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ORIGINAL ARTICLE

Surgical anatomy of the presacral area

Mustafa Güvençer · Sedat Dalbayrak · Hamid Tayefi · Süleyman Tetik · Mesut Yılmaz · Ufuk Erginoğlu · Özdil Baksan · Salih Güran · Sait Naderi

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Abstract
Objective L5–S1 instabilities can be fixated using minimally invasive presacral approach. The close relationship between the sacrum and neurovascular as well as intestinal structures may complicate the procedure during this approach. This requires knowledge regarding the normal anatomy of the presacral area to avoid the iatrogenic injuries. The aim of this study was to measure the distance between the sacrum and the structures anterior to it.
Materials and methods The measurements were performed on ten cadavers fixed with formaldehyde and ten MR imaging studies on individuals without any pathology in the presacral area. The distances between the sacrum and the presacral structures (i.e., middle and lateral sacral arteries, sympathetic trunks, internal iliac arteries and veins, and colon/rectum) were measured.
Results Cadaver study showed that the middle sacral artery was located on the right side in 55.0%, on the left side in 31.7%, and on the midline in the 13.3% of cases. The distance between the sacral midline and middle sacral artery was found to be 8.0 ± 5.4, 9.0 ± 4.9, 8.7 ± 6.0, 8.6 ± 6.4, and 4.7 ± 5.0 mm at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively. The distance between the sacral midline and the sympathetic trunk ranged between 22.4 ± 5.8 and 9.5 ± 3.2 mm in different levels between S1 and coccygeal level. The study also showed that the distance between the posterior wall of the intestine (colon/rectum) and the ventral surface of the sacrum can be as close as 11.44 ± 7.69 mm on MR images.
Conclusion This study showed that there was close distance between the sacral midline and the structures anterior to it. The close relationships, as well as the potential for anatomical variations, require the use of sacral and presacral imaging before presacral approach.

Keywords Middle sacral artery · Presacral anatomy · Presacral approach · Sympathetic trunk

M. Güvençer (✉) · H. Tayefi · S. Tetik
Department of Anatomy, School of Medicine,
Dokuz Eylül University, 35340 Balçova, Izmir, Turkey
e-mail: mustafa.guvencer@deu.edu.tr

S. Dalbayrak · M. Yılmaz · U. Erginoğlu
The First Department of Neurosurgery,
Dr Lütfü Kırdar Research Hospital, Istanbul, Turkey

Ö. Baksan · S. Güran
Sonomed Radiodiagnostic Center, Istanbul, Turkey

S. Naderi
Department of Neurosurgery,
Ümraniye Education and Research Hospital, Istanbul, Turkey

Introduction

L5–S1 intervertebral disc level has been the target of fusion in many clinical situations, including L5–S1 instability, lumbar degenerative scoliosis, and L5–S1 pseudoarthrosis [1, 6, 16, 25]. This level can be fixated using classical anterior, posterior, and lateral approaches. Some rare surgical procedures, such as total L5 spondylectomy with reconstruction of the lumbosacral junction by ventral approach, need evaluation of structures in presacral area to mobilize vascular structures during surgical stage [12]. Recently, a novel minimally invasive presacral approach has been proposed to fixate L5–S1 level axially [6, 16, 26]. This approach requires a small incision lateral to the sacrococcygeal junction, blunt dissection anterior to the sacrum, drilling at the level of S1–2, and fixation of the L5–S1 level. Although there is no need for neural and muscular

retraction during this approach, the close relationship between the sacrum and the structures anterior to it require a special attention [6, 16, 26].

The presacral area is a retroperitoneal space, located between the presacral fascia of the sacrum (Waldeyer's fascia) and parietal peritoneum of the posterior abdominal wall. It contains retrorectal fat, areolar tissue, lymph nodes, median sacral vessels, and superior rectal vessels. It extends from the peritoneal reflection at the rectosigmoid junction to the pelvic bottom [6, 8, 14, 17, 18]. The lateral aspects of the presacral area contain internal iliac artery (IIA), internal iliac vein (IIV), lateral sacral artery (LSA), sympathetic trunk (ST), hypogastric nerves, and inferior hypogastric plexus at the lower levels. The aforementioned structures are under risk of injury during this approach, particularly in case of anatomical variations, as well as in case of deviation from the midline during the surgery. The presence of the presacral anastomoses between the lateral and middle sacral veins complicates the presacral vascular anatomy [2, 5, 24]. On the other hand, the hypogastric nerves and ST may be injured during anterior lumbosacral surgery, leading to retrograde ejaculation [1, 6, 20, 22]. The aim of this study is to determine the distance between the sacral midline and paramedian lines and presacral structures [middle sacral artery (MSA), LSA, ST, and intestine].

Materials and methods

The measurements in the presacral space were performed in ten intact and healthy (no presacral vertebral and vascular abnormality) adult male cadavers fixated with formaldehyde and in MR images of ten intact individuals (six males, four females; mean age 42.5 years, ranging between 32 and 55 years).

The cadaveric study was performed after exposure of the area between L4 and coccyx. After retraction of the rectum and sigmoid colon, the parietal peritoneum and fascia covering the presacral space were opened. The fat tissue surrounding the MSA, the LSA, and the ST was dissected. The midline between the promontorium and the coccygeal apex was determined. The location of the MSA is shown in Figs. 1 and 2, the LSA in Fig. 3, and the ST in Fig. 4 (Table 1, Part A). The cadaveric measurements were performed using a caliper sensitive to 0.1 mm.

Evaluation of the intestine-related axial parameters required a radiological measurement to prevent dissection-related deviations. Therefore, distance of the intestine (colon/rectum) and the midline was measured on MR images (Fig. 5; Table 1, Part B). However, the cadaveric intestinal structures were not appropriate for radiological study. Therefore, this part of the study was performed in healthy individuals.

The radiological measurements were performed digitally in work-station of 1.5-T MR system (Gyroscan Intera, Philips Medical Systems, the Netherlands). The coronal and sagittal (TSE) T2-weighted images were taken into consideration.

Results

Cadaveric measurements

The MSA was found to be on the right side in 33 levels (55.0%), on the left side in 19 levels (31.7%), and on the midline in eight levels (13.3%) (Fig. 1; Table 2). The diameter of the MSA was measured as 2.8 ± 0.5, 2.6 ± 0.4, 2.6 ± 0.4, 2.5 ± 0.4, 2.4 ± 0.4, and 2.3 ± 0.3 mm at the levels of L5–S1, S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively (Fig. 2).

The distance between the MSA and midline was found to be 8.0 ± 5.4, 9.0 ± 4.9, 8.7 ± 6.0, 8.6 ± 6.4, and 4.7 ± 5.0 mm at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively (Fig. 2). This distance was not changed significantly, except for S5–coccyx level. The distance between the LSA and the midline ranged between 17.4 ± 7.5 and 29.8 ± 4.1 mm on the right side and between 14.9 ± 2.1 and 33.2 ± 4.1 mm on the left (Table 3; Fig. 3). While the distance between the right and left IIAs was found to be 59.2 ± 7.8 at the S1–2 level, the distance between the IIVs was found to be 54.0 ± 12.2 mm at the same level. The ST converged as it descends from S1–2 level to the S5–C1 level (Table 4; Fig. 4).

Radiological measurements

The distance between intestine (colon/rectum) and the midline was found to be 20.6 ± 16.5, 23.5 ± 23.1, 23.0 ± 23.4, 13.0 ± 8.9, and 11.4 ± 7.7 mm at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively (Fig. 5). The distance between intestine (colon or rectum) and paramedian line 1 cm to the right of the midline was found to be 13.4 ± 9.5, 23.9 ± 19.8, 24.1 ± 19.8, 18.3 ± 16.9, and 12.61 ± 8.45 mm at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively. The distance between intestine (colon or rectum) and paramedian line 1 cm to the left of the midline was found to be 21.6 ± 9.4, 21.9 ± 19.8, 15.1 ± 5.9, 13.9 ± 7.9, and 13.0 ± 8.5 mm at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx, respectively (Table 5; Fig. 5).

Discussion

The classical anterior, lateral, and posterior approaches have been used for many years for the treatment of the lumbosacral disorders [1, 10, 15, 16, 21, 23, 25]. All these

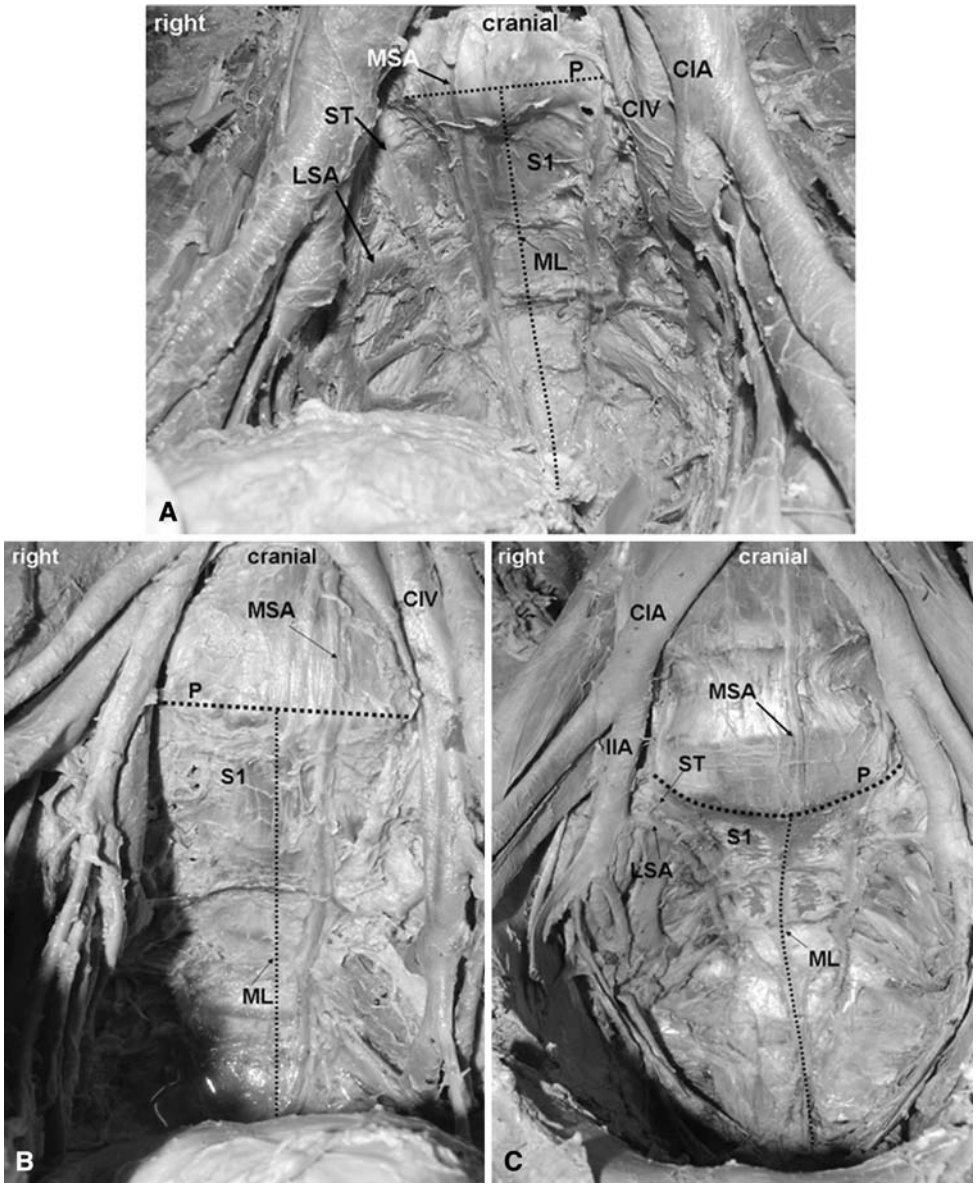

Fig. 1 Position of MSA for ML. **a** MSA is on the *right*. **b** MSA is on the *left*. **c** MSA is on the ML. *MSA* middle sacral artery, *ML* midline, *ST* sympathetic trunk, *LSA* lateral sacral artery, *P* promontorium, *CIA* common iliac artery, *CIV* common iliac vein, *IIA* internal iliac artery

approaches require retraction of muscle, ligament, neural tissues, and vessels. On the other hand, the developments of new technologies have increased the use of the minimally invasive approaches. Minimally invasive anterior lumbar interbody fusion (ALIF) procedure has been popular in the last decade [9, 23]. As in all surgical procedures, a variety of visceral and vascular complications was reported using minimally invasive ALIF procedures [1, 4, 9, 13, 23].

Presacral approach is a novel minimally invasive approach to the L5–S1 intervertebral disc level [6, 16, 23, 26]. It aims L5–S1 discectomy and fixation as well as fusion of this level using a new corridor. Although, there are a variety of anatomical and radiological studies focusing on the neurovascular structures anterior to the L5–S1 level, there are few studies focusing on the presacral anatomy addressing the presacral approach [6, 16, 18, 26].

There exists many neurovascular and intestinal structures in the presacral area, including intestine and MSA in the midline and LSA, IIA, IIV and ST anterolateral to the sacrum. While cadaver measurement can be performed to reveal the neurovascular parameters, the intestine-related measurements cannot be achieved in the cadaver studies. Therefore, a MRI study was also designed to measure the remaining parameters.

Middle sacral artery

Although the MSA is relatively a small vessel (2.3–2.8 mm in diameter), it has been the focus of many anatomical studies addressing ALIF procedure. The location of the venous structures in the presacral area has been the focus of many studies [2, 5, 24]. While Wieslander et al. reported that the

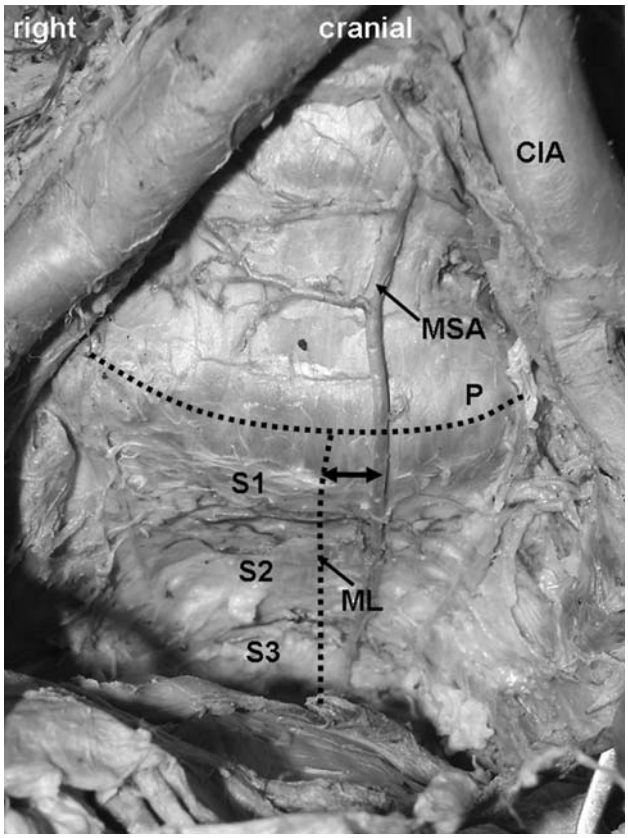

Fig. 2 The measurement of the distance between MSA and ML. *MSA* middle sacral artery, *ML* midline, *CIA* common iliac artery, *P* promontorium

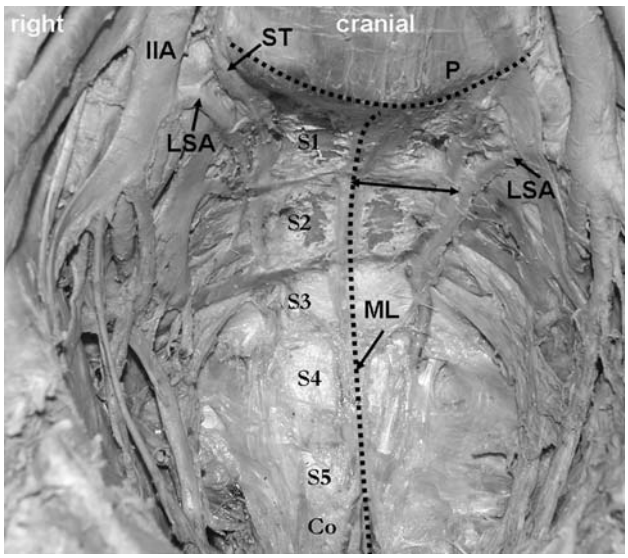

Fig. 3 The measurement of the distance between LSA and ML. *LSA* lateral sacral artery, *ML* midline, *IIA* internal iliac artery, *P* promontorium, *ST* sympathetic trunk

MSA was located on the midline in 8.2% of 54 cadavers [28], Flynn et al. reported that the MSA was located on the midline in eight of eleven cases and crossed the midline in

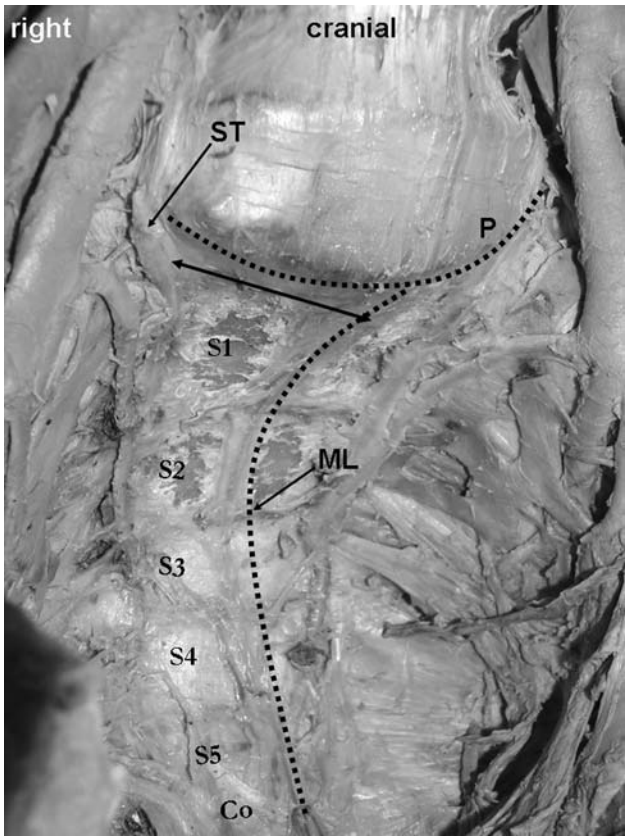

Fig. 4 The measurement of the distance between ST and ML. *ST* sympathetic trunk, *ML* midline, *P* promontorium, *Co* coccyx

almost all cases [11]. This study revealed that the MSA was located on the midline or near the midline. It was found to be on the midline in only 13.3% of cadavers. In the remaining cases, it was 4.7–9.0 mm lateral to the midline.

The detection of the position of the MSA is of importance during paracoccygeal approaches. The precise preoperative determination of MSA is not always possible even on MR angiography studies because of its extreme variability. The surgeon should be aware of this variability. A preoperative angiography should be planned in cases with suspect venous structures in the presacral area.

Sympathetic trunk and lateral sacral artery

Sympathetic trunk and LSA are lateral to the sacral midline, and converge descending from S1–2 level to the S5–coccyx level. The distance between the LSA and midline was measured as 10.6 ± 3.5 mm on the right side and as 14.9 ± 2.1 mm on the left side, at the level of S5–coccyx.

Sympathetic trunk is medial to the LSA. The distance between the ST and midline was measured as 9.5 ± 3.2 mm on the right side and as 9.9 ± 3.7 mm on the left side, at the level of S5–coccyx. The aforementioned distances should be taken into consideration during paracoccygeal approach.

Table 1 The list of measured parameters on cadavers and on MR images

(A) The parameters measured on the cadaver:
The distance between the right and left IIA at the level of S1–2
The distance between the right and left IIV at the level of S1–2
The location of the MSA at different levels
The diameter of the MSA at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx
The distance between the MSA and midline at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx
The distance between LSA and midline at the levels of S2–3, S3–4, S4–5, S5–coccyx
The distance between the ST and midline at the levels of S1–2, S2–3, S3–4, S4–5, and S5–coccyx
(B) The parameters measured on MR images:
The distance between the midline and intestine (colon or rectum) at the levels of S1–2, S2–3, S3–4, S4–5
The distance between the intestine (colon or rectum) and paramedian line 1 cm to the right of the midline at the levels of S1–2, S2–3, S3–4, S4–5
The distance between the intestine (colon or rectum) and paramedian line 1 cm to the left of the midline at the levels of S1–2, S2–3, S3–4, S4–5

MSA middle sacral artery, *LSA* lateral sacral artery, *IIA* internal iliac artery, IIV internal iliac vein, *ST* sympathetic trunk

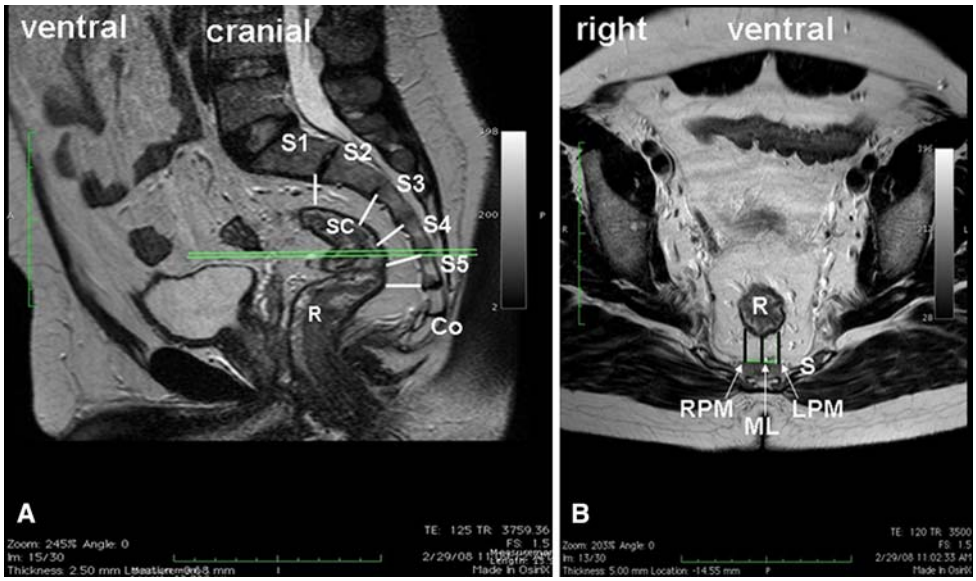

Fig. 5 The measurement methods in MRI study. **a** The measurement of the distance between the anterior surface of the sacrum and posterior surface of the colon/rectum at different sacral levels. **b** The measurement of the distance between the anterior surface of the sacrum and posterior surface of the colon/rectum in the ML, and on 1 cm to the right (RPM) and left (LPM) of ML. *ML* midline, *RPM* right paramedian, *LPM* left paramedian, *S* sacrum, *SC* sigmoid colon, *R* rectum, *Co* coccyx

Distance between the rectum and sacrum

The anteroposterior width of the presacral space is of great importance. This reflects the distance between the rectum and the ventral surface of the sacrum. While the ventral surface of the sacrum is covered by the Waldeyer's fascia, the posterior surface of the rectum is covered by the fascia propria. Presacral space is located between these two layers. The space is limited cranially by peritoneal reflection at the rectosigmoid junction and caudally by the pelvic bottom [6, 8, 14, 18].

The close distance between the anterior aspect of the sacrum and the intestinal structures should be known by spine surgeon. However, the surgeon can retract the intestinal structures anteriorly using either retractors or transrectal finger retraction during presacral approach.

Using MR images of 193 cases, Oto et al. reported that the width of the presacral space was 16.2 mm (male) and 11.9 mm (female) at the S1 level, 16.2 mm (male) and 14.9 mm (female) at the S2 level, and 13.0 mm (male) and 10.6 mm (female) at the S3 level [18]. Using MRI in twelve individuals and CT in two cases, Yuan et al. reported that the distance between the ventral surface of the sacrum and mesorectum was 12 mm on MRI and 13 mm on CT measurements [26].

Major vessels

Previous anatomical studies revealed that the bifurcation and junction of the major vessels (abdominal aorta and vena cava) are superiorly from the S1 level [7]. The injury of these vessels is unlikely [10]. This is so because the

Table 2 Location of the middle sacral artery (MSA) with respect to the midline as detected in the cadaver study

	L5–S1	S1–2	S2–3	S3–4	S4–5	S5–coc
Right of the midline	6	6	7	6	5	3
Left of the midline	4	3	3	3	3	3
Midline	0	1	0	1	2	4

Table 3 The distance between the middle sacral artery (MSA), right (R), and left (L) lateral sacral artery (LSA), and the presacral midline at the cadaver study

Level	MSA (mm)	LSA-R (mm)	LSA-L (mm)
S1–S2	8.0 ± 5.4	–	–
S2–S3	9.0 ± 4.9	29.8 ± 4.1	33.2 ± 4.1
S3–S4	8.7 ± 6.0	21.0 ± 4.4	24.3 ± 5.9
S4–S5	8.6 ± 6.4	17.4 ± 7.5	18.5 ± 4.4
S5–C1	4.7 ± 5.0	10.6 ± 3.5	14.9 ± 2.1

Table 4 Distance between the sympathetic trunk (ST) and presacral midline at different levels of sacrum at the cadaver study

Level	Right (mm)	Left (mm)
S1–S2	22.4 ± 5.8	21.1 ± 4.9
S2–S3	21.2 ± 5.5	18.7 ± 3.6
S3–S4	16.4 ± 5.3	16.5 ± 4.4
S4–S5	13.3 ± 5.2	14.0 ± 4.5
S5–C1	9.5 ± 3.2	9.9 ± 3.7

Table 5 The distance between the intestine (I) and midline (ML), as well as the distance between the intestine and paramedian lines 1 cm to the right and left of the presacral midline (RPM and LPM, respectively)

Level	I–ML distance (mm)	I–RPM (mm)	I–LPM (mm)
S1–S2	20.58 ± 16.53	13.40 ± 9.51	21.56 ± 9.41
S2–S3	23.45 ± 23.12	23.93 ± 19.76	21.85 ± 19.76
S3–S4	22.95 ± 23.37	24.10 ± 19.79	15.09 ± 5.89
S4–S5	13.03 ± 8.90	18.30 ± 16.85	13.91 ± 7.94
S5–C1	11.44 ± 7.69	12.61 ± 8.45	13.04 ± 8.50

entry point to the sacrum during presacral L5–S1 axial fusion is commonly at the level of S1–2. However, the vascular variations may complicate the presacral space anatomy [5, 19, 25]. No anatomical variation was detected in the current series. Bleich et al. reported three anatomical variations of the iliac vein [3]. In the first case, the IIVs converge forming a common trunk draining into the left external iliac vein. In the other two cases, the IIV crosses the median plane and flows into the contralateral common iliac vein.

Other risk factor predisposing to venous injury is the presence of a segmentation anomaly (transitional lumbosacral vertebra). Indeed, this anomaly gives a caudalization of the iliac vein confluence [27]. The aforementioned variations may cause complications during the presacral approach; therefore, a preoperative MR venographic imaging of the sacrum and presacral area is required.

In summary, this study revealed the relationship between the midline and important structures anterior to it. The ST was found to be the only structure with a standard course. The MSA and colon exhibit variability on midline, and on the right and left paramedian lines, respectively. Therefore, a preoperative imaging of sacrum and presacral space is mandatory before the presacral approach. Preoperative exploration such as magnetic resonance venographic images or angioscan can mitigate the risk of arterial damage during mobilization.

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