

18.5 Normal ultrasonographic appearance of the spinal cord in the three acoustic windows

18.5.1 Atlanto-occipital acoustic window

The atlanto-occipital acoustic window corresponds to the junction between the occiput and the atlas. In the sagittal plane, the spinal cord appears as a homogeneous tubular hypoechoic structure that is curved cranio-ventrally, with echoic margins referable to the pia mater and a well-defined echoic central line corresponding to the central canal (► Fig. 18-7a).

The subarachnoid space appears as an anechoic area dorsal and ventral to the spinal cord due to the normal presence of cerebrospinal fluid. The subarachnoid space is externally delimited by a hyperechoic line referable to the dura mater together with the arachnoid and coinciding with the margin of the spinal canal. In fact, the dura mater and arachnoid membrane cannot be differentiated from each other ultrasonographically.

Cranially the spinal cord shows an enlargement corresponding to its transition into the medulla oblongata at the level of the great foramen, whereas the central canal is displaced dorsally. At this point it is possible to image ultrasonographically an anechoic triangular space, whose size may vary depending on the degree of head flexion: it corresponds to the caudal portion of the cerebrospinal fluid-filled fourth cerebral ventricle. By flexing the head, it is possible to highlight additionally echoic structures consistent with parts of the medulla oblongata, pons and cerebellum (► Fig. 18-7a). In the transverse view, the spinal cord appears as an ellipsoid hypoechoic structure with echoic margins (pia mater). The central canal is visible as an echoic dot that is surrounded by a hypoechoic butterfly-shaped image in the transverse plane, corresponding to the grey matter. In the transverse plane, the subarachnoid space has a mildly echoic, striated appearance that may not be so evident in sagittal imaging. This echoic lattice is due to the presence of the trabeculae of the subarachnoid space that connect the arachnoid and pia mater.

If the probe is angled at 45° cranio-ventrally, the caudal portion of the fourth cerebral ventricle appears as an anechoic semilunar space between the spinal cord and the subarachnoid space.

Lateral to the spinal cord, it is possible to image the emergence of the echoic denticulate ligaments as well as

the emergence of the echoic dorsal and ventral roots, respectively, dorsal and ventral to the denticulate ligament. Round anechoic areas can be depicted dorsolateral to the echoic dura mater: they can be confirmed by color Doppler examination to be vessels in the hypoechoic epidural space. The presence of fat and/or connective tissue in the epidural space explains its slight echogenicity. Dorsal to the neural structures it is possible to differentiate the dorsal atlanto-occipital membrane (a thick hyperechoic band) and the major dorsal straight muscle of the head.

Laterally, the rims of the occipital condyles are represented by two hyperechoic medially concave curved lines, which are responsible for distal acoustic shadowing (► Fig. 18-7b) (Testoni et al. 2010a, b, Testoni et al. 2012, Gentile et al. 2012, Braun et al. 2015, Braun and Attiger 2016).

18.5.2 Lumbar acoustic window

The lumbar acoustic window corresponds to the L5-L6 interlumbar space. In the sagittal plane, the spinal cord appears as a hypoechoic tubular structure with echoic margins (pia mater) and a central echoic single line corresponding to the central canal. The spinal cord is surrounded by the anechoic cerebrospinal fluid in the subarachnoid space. The arachnoid-dura mater complex corresponds to the echoic margin of the spinal canal dorsal and ventral of the subarachnoid space (► Fig. 18-8a). The epidural space can be imaged as a thin hypoechoic space adjacent to the arachnoid-dura mater complex (hyperechoic line).

A transverse view of the spinal cord shows the hypoechoic, oval spinal cord with the echoic central echo and the echoic pia mater directly surrounding the spinal cord lying within the anechoic subarachnoid space (► Fig. 18-8b). It is not always possible to differentiate the butterfly-shaped grey matter of the spinal cord in the interlumbar window. The spinal cord gives rise to the paired echoic dorsal and ventral nerve roots, and it is fixed in position by the denticulate ligaments, which merge laterally from the spinal cord as echoic structures.

The surfaces of the vertebral bodies appear as hyperechoic contours ventral to the spinal cord. The hyperechoic vertebral arches produce ventral acoustic shadows on transverse views, and the hyperechoic contours of the spinous processes dorsally produce ventral acoustic shadows in sagittal views. The epaxial muscles appear as hypoechoic areas adjacent to the laminae (► Fig. 18-8b) (Testoni et al. 2010a, b, Testoni et al. 2012, Gentile et al. 2012, Braun and Attiger 2016).

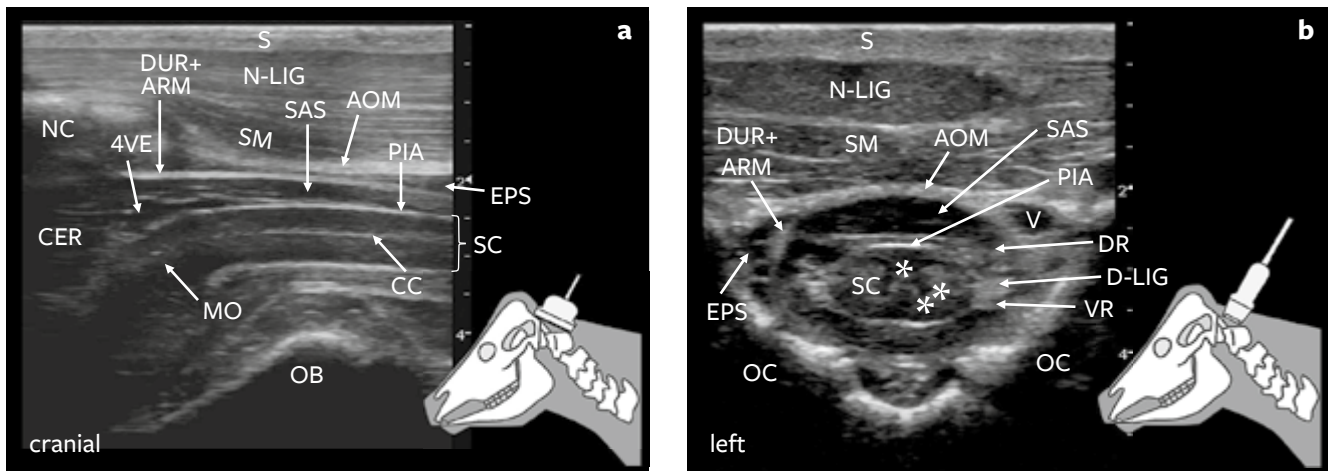


Fig. 18-7a, b: Sagittal (a) and transverse (b) sonograms (7.5 MHz linear) of the spinal cord taken at the atlanto-occipital acoustic window of a one-month-old Holstein calf, showing a normal ultrasonographic appearance of the relevant anatomical structures; in order from outside to inside: the skin (**S**), the nuchal ligament (**N-LIG**), the nuchal crest (**NC**) of the occipital bone, the major dorsal straight muscle of the head (**SM**), the thick echoic dorsal atlanto-occipital membrane (**AOM**), the anechoic epidural space (**EPS**), the echoic dura mater with the arachnoid membrane (**DUR+ARM**), the anechoic subarachnoid space (**SAS**), the echoic pia mater (**PIA**), the homogeneous tubular hypoechoic spinal cord (**SC**) with the thin echoic central canal (**CC**) originating cranially from the medulla oblongata (**MO**); the cerebellum (**CER**), the anechoic 4th ventricle (**4VE**), the hyperechoic contour of the occipital bone (**OB**). All of these structures can also be differentiated in the transverse sonogram (**b**). Furthermore, the gray (*) and white matter (**) of the spinal cord (**SC**), the dorsal (**DR**) and ventral roots (**VR**) of the segmental nerves and the denticulate ligament (**D-LIG**) can be distinguished; vessel (**V**) and the hyperechoic contour of the occipital condyles (**OC**).

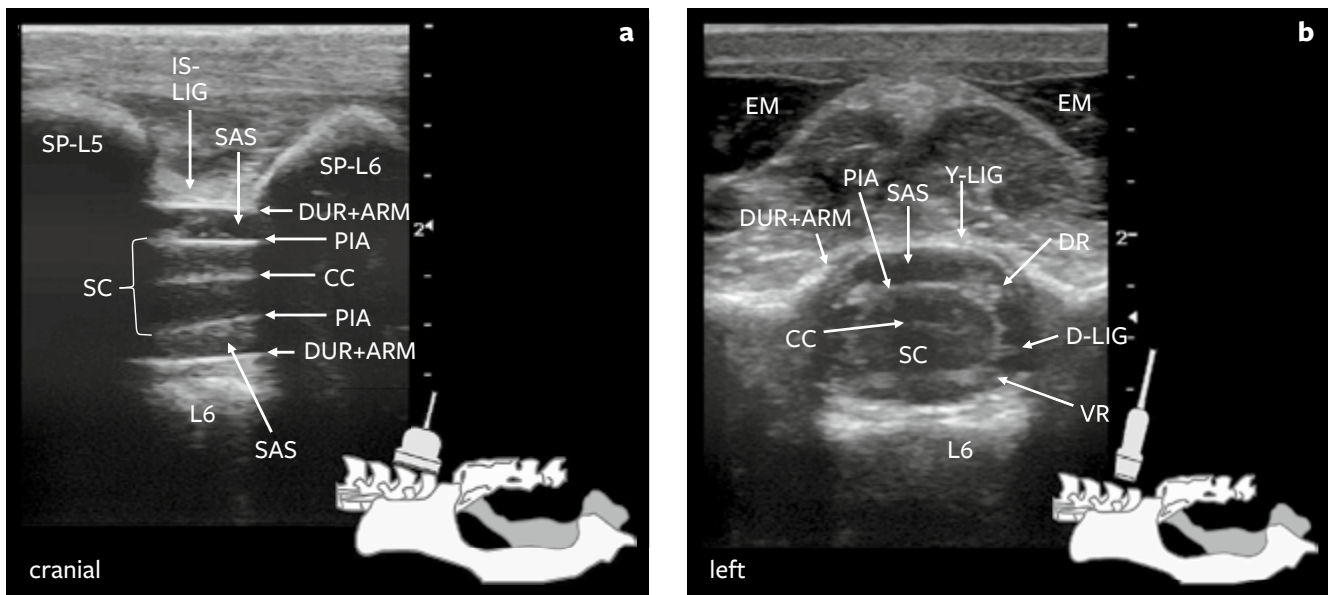


Fig. 18-8a, b: Sagittal (a) and transverse (b) sonograms (7.5 MHz linear) of the spinal cord taken at the lumbar window between the spinous processes of the 5th (SP-L5) and 6th lumbar vertebrae (SP-L6) of a one-month-old Holstein calf showing a normal ultrasonographic appearance of the relevant anatomical structures: the echoic interspinous ligament (**IS-LIG**), the echoic dura mater with the arachnoid membrane (**DUR+ARM**), the anechoic subarachnoid space (**SAS**), the echoic pia mater (**PIA**), the homogeneous tubular hypoechoic spinal cord (**SC**, **bracket**) with the thin echoic central canal (**CC**); and the hyperechoic contour of the vertebral body of **L6**. All these structures can also be differentiated in the transverse sonogram (**b**). Further, the echoic dorsal (**DR**) and ventral roots (**VR**) of the segmental nerves, the echoic denticulate ligament (**D-LIG**) and the yellow ligament (**Y-LIG**) dorsally are visible. The epaxial muscles (**EM**) appear as hypoechoic areas located dorsal to the vertebral arch.

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