



Surgical anatomy of the pelvis for total pelvic exenteration with distal sacrectomy: a cadaveric study

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Abstract

Purpose Intraoperative bleeding from the pelvic venous structures is one of the most serious complications of total pelvic exenteration with distal sacrectomy. The purpose of this study was to investigate the topographic anatomy of these veins and the potential source of the bleeding in cadaver dissections.

Methods We dissected seven cadavers, focusing on the veins in the surgical resection line for total pelvic exenteration with distal sacrectomy.

Results The presacral venous plexus and the dorsal vein complex are thin-walled, plexiform, and situated on the line of resection. The internal iliac vein receives blood from the pelvic viscera and the perineal and the gluteal regions and then crosses the line of resection as a high-flow venous system. It has abundant communications with the presacral venous plexus and the dorsal vein complex.

Conclusion The anatomical features of the presacral venous plexus, the dorsal vein complex, and the internal iliac vein make them highly potential sources of bleeding. Surgical management strategies must consider the anatomy and hemodynamics of these veins carefully to perform this procedure safely.

Keywords Pelvic exenteration · Sacrum · Iliac vein · Hemodynamics · Cadaver

Introduction

Total pelvic exenteration offers the best chance of cure for patients with locally advanced or recurrent rectal cancer invading the adjacent organs. When the tumor invades the sacrum, sacrectomy should be considered. The 5-year overall survival rate of patients treated with conventional radiotherapy alone was reported as less than 10% [1]. However, Milne et al. reported that the 5-year survival rate of patients

who underwent total pelvic exenteration with sacrectomy was as high as 38% [2]. Total pelvic exenteration with distal sacrectomy, in which the sacrum is resected below the second sacral vertebra, is regarded as the procedure of choice for maximal curability and minimal motor disturbances caused by resection of the sacral nerve. However, this radical resection is a challenge for surgeons because of its complex nature and high postoperative morbidity [3, 4].

Intraoperative bleeding is one of the most serious and life-threatening complications of total pelvic exenteration with distal sacrectomy. In this procedure, the presacral venous plexus, the dorsal vein complex, and the internal iliac vein are potential sources of bleeding [5]. Thus, understanding the topographic anatomy of these veins and their tributaries is critical to minimizing intraoperative bleeding. The veins are located deep in the pelvis, so stepwise meticulous dissection of the surrounding structures, such as the pelvic muscles and fasciae, is imperative. Yet, the surgical anatomy of the pelvic veins has not been a topic of focus in the literature.

The purpose of this study was to describe in detail the topographic anatomy of the presacral venous plexus, the dorsal vein complex, and the internal iliac vein, and to clarify

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the potential source of serious bleeding. We focused especially on the veins in the line of resection when performing total pelvic exenteration with distal sacrectomy.

Materials and methods

All study protocols were performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Seoul in 2008). This study was approved by the Jichi Medical University Institutional Review Board (No. 13–23). The subjects of this study were seven cadavers (six males and one female, aged 73–94 years), preserved in 10% formalin. There was no evidence of disease in the pelvic organs. Colored resins were injected into the inferior vena cava to visualize the venous structures.

Dissections were performed as in total pelvic exenteration with distal sacrectomy, including abdominal and perineal phases. In the abdominal phase, dissection was carried out in the order of posterior, anterior, and lateral. The resection line in each dimension was defined as follows: posterior, the line of the inferior border of the second sacral vertebra; anterior, the anterior pelvic attachment of the levator ani muscle and the membranous urethra; and lateral, the line between the second sacral foramen and the lateral attachment of the coccygeal muscle. Following the abdominal phase, perineal dissection was carried out with the cadaver in the prone position to accommodate the dissection plane of the abdominal phase. Finally, the pelvic organs were removed with the distal sacrum.

We removed the left hemi-pelvis, preserving the veins anterior to the urinary bladder in three cadavers, including one female, after the posterior part of the dissection. The course and distribution of the presacral venous plexus and the dorsal vein complex were examined in detail in these three cadavers. In the remaining four cadavers, we initially hemisected in the mid-sagittal plane to observe the course and the distribution of the internal iliac vein. We examined the fasciae and neurovascular structures related to the surgical procedure carefully and recorded each step of the dissection with a digital camera (Pentax WG-1) and a video camera (Panasonic AG-MDC10G).

Results

Abdominal phase

Posterior pelvis

Posterior to the rectum, we identified three fasciae from the ventral to the dorsal direction on the anterior surface of the sacrum, including the proper rectal fascia enveloping

the mesorectum, the parietal pelvic fascia covering the pelvic autonomic nerves ventrally, and the presacral fascia. Dissection posterior to the rectum was carried out behind the presacral fascia, which revealed the median sacral vein running caudally on the anterior surface of the sacrum (Fig. 1, white arrows). The wall of the median sacral vein was thin and firmly adherent to the periosteum. The median sacral vein formed anastomoses with several veins running horizontally toward the pelvic side wall (white arrowheads) and then formed the presacral venous plexus, a potential source of bleeding. The median sacral vein passed the inferior border of the second sacral vertebra, corresponding to the posterior resection line.

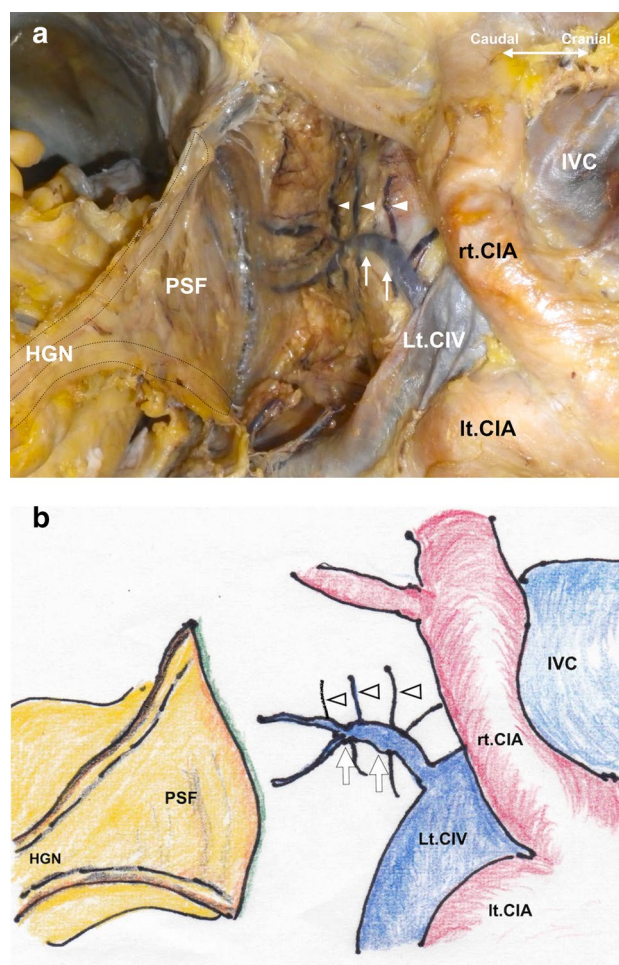


Fig. 1 Posterior Pelvis. Venous structures in the posterior pelvis after dissection posterior to the presacral fascia. a: digital image, b: schematic drawing. IVC inferior vena cava; rt. CIA right common iliac artery; Lt. CIA left common iliac artery; Lt. CIV left common iliac vein; PSF presacral fascia; HGN hypogastric nerve. White arrows show the median sacral vein and white arrowheads show the veins communicating with the median sacral vein

Anterior pelvis

With posterior traction applied to the urinary bladder, a loose avascular space known as the retropubic space was noted to extend behind the pubic bone. Dorsal to this space, we identified the endopelvic fascia, a firm fascia covering the urinary bladder. We severed the puboprostatic ligament (shown as black stars in Fig. 2) at the pubic attachment to expose the ventral aspect of the membranous urethra. The deep dorsal penile veins (black arrows) joined the internal pudendal veins (black arrowheads) at the urogenital diaphragm. Ventral to the membranous urethra, they became tortuous and thin-walled veins termed the “dorsal vein complex”. Cranial to the membranous urethra, the veins of the dorsal vein complex made networks in the prostate and

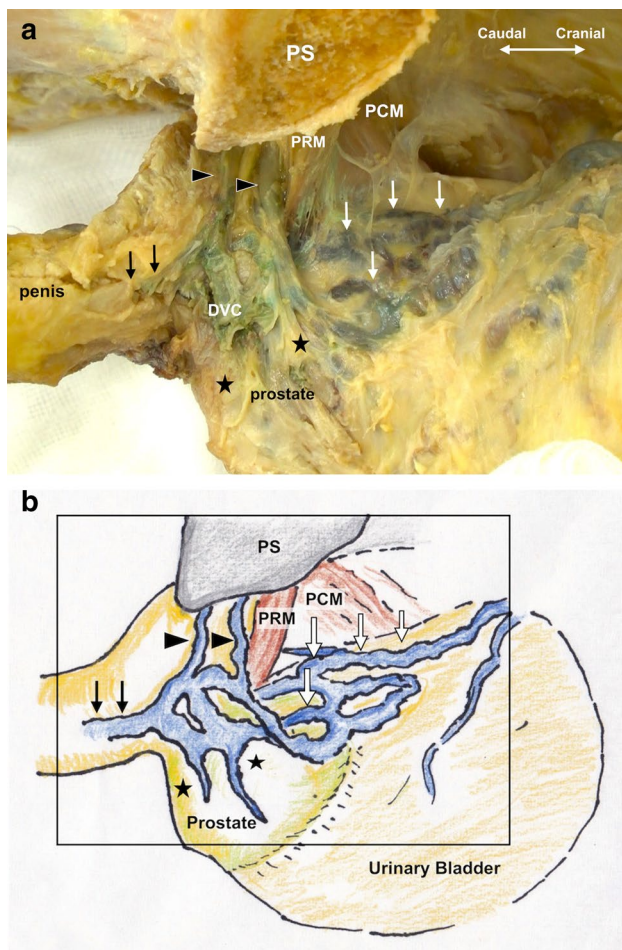


Fig. 2 Anterior pelvis. Anterior right hemi-pelvis after dividing the puboprostatic ligament. **a**: digital image, **b**: schematic drawing. **a** corresponds to the black square region in **(b)**. *PS* pubic symphysis, *DVC* dorsal vein complex, *PRM* puborectal muscle, *PCM* pubococcygeal muscle. The black arrows and arrowheads show the deep dorsal penile veins and the internal pudendal veins, respectively, and the white arrows show the lateral prostatic veins. The black stars show the severed stumps of the puboprostatic ligament

subsequently anastomosed with the veins at the ventrolateral aspects of the prostate and urinary bladder. At the ventrolateral aspect, they communicated with several tortuous veins (white arrows), which received blood from the genitourinary organs and drained into the internal iliac vein. It is noteworthy that the dorsal vein complex was situated beneath the endopelvic fascia and adhered to it. Therefore, its course and distribution were not well visualized from above the fascia.

Lateral pelvis (Online Resource 1)

Dissection of the lateral pelvis was commenced by dividing the peritoneum at the root of the common iliac artery and proceeding along the superior vesical artery. By retracting the genitourinary organs medially, a dissection plane lateral to the internal iliac vessels developed anteriorly to the retropubic space. After this dissection, we identified fatty tissues containing lymph nodes in the lateral pelvic wall. Clearance of these tissues created a space between the pelvic side wall and the internal iliac vessels where the obturator nerve and vessels coursed. The dorsal boundary of this space was formed by firm fascia called the piriformis fascia.

The internal iliac vessels were covered medially by the pelvic autonomic nerves. Following dissection of these nerves, the internal iliac artery was transected at its root with dissection proceeding peripherally, revealing the course of the internal iliac vein behind the artery (Fig. 3). The tributaries of the internal iliac vein were categorized into the visceral and the parietal venous systems. The veins communicating with the dorsal vein complex traveled along the lateral aspect of the genitourinary organs to join the internal iliac vein distally (black arrowheads and arrow). The veins from the proximal genitourinary organs, including the superior vesical vein, joined the internal iliac vein proximally (blue arrowheads and arrow).

After dividing the visceral venous system, we identified the parietal venous system, which drains the blood from the dorsal aspect of the pelvis (Fig. 4). The internal pudendal and inferior gluteal veins (white and yellow arrowheads, respectively) entered the pelvis through the space between the piriformis fascia and the fascia of the coccygeal muscle. These veins joined together to form a trunk of the parietal venous system, which received blood from the lateral sacral vein and the veins of the pelvic viscera and joined the superior gluteal vein. There were numerous tributaries adherent to the piriformis fascia (black star), which is also a potential source of bleeding because of its high venous flow and anatomical features.

Dissection behind the piriformis fascia revealed a loose avascular space extending around the sacral nerves and the sciatic nerve. As this dissection advanced medially, the dissection plane was defined just medial to the sacral foramen, where the piriformis fascia attaches to the anterior

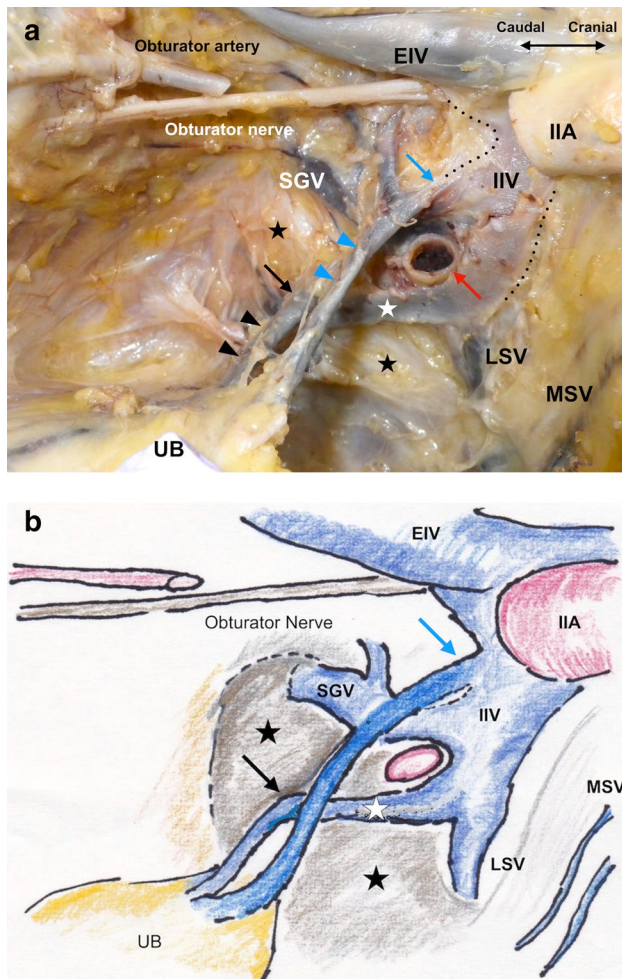


Fig. 3 Visceral venous system of the internal iliac vein. The lateral aspect of the pelvis after removal of the internal iliac artery and its branches. a: digital image, b: schematic drawing. *UB* urinary bladder, *IIA* internal iliac artery, *IIV* internal iliac vein, *EIV* external iliac vein, *SGV* superior gluteal vein, *MSV* median sacral vein, *LSV* lateral sacral vein. The blue arrowheads and arrow show the superior vesical vein and its confluence with the internal iliac vein, respectively, while the black arrowheads and arrow show the vein from the dorsal vein complex and its confluence with the internal iliac vein, respectively. The red arrow shows the severed stump of the superior gluteal artery. The white and black stars indicate the trunk of the parietal venous system and the piriformis fascia, respectively. The black dotted lines show the outlines of the internal iliac vein

surface of the sacrum. After dissection behind the piriformis fascia, the trunk of the parietal venous system could be transected in front of the second sacral nerve, corresponding to the lateral resection line. The lateral sacral vein was examined after dissection of the piriformis fascia (Fig. 5). This vein coursed cranially along the lateral border of the sacrum beneath the coccygeal and piriformis fascia and crossed the lateral resection line. It had several communications with the trunk of the parietal venous system and the presacral venous plexus (yellow arrow).

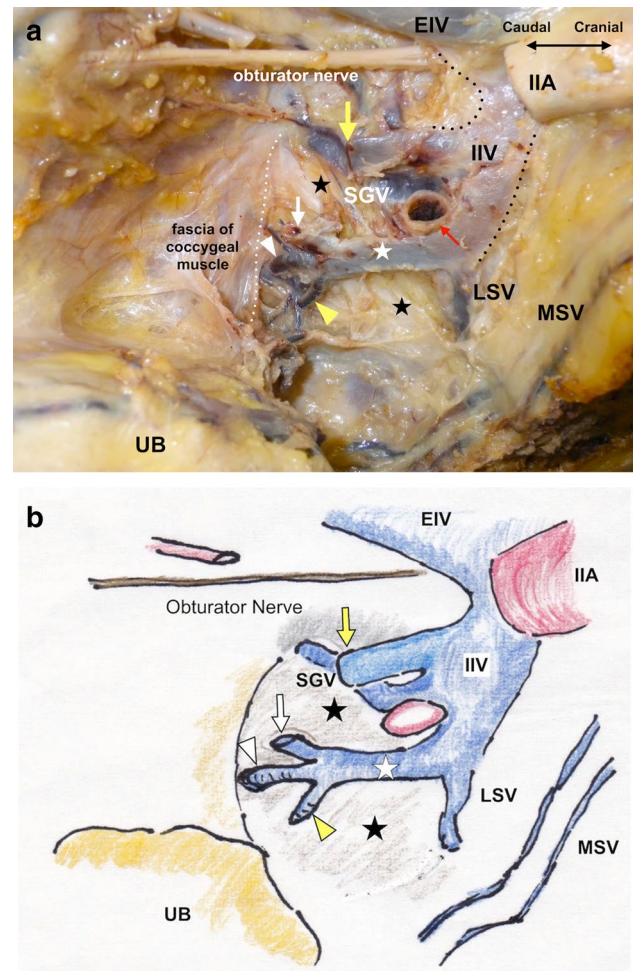


Fig. 4 Parietal venous system of the internal iliac vein. The lateral aspect of the pelvis after removal of the visceral venous system of the internal iliac vein following dissection from the state shown in (Fig. 3) a: digital image, b: schematic drawing. *UB* urinary bladder, *IIA* internal iliac artery, *IIV* internal iliac vein, *EIV* external iliac vein, *SGV* superior gluteal vein, *MSV* median sacral vein, *LSV* lateral sacral vein. The yellow, white and red arrows show the severed stumps of the superior vesical vein, the vein from the dorsal vein complex, and the superior gluteal artery, respectively. The white and black stars indicate the trunk of the parietal venous system and the piriformis fascia, respectively. The black and white dotted lines show the outlines of the internal iliac vein and the cranial border of the fascia of the coccygeal muscle, respectively, while the white and yellow arrowheads show the internal pudendal vein and the inferior gluteal vein, respectively

Cranial to the second sacral foramen, this vein coursed laterally to join the internal iliac vein.

Perineal phase (Online Resource 2)

After completing the abdominal phase, the perineal dissection was performed in the prone position. The gluteus maximus muscle was first dissected laterally with the perineal

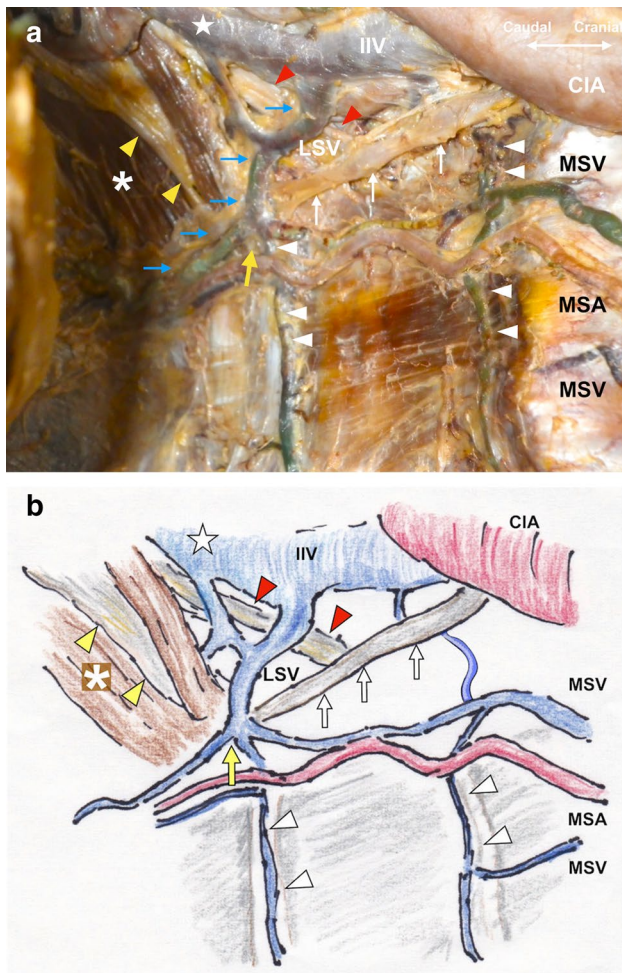


Fig. 5 Lateral sacral vein. The right hemi-pelvis after removal of the internal iliac artery, the visceral venous system of the internal iliac veins and the piriformis fascia. **a**: digital image. **b**: schematic drawing. *CIA* common iliac artery; *IIV* internal iliac vein; *LSV* lateral sacral vein; *MSV* median sacral vein; *MSA* median sacral artery. The blue arrows show the course of the lateral sacral vein. The red and yellow arrowheads show the first and the second sacral nerves, respectively, while the white arrows indicate the sympathetic trunk. The white arrowheads show the veins communicating with the median sacral vein and the yellow arrow shows the anastomosis between the lateral sacral vein and the presacral venous plexus. The white star and asterisk indicate the trunk of the parietal venous system and the piriformis muscle, respectively

skin to expose the posterior surface of the sacrum, the sacrotuberous ligament, and the piriformis muscle. During this dissection, the veins draining blood from the gluteus maximus muscle into the superior or inferior gluteal vein were divided. After dissection of the gluteus maximus muscle, the sacrotuberous ligament was severed to visualize the course of the internal pudendal vessels, the pudendal nerve and the inferior gluteal vessels (Fig. 6).

To access the anterior resection line used in the abdominal phase, the levator ani muscle was divided toward the

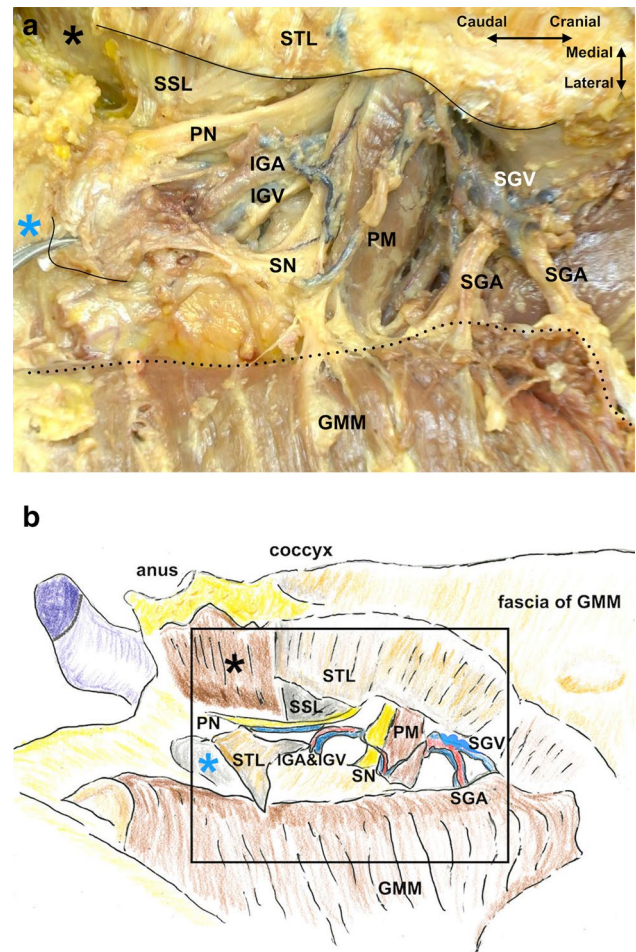


Fig. 6 Perineal and gluteal region. Neurovascular structures of the perineal and the gluteal region in the right hemi-pelvis after resection of the sacrotuberous ligament in the same specimen as shown in Figs. 3, 4. Part of the sciatic nerve is covered by the piriformis muscle. **a**: digital image, **b**: schematic drawing. **a** corresponds to the black square region in **(b)**. *SGV* superior gluteal vein, *SGA* superior gluteal artery, *IGV* inferior gluteal vein, *IGA* inferior gluteal artery, *PM* piriformis muscle, *GMM* gluteus maximus muscle, *PN* pudendal nerve, *SN* sciatic nerve, *SSL* sacrospinous ligament, *STL* sacrotuberous ligament. The black and blue asterisks show the levator ani muscle and the ischial tuberosity, respectively. The black dotted line shows the lateral dissection margin of the gluteus maximus muscle and the black line shows the resection line of the sacrotuberous ligament

membranous urethra with vessels running medially from the internal pudendal vessels. The membranous urethra and the dorsal vein complex were transected, corresponding to the anterior resection line. Next, the sacrospinous ligament, the internal pudendal vessels, the pudendal nerve, and the inferior gluteal vessels were divided to access the lateral resection line in the abdominal phase. The sciatic nerve, lateral to the inferior gluteal vessels, was dissected free from the piriformis muscle to prevent injury during transection of the piriformis muscle. The piriformis muscle was divided dorsal to the sciatic nerve.

Osteotomy commenced on each side of the second sacral nerve toward the second sacral foramen and proceeded along the inferior border of the second sacral vertebra. During the osteotomy, vessels communicating between the inferior and superior gluteal vessels were divided at the lateral edge of the sacrum. The specimen was then extracted in the prone position. The cadavers were returned to the lithotomy position to secure hemostasis on the ventral side of the osteotomy line. The median and lateral sacral veins were found at the inferior border of the second sacral vertebra and in the second sacral foramen, respectively. As the superior gluteal vein entered the pelvis cranial to the second sacral nerve, it did not cross the resection line and could be spared.

Discussion

Several investigators have advocated the safety of total pelvic exenteration with distal sacrectomy [2, 3]. However, it has not been considered a standard procedure because of possible life-threatening hemorrhage [6]. The presacral venous plexus and the dorsal vein complex, consisting of friable veins, are susceptible to injury and the vulnerability of these venous structures would be responsible for massive hemorrhage. The internal iliac vein, as a high-flow venous system, has abundant communications with the presacral venous plexus and the dorsal vein complex.

Presacral venous plexus

The median sacral veins on the posterior resection line are at risk of severe bleeding due to the anatomical features in this area [5, 7, 8]. Because the presacral venous plexus lacks valves, blood in the vena cava system can readily flow back into this venous system while the patient is in the lithotomy position [7, 9–13]. The other anatomical features of being thin-walled and adherent to the periosteum of the sacrum make the presacral venous plexus susceptible to intraoperative injury. Encircling and ligating the median sacral veins could result in injury to these vulnerable veins and once injured, hemostasis would be difficult.

The results of this study confirmed communication between the parietal venous system and the presacral venous plexus via the lateral sacral veins. Venous blood from the perineal and the gluteal regions flows into the presacral venous plexus through these venous communications after ligation of the trunk of the internal iliac vein [14, 15]. This is a potential source of severe hemorrhage from the presacral venous plexus. Prior to osteotomy, complete division of the veins on the lateral resection line, including the lateral sacral, the internal pudendal and the inferior gluteal veins, is required to block the blood flow into the presacral venous plexus. In spite of this inflow control, there is still blood

supply from the inferior vena cava to the presacral venous plexus on the osteotomy line, which could also be a potential source of bleeding. As hemostasis of the presacral venous plexus could not be achieved before osteotomy and extraction of the specimen, osteotomy, should be performed at the final stage of the resection.

Dorsal vein complex

The dorsal vein complex, being ventral to the membranous urethra, is thin-walled and adherent to the thick endopelvic fascia. Obtaining an optimal view of this venous system is made difficult by its anatomical location where the pubic bone hangs over the membranous urethra and this complex. These anatomical features make dissection and control of bleeding difficult [16–18].

Various surgical approaches have been proposed for safe ligation and transection of the dorsal vein complex. After incising the endopelvic fascia on both sides of the prostate, these veins and the surrounding endopelvic fascia are compressed and ligated as a bundle. This technique helps avoid laceration of these friable veins [17, 18]. An approach from both the abdominal and perineal sides is effective for avoiding visual obstruction by the pubic bone [19]. These procedures should be performed before ligation of the trunk of the internal iliac vein, if technically feasible. Because the dorsal vein complex drains into the internal iliac vein, prior ligation of the internal iliac vein would lead to congestion of these veins, which might be a potential source of bleeding [5].

Internal iliac veins

Variations in the anatomy of the internal iliac veins and their tributaries related to embryological factors are occasionally observed. These variations can result in complicated bleeding. Chong et al. reported anomalies of the internal iliac veins in 26.7% of patients who underwent extended pelvic lymphadenectomy [20]. The most frequent anomaly is a separated trunk of the internal iliac vein [20–22]. These aberrant internal iliac veins are located in the presacral area and often obscured by overlying fibrous tissue. Surgeons who are unaware of these venous variations are likely to injure the veins. Consequently, massive bleeding will occur when they perform osteotomy and extract the specimen.

The trunk of the parietal venous system of the internal iliac vein is a high-risk source of bleeding because of its venous anastomoses and high blood flow. Among its tributaries, the lateral sacral vein is also a potential source of bleeding because its blood flow will increase significantly after ligation of the trunk of the parietal venous system. The trunk of the parietal venous system and the lateral sacral vein are adherent to the piriformis fascia in the deep pelvis. For safe management of these two veins, it is necessary

to dissect the avascular space behind the piriformis fascia around the second sacral nerve toward the sacral foramen. After this dissection, the veins are freed from the nerve and can be ligated and transected on the lateral resection line. Considering the hemodynamics of the pelvic veins is necessary to prevent severe hemorrhage. If the proximal part of the internal iliac vein is ligated first, the pelvic venous flow will be congested and diverted to the perineal, gluteal, and sacral veins via the communications. These regulatory functions would affect the configuration of the veins and cause critical bleeding.

This study had several limitations. First, in patients with locally advanced primary or recurrent rectal cancer, distinct surgical layers may not be identified because of the fibrosis caused by inflammation around the tumor or prior treatment. The approach described here uses the pelvic fascia as a landmark for fine dissection and might be difficult to perform in some patients. Second, since this is a cadaver study, the configuration change of the veins, induced by fluctuation of the blood supply, is impossible to see. Third, only a limited number of cadavers were examined, so it was impossible to investigate the numerous variations of veins on the anterior surface of the sacrum [20, 21].

In summary, the presacral venous plexus, the dorsal vein complex and the internal iliac veins are considered as high-risk sources of bleeding during total pelvic exenteration with distal sacrectomy. Reducing blood flow into these veins at the line of resection is essential to prevent massive intraoperative hemorrhage. Surgical management strategies considering the anatomical features and hemodynamics of these veins are of vital importance to conducting this procedure safely.

Compliance with ethical standards

Conflict of interest We have no conflicts of interest to declare.

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