

Radiologic Anatomy of the Sacral Canal

Veronica Macchi, Andrea Porzionato, Aldo Morra, Carla Stecco, and Raffaele De Caro

Abstract The extradural space is currently investigated through fluoroscopy and ultrasound for surgical approach, whereas magnetic resonance imaging has been used to provide detailed information. The aim of the present paper is to describe the radiologic anatomy of the sacral canal through a review of its appearance in the different radiologic techniques. CT is able to visualise also the sacrum and the content of the sacral canal, triangular in shape in the transverse images, being able to establish the measurement of the transverse area of the dural sac and of the canal diameter. On the sagittal CT scans, the sacrococcygeal membrane appears as a hypodense structure, between the posterior end of the sacral vertebra and the posterior tip of the coccyx. In magnetic resonance imaging, on T2-sagittal plane images, the sacral canal appears hyperintense, due to the presence of the liquor. The dural sac appears as a hypointense band and its termination as hypointense cul de sac in the context of the hyperintensity of the sacral canal. The sacrococcygeal membrane appears as a hypointense band between the posterior end of the sacral vertebra and the posterior tip of the coccyx. On ultrasound imaging, in the transverse sonographic view, two hyperechoic reversed U-shaped structures correspond to the two bony prominences of sacral cornua, between which there were two hyperechoic band-like structures. The band-like structure on top is the sacrococcygeal ligament. The band-like structure at the bottom is the dorsal surface of the sacrum. The sacral hiatus corresponds to the hypoechoic region observed between the two hyperechoic band-like structures.

Keywords Sacral hiatus · Sacral canal · Extradural space

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Introduction

Spina bifida occulta is a condition where there is incomplete fusion of the neural arch of the vertebra, usually in the lumbosacral region [1]. When this condition occurs in the sacrum, the level of non-closure of the lamina of the sacral bodies is variable [2]. Many sacra have S5 or also S4 open, exposing the dorsal surface of the fifth sacral body [3]. Many radiological studies have investigated the prevalence of this condition in the sacrum in various populations, also analysing X-rays that were originally taken for other diagnostic purposes [4], or combined X-ray and computed tomography to determine the level of sacral crest closure [5], raising the question as to whether a standard frontal X-ray image of the whole of the sacrum gives a clear enough image to confidently diagnose spina bifida occulta at all levels [6].

The extradural space has also been investigated through fluoroscopy [7] or ultrasound [8–14] for surgical approach, whereas magnetic resonance imaging has been used to provide detailed information on the anatomy of the extradural space in living subjects [15].

The aim of the present study is to describe the radiologic anatomy of the sacral canal through a review of its appearance in the different radiologic techniques.

X-Rays

In an antero-posterior projection of the pelvis, the sacrum appears as a large, triangular bone, derived from the fusion of five vertebrae; its blunted, caudal apex articulates with the coccyx. In the lateral radiograph, the sacrum shows its pelvic concavity, opened infero-anteriorly, which continues with the supero-anteriorly opened concavity of the coccyx [16]. Thus, the sacrum does not lie in the coronal plane, because of the sharp lumbosacral angle. Moreover, the bone is more vertical in males than in females and the female sacrum is more curved, especially in the lower half of the bone [17].

A tilt of the X-ray beam 10–15° [17] or 20° [18] cephalad allows the best possible view of this bone, and the angle may need to be increased if there is a greater posterior tilt of the sacrum, for example in a female patient [17]. In a comparative study between X-ray and cadavers dissection, Albrecht et al. [6] found that a single antero-posterior view with 10–15° cephalad angulation provided the clearest image of the whole sacrum.

In an antero-posterior (Fig. 1) X-ray of the sacrum, the sacral hiatus appears as a more radiotransparent zone at the lower end of the sacrum, due to the presence of the inverted U- or V-shaped foramen, formed by the failure of the vertebral arch at fifth sacral vertebra to meet in the median plane. The sacral hiatus is covered by fibrous tissue (sacroccocyx membrane) [3]. A complicating factor in diagnosing images of this area is the presence of intestinal gas, fecal matter, and the full urinary bladder overlying the sacrum. This can make it difficult to see the sacrum and hence make it difficult to diagnose. For this reason, radiography positioning texts [17–19] recommend that the patient both empties the bladder and has a cleaning enema before a sacral X-ray. This rarely occurs in practice, especially if the X-rays are not specifically requested for the sacrum.

Fluoroscopy is most commonly used in interventional spine procedures [20] and is frequently used in confirming the location of caudal epidural needle. It has been advocated that caudal epidural needle placement should be confirmed by fluoroscopy alone or by epidurography [7]. Radiographic contrast administration can confirm the location of the caudal epidural needle with the Christmas tree-like appearance, due to the bath of the contrast dye of the external aspect of the dura mater and nerve roots [8]. Radiation exposure is the major concern when obtaining fluoroscopic

images; actually pulsed imaging is preferred during fluoroscopy because it can reduce overall exposure by 20–75% [7].

Although myelography has been replaced in large part by MR imaging, it remains indicated in some instances (for instance the presence of metal hardware that precludes examination of the spinal canal and cord by magnetic resonance imaging or computed tomography). Subarachnoid contrast agent for myelography is most commonly introduced by a lumbar approach and in these cases lateral fluoroscopy can be helpful in determining an entry site on the skin slightly caudal to the hiatus at about the S5 level, allowing for alignment of the needle nearly parallel to the posterior aspect of the upper sacral vertebral bodies [21].

Computed Tomography

Computed tomography (CT), with its cross-sectional scan provides the capability to visualize the sacral canal, formed by sacral vertebral foramina, and appears triangular in axial images. Its caudal opening is the sacral hiatus. In the sagittal CT images, the sacroccocygeal membrane appears as a hypodense structure, between the posterior end of the sacral vertebra and the posterior tip of the coccyx (Fig. 2). CT is able to visualise also the content of the sacral canal, being able to establish the measurement of the transverse area of the dural sac and of the canal diameter [22]. Solomon et al [23] studied the opening of the sacral canal in 2 population groups: born 1940 to 1950 and 1980 to 1990 and have reported that the individuals born later have significantly more open sacral arches when compared with those born 40 years earlier, especially in the midsacral region. Also,

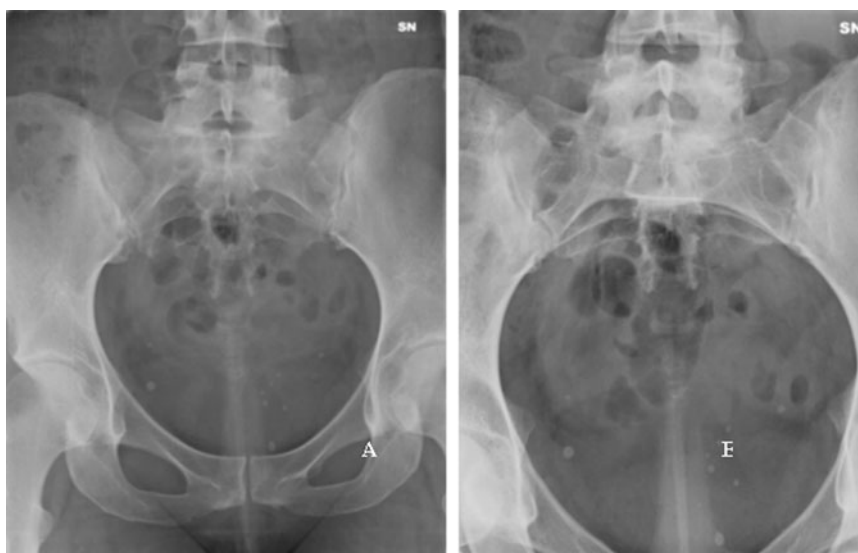
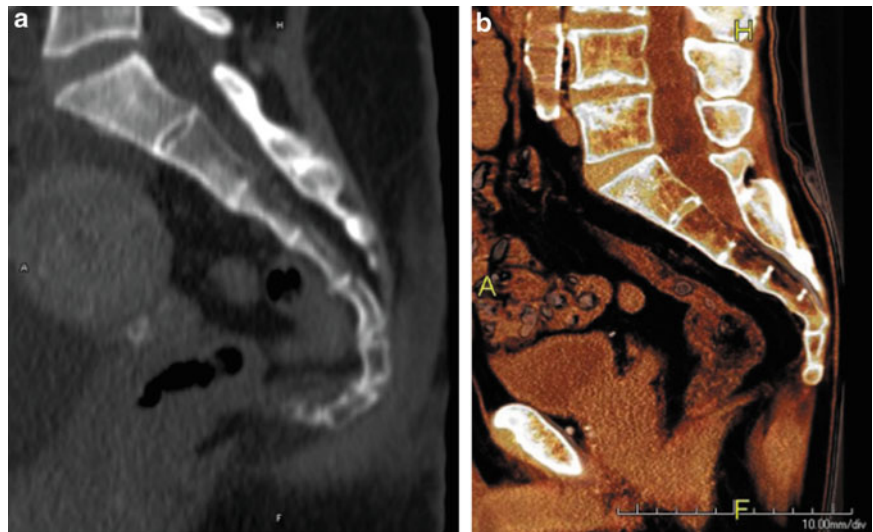


Fig. 1 Antero-posterior radiograph of the sacrum showing the sacral hiatus

Fig. 2 CT sagittal image (a) and volume rendering reconstruction (b), showing the caudal space, the sacrococcygeal membrane appears hypodense (*asterisk*)



males have open sacral arches in the rostral segments of the sacrum more than females. CT can be used as guide for sacroplasty for the proper cannula placement prior to cement injection [24]. CT is able also to show with great details the soft tissues and on in vivo CT studies, Scapinelli [25] documented the appearance of the lumbo-sacral meningo-vertebral ligaments, most commonly on transverse images, as a median sagittal septum, easily identifiable when the extradural fat that it crosses is abundant.

Magnetic Resonance Imaging

Magnetic resonance (MR) imaging offers a detailed representation of the sacral canal and of its content (cauda equina and the filum terminale, and the spinal meninges) with a high quality tissue contrast and on multiple planes. Opposite the middle of the sacrum, the subarachnoid and subdural spaces close: the lower sacral spinal roots and filum terminale pierce the arachnoid and dura mater at that level [3]. The images of the sacrum have been obtained on sagittal and transverse planes. It can also be visualised whole or in part during the exams of the lumbar vertebral columns. Usually a phase array spine coil is used and the patient is in the supine position. The relevant anatomy of the sacral canal is demonstrated by the T2-sagittal plane images [15, 26, 27], in which the sacral canal appears hyperintense, due to the presence of the liquor. The dural sac appears as a hypointense band and its termination as hypointense cul de sac in the context of the hyperintensity of the sacral canal. The sacrococcygeal membrane appears as an hypointense band between the posterior end of the sacral vertebra and the posterior tip of the coccyx (Fig. 2). McDonald et al. [15] reported that the median level of termination of the dural sac is located at the level of the middle one third of the S2, extending from the upper border

of S1 to the upper border of S4. The mean level for males was also the upper one-third of S2 and for females the middle one-third of S2. Crighton et al. [27] reported that the distance of termination of the dural sac from the beginning of the sacrococcygeal membrane was 1.4 cm (Fig. 3).

Ultrasonography

Diagnostic imaging including plain radiography, computed tomography, and magnetic resonance imaging can provide accurate anatomic information regarding the location of the epidural space, but their use is impractical in most clinical settings where epidural analgesia is used. In contrast, the safety and feasibility of bedside ultrasonography during pregnancy or in neonates or children are well established [8–14]. The sacral canal is studied with patient in prone position and a linear-array ultrasound transducer by using the “acoustic window” [10] in both the longitudinal midline and cross-sectional planes to identify the sacral hiatus. In the transverse sonographic view, two hyperechoic reversed U-shaped structures correspond to the two bony prominences of sacral cornua, between which there are two hyperechoic band-like structures. The band-like structure on top is the sacrococcygeal ligament. The band-like structure at the bottom is the dorsal surface of the sacrum. The sacral hiatus corresponds to the hypoechoic region observed between the two hyperechoic band-like structures [8, 11]. The longitudinal view is obtained by rotating the transducer 90°. In the longitudinal sonographic view, the hyperechoic structure corresponds to the ventral end of the sacrum, and the deep hyperechoic band like structure corresponds to the posterior surface of the sacrum. The hypoechoic band-like structure between the two hyperechoic zones corresponds to the sacrococcygeal ligament.



Fig. 3 MR sagittal image of the caudal space

To avoid the most important limitation of the ultrasound-guided caudal epidural injection, i.e. inadvertent intravascular injection [28, 29], color Doppler ultrasonography can be added. The color Doppler ultrasonography shows unidirectional flow (observed as one dominant color) of the injection of the solution through the epidural space beneath the sacrococcygeal ligament, with no flows being observed in other directions (observed as multiple colors) [14].

Conflicts of Interest Statement We declare that we have no conflict of interest.

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