniation into the superior endplate of L3 vertebral body with adjacent bone marrow oedema, this is abnormal and not a normal variant and frequently symptomatic (fig a T2w, fig b T1w, fig c STIR)

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**Fig. 0:** Figure 6c: 57 year old patient with backpain and known hyperparathyroidism. The MRI demonstrates an abnormal bone marrow signal pattern and a disc herniation into the superior endplate of L3 vertebral body with adjacent bone marrow oedema, this is abnormal and not a normal variant and frequently symptomatic (fig a T2w, fig b T1w, fig c STIR)

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Fig. 0: Figure 7a: Multiple typical haemangiomas in multiple vertebral bodies with high signal in T1w (fig a) and T2w (fig b) sequences and complete signal suppression in STIR weighting. There is a transitional lumbosacral vertebra, the caudal most degenerate disc is taken as L5/S1. There is a large haemangioma in L2 vertebral body with typical corduroy appearance, well appreciated on the axial images in T1w (fig d) and T2w (fig e).

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References


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