MRI Atlas

Orthopedics and Neurosurgery, The Spine

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1. Auflage 2006. Buch. x, 298 S. Hardcover
ISBN 978 3 540 33533 7
Format (B x L): 21 x 27,9 cm
Gewicht: 1051 g

1 Normal Anatomy and Variants

1.1 Normal Anatomy

MR Technique

The standard MR protocol for a routine evaluation of the spine always comprises imaging in sagittal and axial planes, while coronal images are necessary only to answer specialized questions.

Typical sequences are T1- and T2-weighted sequences, T2-weighted fast spin echo sequences, which may be supplemented by fat-suppressed sequences.

MR Findings

The signal intensity of the marrow in adult vertebrae varies with its fat content and is high relative to muscle on T1- and T2-weighted images. The presence of residual red marrow decreases the signal on T1 and T2. Cortical bone and ligaments have a very low signal intensity on both T1 and T2. The signal intensity of vessels is low or high, depending on the pulse sequence used and the flow velocity of the blood (cervical spine, Figs. 1.1–1.4; thoracic spine, Figs. 1.5–1.8; lumbar spine, Figs. 1.9–1.12).

1.2 Conjoined Nerve Roots

Anatomy

Conjoined nerve roots are a normal anatomic variant.

MR Technique

Most conjoined nerve roots are discovered incidentally on routine sagittal or axial MR images.

MR Findings

Two adjacent intraspinal nerve roots of normal signal intensity. Both roots emerge at the same level and can be traced to their shared origin. The presence of conjoined nerve roots is characterized by an asymmetrical appearance because no nerve root exits the thecal sac at the level above or below on the same side. Conjoined nerve roots have the same MR signal intensity and contrast enhancement pattern as normal nerve roots (Fig. 1.13).

MR Pitfalls

Conjoined nerve roots may easily be mistaken for disc herniations or free disc fragments.

Clinical Significance

Conjoined nerve roots are normal anatomic variants but are nevertheless important because they are quite common and must not be confused with pathology such as disc sequesters or root neurinoma in patients with clinical symptoms.

1.3 Transitional Vertebra

Anatomy

Transitional vertebrae are vertebrae whose structure features some of the characteristics of the adjacent spinal region. Such indeterminate vertebrae can occur at all spinal junctions and are designated as occipitocervical, cervicothoracic, thoracolumbar, or lumbosacral. There may be complete or incomplete assimilation between adjacent vertebrae.

Pathomechanism

Transitional vertebrae are not considered malformations although they are associated with shifts in the vertical segmentation of the spine. The shift involves not only the bony elements but also muscles, nerves, vessels, and other anatomic structures.

Cranial shift is reported to be more common than caudal shift. The normal numerical distribution of vertebrae (seven cranial, twelve thoracic, five lumbar, five sacral, and four coccygeal vertebrae) is present in only two thirds of individuals. Transitional vertebrae are most common at the lumbosacral junction (lumbarization of the first sacral vertebra, sacralization of the fifth lumbar vertebra).

MR Technique

Transitional vertebrae are best identified on sagittal T1- or T2-weighted images (Fig. 1.14).

Most transitional vertebrae are detected incidentally on MR images. Correct identification of the level of a transitional vertebra is possible only on images showing the entire spine. In most patients, a transitional vertebra is already known from prior radiographs.

Whenever the involved segment cannot be clearly identified, it must be mentioned in the report and a choice must then be made and consistently applied.

Clinical Significance

Transitional vertebrae can be entirely asymptomatic or can impair the overall static stability of the spine or the biomechanical function of individual motion segments and thus predispose to degenerative spinal disorders. This is especially the case when there is only partial assimilation (e.g. incomplete sacralization of the fifth lumbar vertebra). Of particular significance are skeletal abnormalities of the occipitocervical junction. So-called atlas assimilation (partial or complete fusion of the atlas to the occiput) is rare but is associated with considerable dysfunction (osseous torticollis or wryneck) and often causes neurologic deficits (disturbance of the pyramidal tract, Arnold-Chiari malformation).

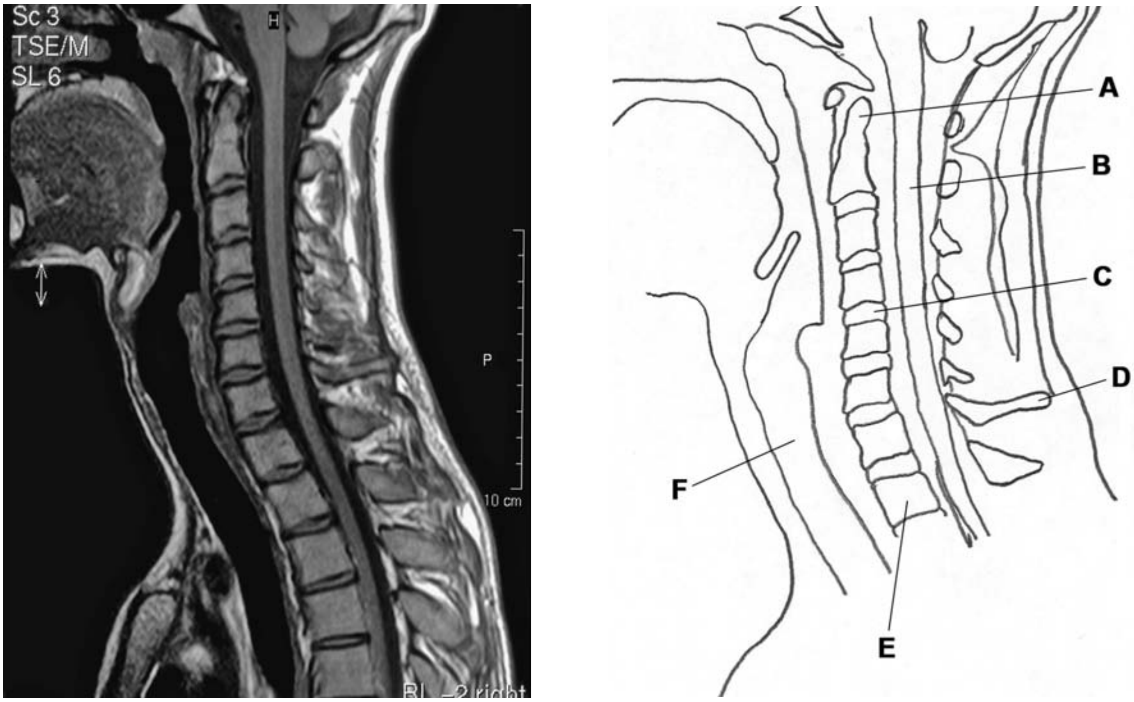


Fig. 1.1. Midline sagittal T1-weighted image of the normal cervical spine obtained with a turbo spin echo (TSE) sequence. Homogeneous appearance of the vertebral marrow. The intervertebral discs are of normal height and nearly isointense to bone. The spinal cord has slightly higher signal intensity relative to the darker cerebrospinal fluid (CSF). A thin layer of soft tissue is depicted anterior to the spine at the level of the epipharynx and pharynx. The soft-tissue-signal structure anterior to the C5 vertebral body represents the proximal portion of the esophagus directly below the glottis. **A** dens axis, **B** spinal cord, **C** C4-5 intervertebral disc, **D** C7 spinous process, **E** T1 vertebral body, **F** trachea

Fig. 1.2. Sagittal T2-weighted TSE image of the normal cervical spine obtained with presaturation of anterior soft tissue structures to eliminate motion artifacts caused by swallowing. The CSF is markedly hyperintense relative to the cord. The vertebral marrow is homogeneous and of similar signal intensity as on T1-weighted images. The CSF appears somewhat inhomogeneous due to pulsation artifacts. The intervertebral discs are of normal height and exhibit some inhomogeneity in signal intensity due to variable fluid content. The posterior neck muscles are clearly seen as low-signal-intensity structures surrounded by fatty tissue

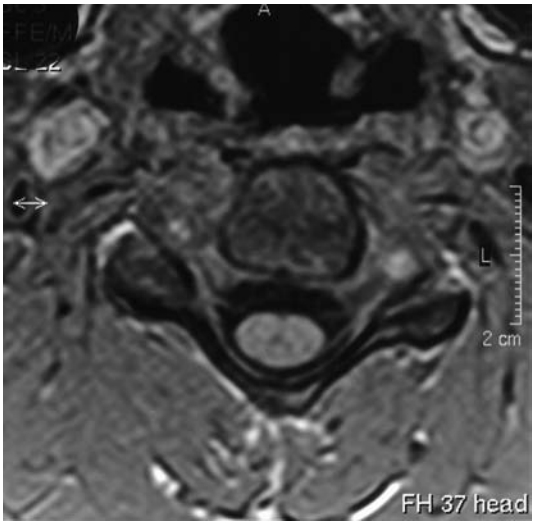


Fig. 1.3. Axial T1-weighted TSE image of the cervical spine through the C4-5 level. There is good visualization of both C5 neural foramina. The spinal nerve roots exiting anteriorly at an angle of about 45° are not very well appreciated on sagittal images. Within the foramina the nerve roots and spinal nerves are seen as low-signal-intensity structures in the bright fatty tissue. The spinal cord has an oval configuration and is well defined by its high signal intensity relative to the surrounding CSF. The posterior portions of the vertebral arch are depicted as delicate bony structures outlined by a dark rim of cortical bone. The vessels are ill-defined relative to surrounding soft tissue

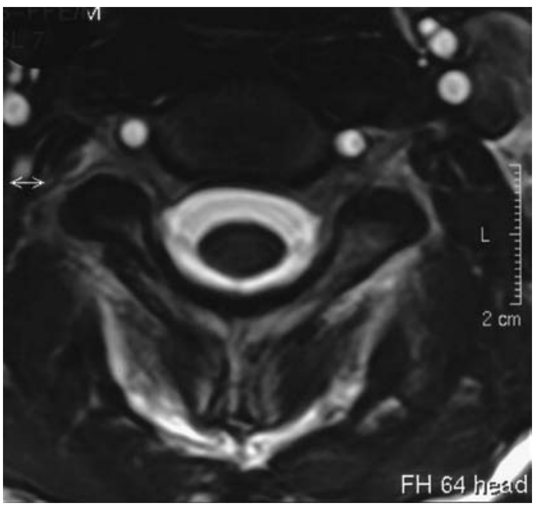


Fig. 1.5. Sagittal T1-weighted image of the thoracic region. Reliable identification of the individual thoracic vertebrae is possible only on images that also visualize portions of the cervical or lumbar spine. The long spinous process at the top is that of C7 (prominent vertebra), thus the spinal region shown extends from C7-T1 to the mid-L2 level. The signal intensities of the different structures are the same as in the cervical region. The epidural fatty tissue posterior to the dural sac is visualized more clearly. The black structure extending down to the T6 level in front of the spine is the air-filled trachea

Fig. 1.4. Axial T2-weighted image of the cervical spine through the C3-4 level obtained with a gradient echo (GRE) sequence. There is good differentiation of the bright CSF and dark, homogeneous spinal cord. Note the bright vessel signal, which is typical of GRE sequences

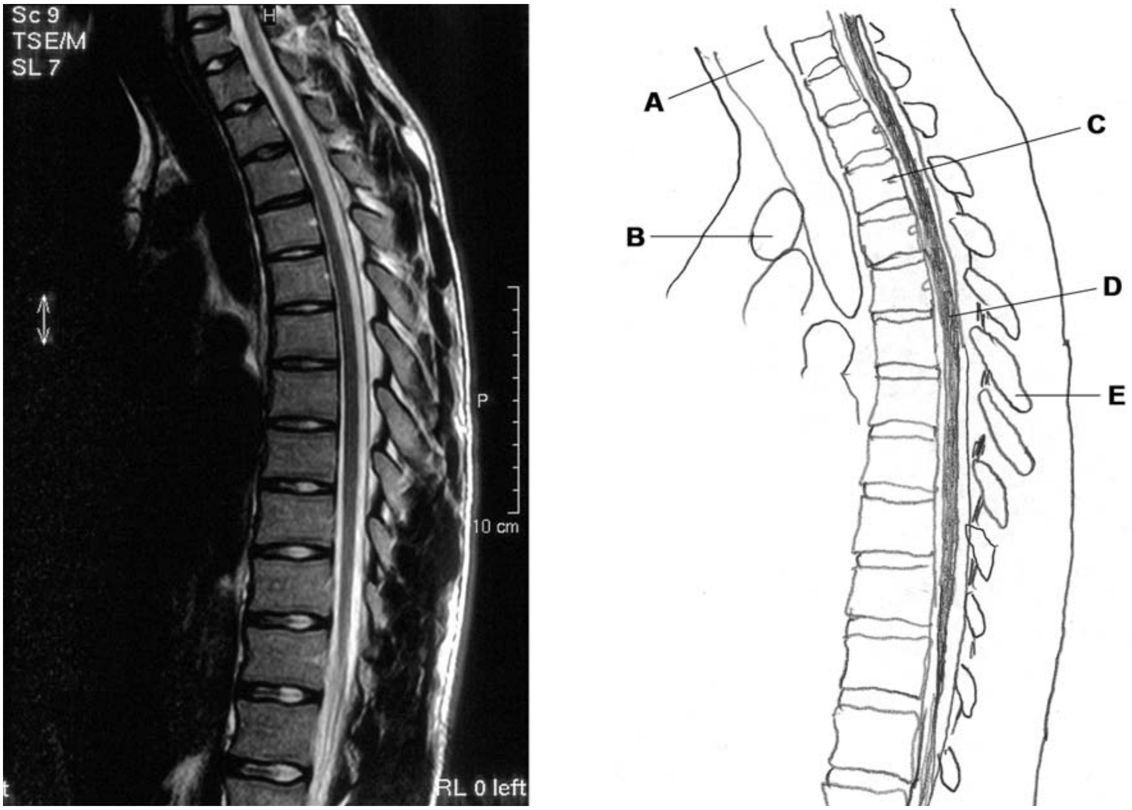


Fig. 1.6. Sagittal T2-weighted image of the thoracic region from C7-T1 to mid-L2. Normal signal intensities of the vertebrae, spinal cord, and soft tissue. Fat and CSF are of the same signal intensity and are separated only by a thin dark line, the dura. **A** trachea, **B** supra-aortic vessels, **C** T3 vertebra, **D** spinal cord, **E** spinous process

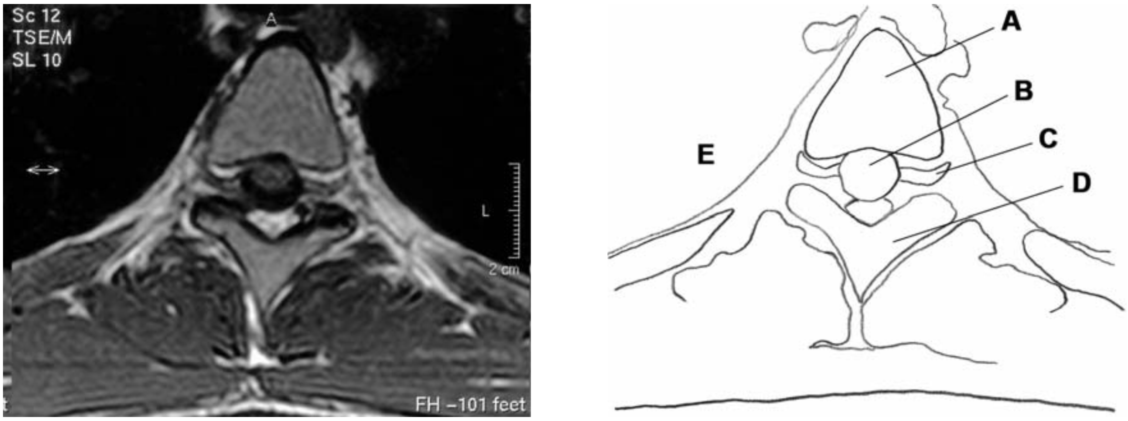


Fig. 1.7. Axial T1-weighted image of the thoracic spine at the level of the T8-9 neural foramina. In relation to the transverse diameter, the anteroposterior diameter of the thoracic vertebral bodies is greater than that of the cervical vertebrae. The nerve roots emerge at an angle of approximately 90°. Within the foramina, the nerve roots are identified by their low signal relative to the bright fatty tissue. The extensor and other back muscles are seen as low-signal-intensity structures relative to fatty tissue in the individual muscle compartments and fasciae. The black areas to the right and left of the vertebral body are the air-filled lungs, which emit no signal. **A** T8 vertebral body, **B** dural sac, **C** left T8 nerve root, **D** vertebral arch/spinous process, **E** lung

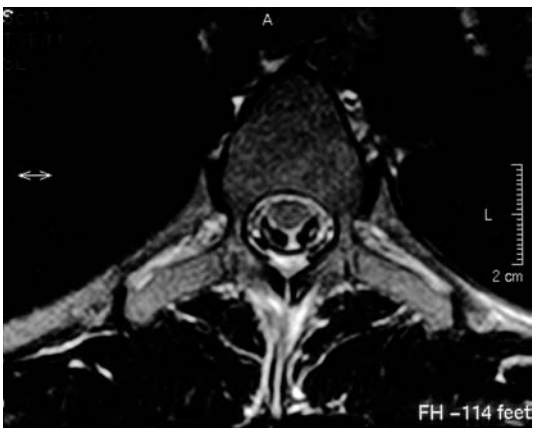


Fig. 1.8. Axial T2-weighted image of the thoracic spine through the T9 level. The pedicles above the neural foramina and the transverse processes are depicted with normal bone signal. The costotransverse joints and portions of the ribs are clearly visible next to the vertebral body and transverse processes. The elongated areas of reduced signal intensity seen in the CSF posterolateral to the cord represent pulsation artifacts

Fig. 1.9. Midline sagittal T1-weighted image of the lumbar spine from T9-10 through S2. The conus medullaris is identified as a slight enlargement of the cord at the T11-12 level. The more delicate nerve fibers of the cauda equina are seen below the conus. Normal appearance and signal intensities of the intervertebral discs and bone

Fig. 1.10. Axial T2-weighted image through the L4-5 level. The neural foramina are oriented anteriorly at an angle of approximately 80°. The facet processes extend posteriorly at an angle of about 45%. The width of the foramina at this level is delimited posteriorly by the facet joints and anteromedially by the disc/L5 endplate. The structures seen posterior to the facet joints are the posterior elements including the spinous process of the L4 vertebra

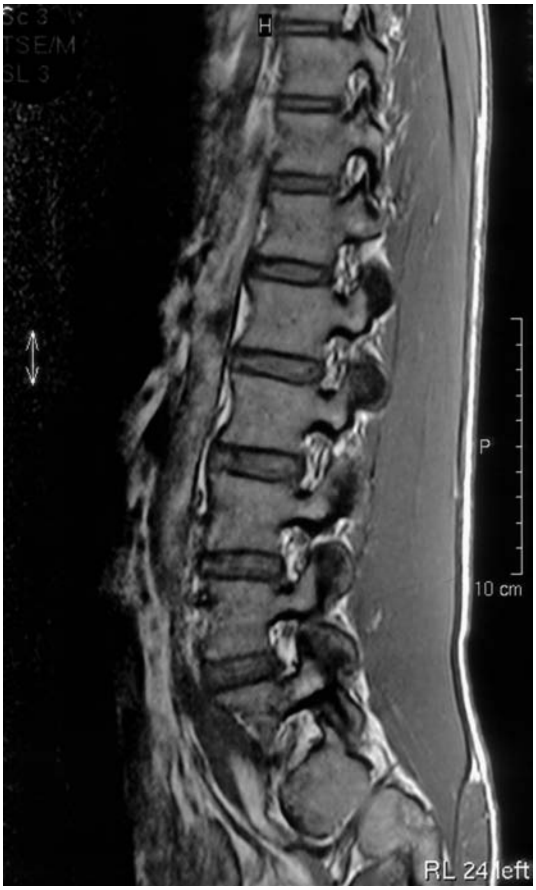
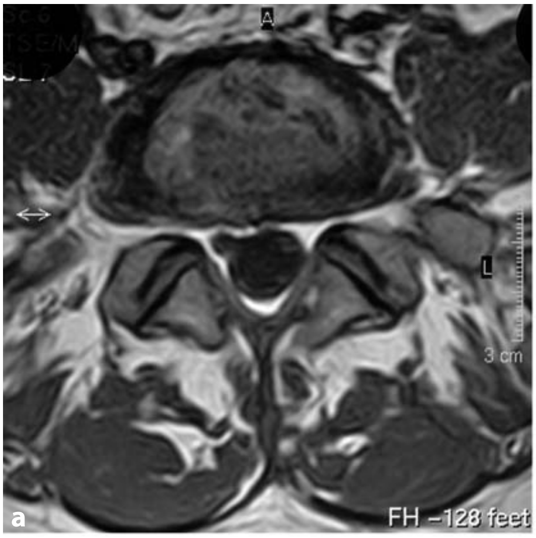


Fig. 1.11. Left parasagittal T1-weighted image of the lumbar spine at the level of the neural foramina. The foramina have an oval configuration with a greater superoinferior diameter. They mostly contain fat in which the spinal nerve roots are discernible as low-signal-intensity punctate structures, typically located in the upper third. The abdominal aorta is seen anterior to the lumbar spine, roughly from T12 through L3-4, as an inhomogeneous vascular structure of mostly high signal intensity. Posterior to the spine, the strong back extensor muscles are depicted as a wide band of intermediate signal intensity beneath the subcutaneous fatty tissue layer

Fig. 1.12. Axial T2-weighted image of the lumbar spine at the L4 level. The Y-shaped hyperintensity in the L4 vertebral body represents venous channels that drain into the epidural veins. The cauda equina fibers are visualized as punctate structures of low signal intensity within the bright CSF. The strong psoas muscle is seen to the right and left of the vertebral body. The inferior vena cava is depicted anterior and to the right of the vertebra adjacent to the two proximal common iliac arteries



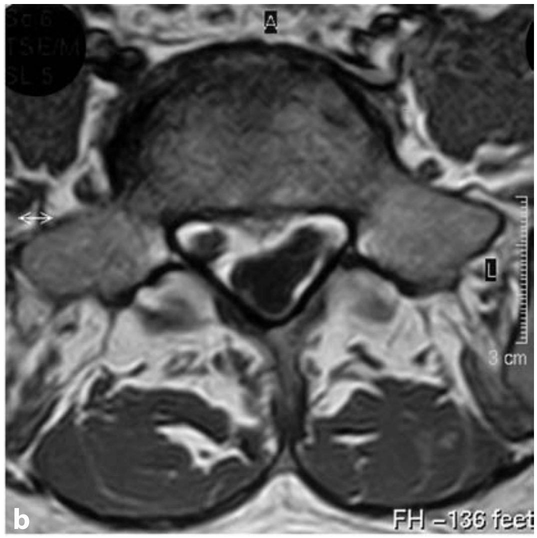


Fig. 1.13a–c. Axial T1-weighted images at the L4-5 and L5 levels. The images illustrate the asymmetrical appearance of the thecal sac resulting from the presence of conjoined L5 and S1 nerve roots on the left

a At this level, only the right L5 nerve root is seen while there is no corresponding root on the left

b The L5 and S1 nerve roots on the left emerge at the same level and are seen as an oval mass

c Both nerve roots are depicted intraspinally to the left of the thecal sac as masses of low signal intensity. On the right, only the L5 nerve root is visualized while the S1 root about to emerge is seen only as an outpouching of the thecal sac

Fig. 1.14. Sagittal T2-weighted image of the lumbar spine and thoracolumbar junction. There is lumbarization of S1 and the lowest intervertebral disc is therefore that of the S1-2 segment. In addition, there are marked degenerative changes of the lower lumbar spine with posterior intervertebral disc herniations at the L3-4 and L4-5 levels