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Research Article

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Surgical Anatomy of The Female Pelvis and It's Applications in Obstetrics, Urogynecology, and Gynecologic Oncology Surgeries

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Abstract

A thorough knowledge of pelvic anatomy is essential tool for competent surgeons to lower the rate of the surgical complications of the most advanced Gynecological surgeries such as gynecology oncology and the urogynecology. In this article, we explained the surgical anatomy of female reproductive organs and its applications in obstetrics and gynecologic surgeries.

Key Words: obstetrics and Gynecologic surgeries; avascular spaces; Pelvic anatomy.

1. Introduction

The science of anatomy is understanding and obtaining knowledge of the structures of the human body. Surgery then is the practical application of this science to restore the normal anatomy or resect malignancies to mitigate the pain and improve function and quality of life.

A thorough understanding of female pelvic anatomy is essential for the management of most female reproductive tract malignancies and acts as guidance to help the surgeon navigate through structures to achieve the required outcome.

The gross **anatomy of the pelvis**—the bladder, uterus, fallopian tubes, ovaries, rectum, and muscles—has remained unchanged; however, knowledge of the anatomy of various structures that surround these organs is beyond the scope of this article. In this article, we will discuss the anatomy of the vicinity of these organs rather than the organs themselves. We will focus on their location and the anatomy related to these locations, such as vessels, potential spaces, and nerves. In this article, we used various supporting laparoscopic images with referenced videos.

2. Pelvic Anatomy

2.1. Sacral promontory (SP)

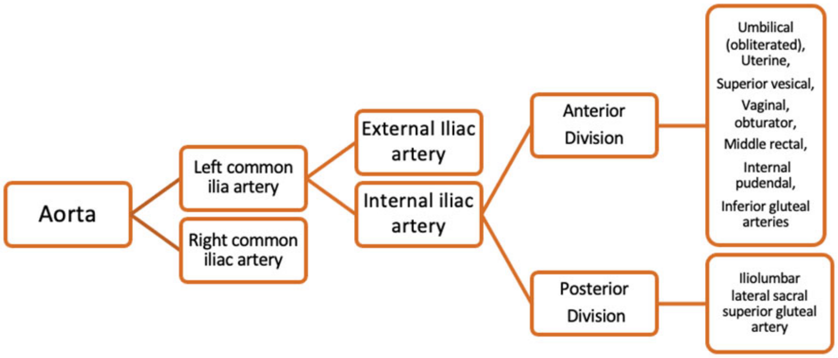
The sacral promontory (SP) is a protuberant structure of the bony pelvis. It can be used as a reference point for surgeries with extensive adhesions and altered general anatomy. Hence, the orientation of structures in the pelvis should always begin with identifying the SP.

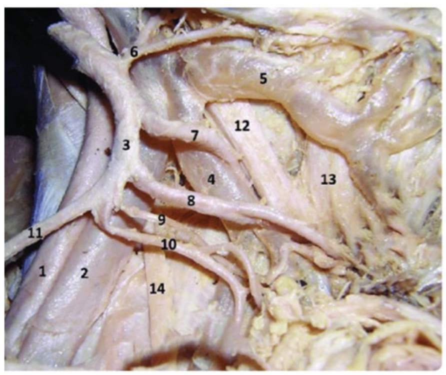
The sacral promontory is considered an important anatomical landmark for the following (Figures-):

- It is the site where the common iliac vessels bifurcate into the internal and external iliac vessels.
- At SP's level and over the bifurcation of the iliac vessels, the ureter crosses over from the lateral to the medial side
- The right and left hypogastric nerves union to form parasympathetic superior hypogastric nerve plexus at the SP level. Tracing the hypogastric nerves inferiorly, the nerve fibers of the Hypogastric plexus are seen at this level.
- The transperitoneal dissection of the Para-aortic Lymph node starts from the sacral promontory.
- Lateral dissection to the sacral promontory, the pararectal retroperitoneal space can be opened by dissection lateral to the sacral promontory (oncological approach or lateral approach will discuss later) or medial to the infundibulopelvic ligament (endometriotic approach or the medial approach).
- The mesentery of the small bowel crosses the sacral promontory to the right sacroiliac joint.
- This reflection of the small bowel along this line helps delineate pelvic organs from abdominal organs.

3. Vessels

The aorta bifurcates into the common iliac vessels at the level of L1. The region of vascular importance lies at the level of the sacral promontory where the common iliac vessels divide into the internal and external iliac vessels (chart -1, Figure-1).

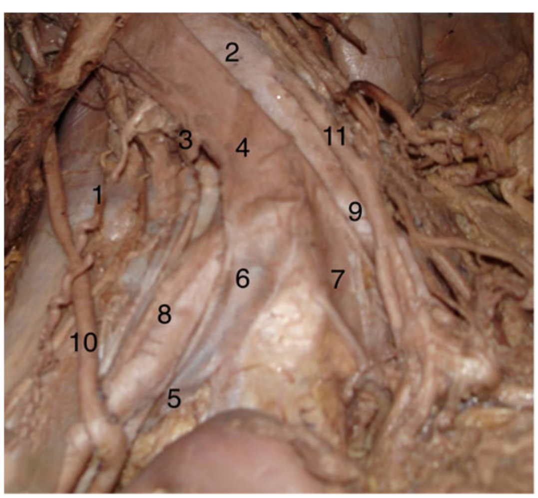




1. External iliac artery
2. External iliac vein
3. Internal iliac artery
4. Anterior division of internal iliac vein
5. Posterior division of internal iliac vein
6. Common trunk for iliolumbar and lateral sacral arteries
7. Superior gluteal artery
8. Common trunk for inferior gluteal and internal pudendal arteries
9. Middle rectal artery
10. Common trunk for superior vesical and obturator arteries
11. Medial umbilical ligament
12. Lumbosacral trunk
13. Ventral ramus of first sacral nerve
14. Obturator nerve

Figure 1-chart -1: Dissection of the Cadaveric body to demonstrate the left half of the pelvis showing variant branches of the internal iliac artery. Source: Reproduced after permission from Dr. Nayak S.B, et al. Variant branching pattern of the right internal iliac vessels in a male. A case report, January 2013, Archives of Clinical and Experimental Surgery (ACES) 3(4):1. DOI: 10.5455/aces.20121009120145

It is worth mentioning that the ovarian artery arises directly from the abdominal aorta. The significance of this in the surgical application is to avoid excessive traction on the utero-ovarian ligament during the lateral discussion to retroperitoneal space.



1. Right ovarian Artery
2. Aorta
3. Right ovarian Vein (OV)
4. IVC
5. Right external iliac vein (REIV).
6. Right common iliac vein (RCIV)
7. Left common iliac vein (LCIV).
8. Right common iliac artery (RCIA)
9. Left common iliac Artery (LCIA).
10. Right Ureter
11. Inferior Mesenteric Artery

Figure : Right ovarian artery origin from the Aorta can be seen in an image taken from a corpse. IVC receives drainage from the right ovarian vein. (REIV) Right external iliac vein. IVC, or inferior vena cava. To demonstrate the creation of the Right Common Iliac Vein (RCIV), the Right Common Iliac Artery is pushed to one side and the Internal Iliac Artery is severed [1].

The internal iliac artery (IIA) divides into anterior and posterior divisions at the level of the greater sciatic foramen. Each division has three parietal branches that supply non-visceral structures.

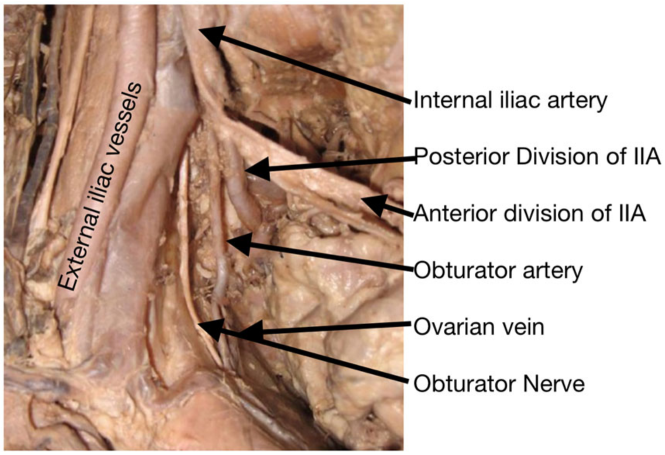


Figure 2: The posterior division gives three parietal branches of the iliolumbar, lateral sacral, and superior gluteal artery which all supply the gluteal region [1].

The anterior division travels parallel to the ureter and divides into inferior gluteal, internal pudendal, and obturator arteries. More branches of the anterior division include the uterine, vaginal, and middle rectal arteries and the superior vesical arteries. The first branch of the anterior division is the uterine artery (Figure-3). The uterine artery is the only vessel to cross horizontally over the ureter. This is of chief clinical significance because it helps easy identification of the uterine artery. The dissection of tubular structures is done in a parallel direction to the long axis of the structure. Therefore, the uterine artery could be accidentally ligated or injured during the dissection of the ureter.

The second branch of IIA is the superior vesical artery at a level higher than the uterine artery and then continues as the obliterated hypogastric artery to the anterior abdominal wall.

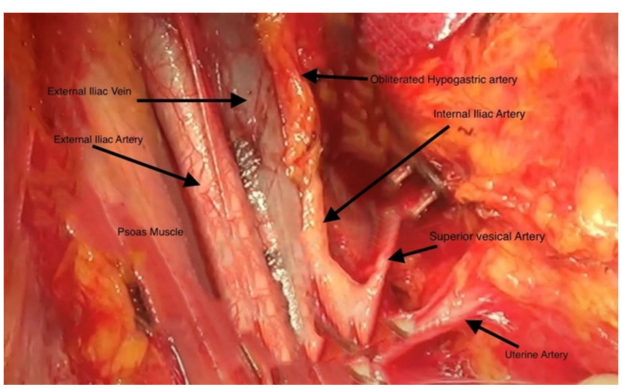


Figure 3: Paravesical Space and External Iliac vessels, Internal Iliac artery, Superior vesical artery, and uterine artery. Source: Reproduced after permission of Erebouni medical center. Type C1 Radical Hysterectomy with elements of total mesometrial resection. https://youtu.be/59IArMhul-Q

The internal iliac veins also lie parallel to the internal iliac artery (IIA). Tracing retrograde the obliterated Umbilical artery leads the surgeon to the Internal Iliac artery; careful ligation of the IIA, not the vein. You can differentiate the IIA from IIV by tracing uterine artery retrograde and dissecting to separate the internal iliac artery from the vein (Figure-3).

The obturator artery lies lateral to the paramedical space underneath the obturator nerve. It is the only lateral branch of the internal iliac artery (Figure-5). The obturator nerve is considered an important surgical landmark of the lower limit of the dissection of the obturator lymph nodes.

Dissection beyond this leads to damage to the obturator vessels and significant bleeding. The external iliac vessels are the first structure to be visualized after dissecting the pararectal spaces using the lateral approach.

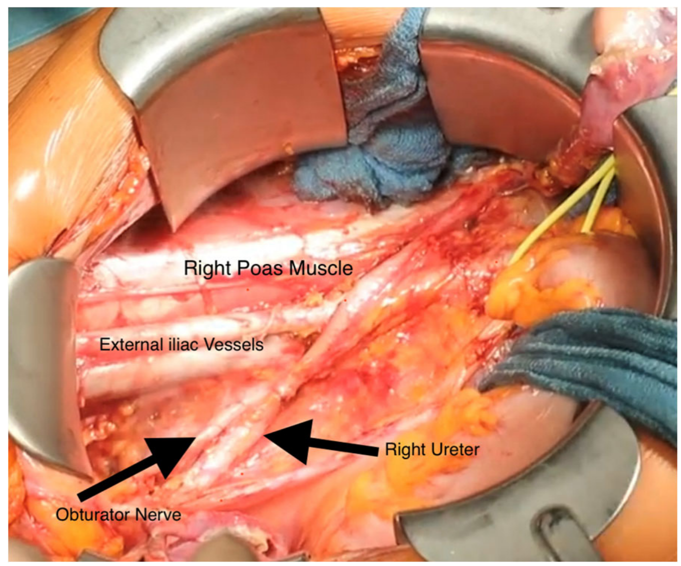
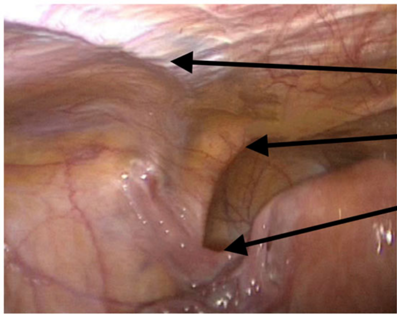


Figure 4: Lateral Dissection. External Iliac vessels lie on the Psoas muscle and Ureter crosses over. Source: Reproduced after permission of Erebouni medical center. Type C1 Radical Hysterectomy with elements of total mesometrial resection. https://youtu.be/59IArMhul-Q

The external iliac artery travels along the iliopsoas muscles and travels down to supply the lower limbs. The inferior epigastric artery arises from the external iliac artery and then travels above the transversal fascia under the anterior abdominal wall (Figure-4). During laparoscopic surgeries, placement of the Laparoscopic port should be done with caution to prevent damage to the inferior epigastric artery since this will lead to significant bleeding.



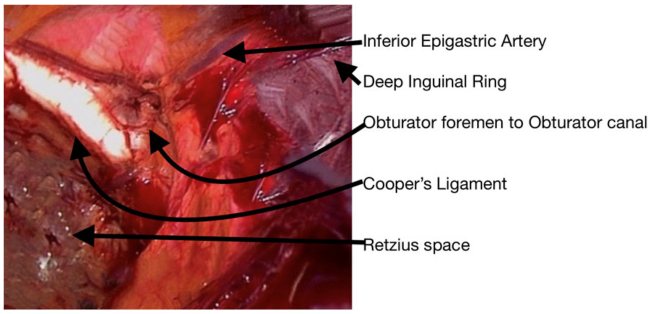


Figure 5: Cooper's Ligament, obturator vessels (Also known as the corona mortis), and Inferior epigastric Vessels branch the external iliac artery

The obturator vessels (Also known as the corona mortis), is anastomosis between the obturator and the external iliac or inferior epigastric arteries or veins, located on the superior pubic ramus arching over Copper's ligament (Figure-5). The Cooper's ligament (or pectineal ligament) can be identified as shiny, white, and tough tendinous tissue.

The corona mortis or obturator vessels, leave the pelvic cavity via the obturator canal. The corona mortis is known as the "crown of death", surgeons should exercise caution during surgery, significant hemorrhage may occur if the corona mortis vessels are accidentally injured, and hemostasis will be difficult to achieve because they may retract into the obturator canal. Otherwise, it is easy to accidentally damage the inferior epigastric vessels or the corona mortis upon placement of the side Laparoscopic port, which may cause significant hemorrhage or even require conversion to open surgery.

3.1. Uterine artery

The uterine artery is the first branch to arise from the anterior division of the internal iliac artery (Figure 6A). It crosses horizontally over the ureter (water under the bridge) and is best visualized in the pararectal space.

Skeletonizing the uterine artery is the most important step in hysterectomies. Identification of the uterine artery can be achieved by cephalad traction of the medial umbilical ligament, which will lead to the anterior division of the IIA artery (Figure 6B). This approach is called the " medial umbilical ligament approach" to access paravesical space for a hysterectomy. Paravesical space is formed by the bladder, EIA, and Cardinal ligament. The MUL Approach starts with the dissection of the round ligament and anterior bladder flap. MUL is located laterally in the lateral paravisical space (Figure 6C). Downward traction on the Medial umbilical ligament will cause tempting of the anterior abdominal wall for correct identification of the medial umbilical ligament.

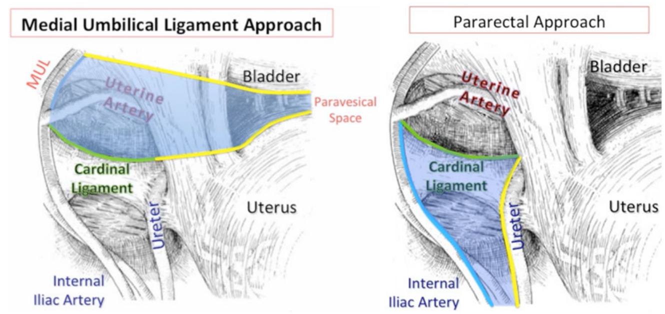
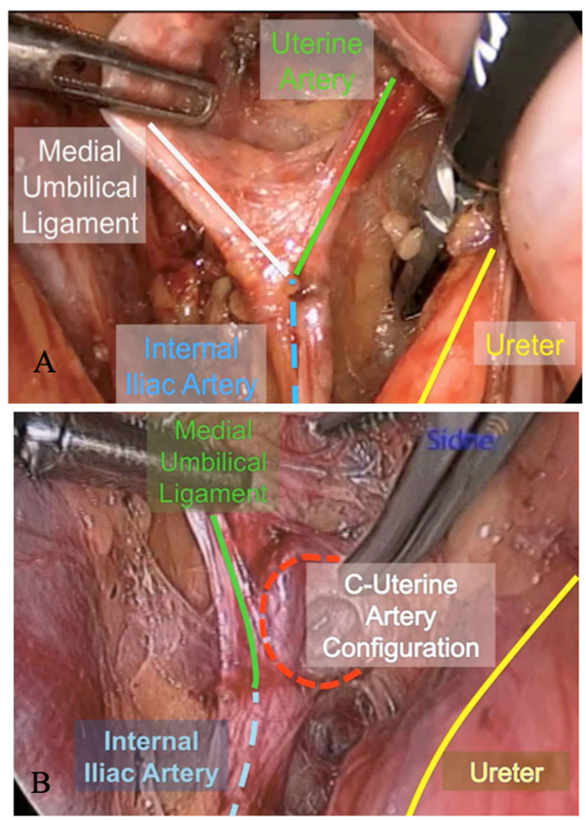


Figure 6: Approach to the medial umbilical ligament. a pararectal approach to the perihelion. Source: Reproduced after permission from Surgical Gynecologic Society, Video Presentation 01 Anatomic and Vascular considerations in laparoscopic uterine artery ligation during hysterectomy A. Pete. https://vimeo.com/156356513.

The uterine artery can be accessed through the "lateral retroperitoneal approach" which starts by incising the round ligament and opening the peritoneum of the lateral pelvic wall to access the retroperitoneal space. Lateral traction on the MUL is useful in identifying the "C- uterine artery configuration.



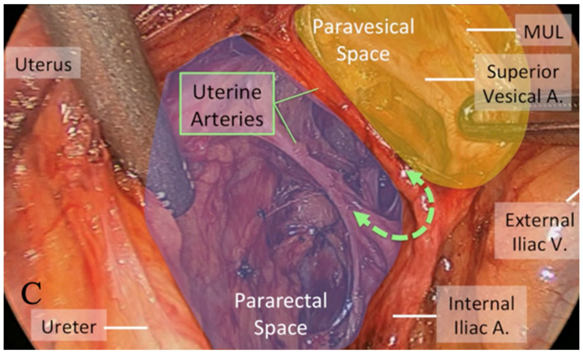


Figure 7: Ureter in Picture A situated on the IIA's (internal iliac artery) side. The first branch of IIA is the uterine artery. The Obliterated Hypogastric Artery and, later, the Medical Umbilical Ligament (Urachus) are produced by continuing the anterior division of the IIA. C-uterine artery configuration in image B. Image C: The anatomical relationships between the pararectal and paravesical spaces. Source: Reproduced after permission from the Society of gynecologic surgeries. Taken from Video presentation 01 Anatomic and vascular considerations in laparoscopic uterine artery ligation during hysterectomy A. Pete. https://vimeo.com/156356513

The uterine artery is located anterior to the ureter, while the uterine vein lies posterior to the ureter (Figure-8). This helps differentiate the bleeding in the pararectal area. Lifting the uterine end of the ureter will compress and cease the arterial bleeding from the UA but will not cease the venous bleeding from the uterine vein. Perhaps, Lifting the ureter will worsen the venous bleeding from UA.

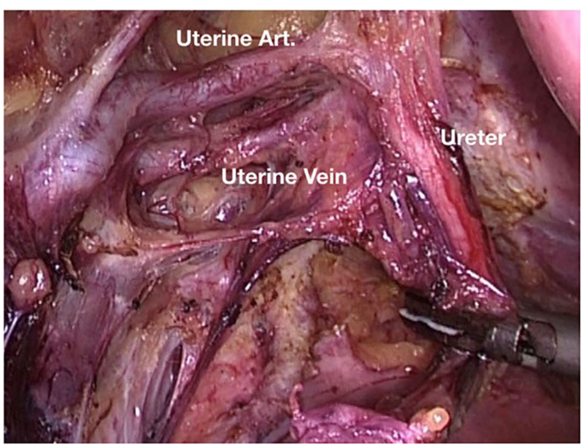


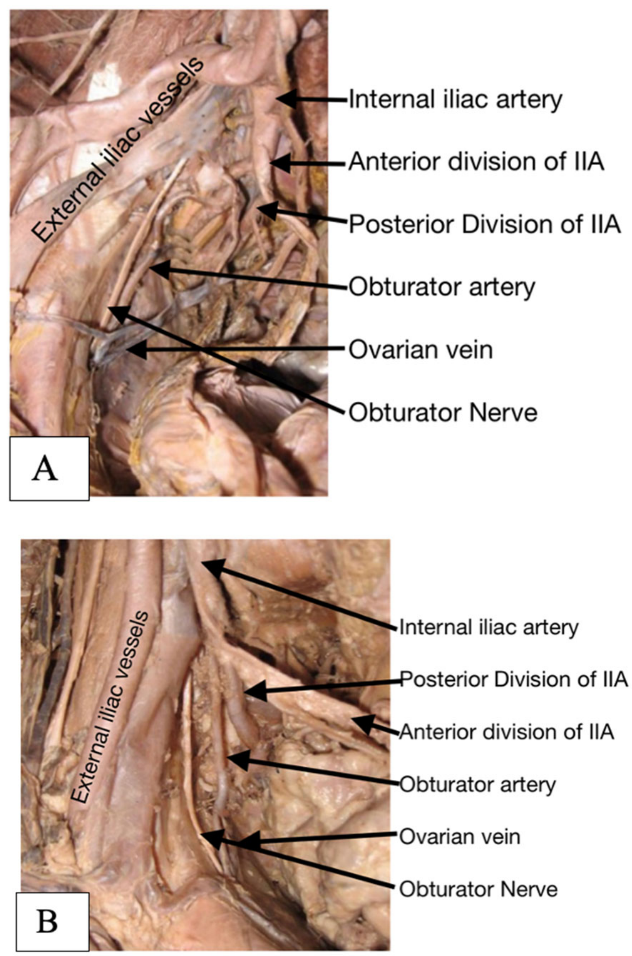
Figure 8: The ureter lies between the uterine artery and the uterine vein. Source: Reproduce after permission from Dr. Kostov. Source: Reproduced after permission from video presentation with the title "Anatomic and Vascular Considerations in Laparoscopic uterine artery ligation during Hysterectomy." by the Society of gynecologic surgeries (SGS). ttps://vimeo.com/156356513

3.2. Obturator vessels (Corona Mortis)

In cadaver study by Pai et al 2009 found the most common origin of the obturator artery (Corona Mortis) in both males and females is from the internal iliac artery in 77%, more often from the anterior division. In rare cases, OA could originate from the posterior division as a separate branch or with a common origin with the superior gluteal/ iliolumbar artery [1]. Accurate anatomical localization of the corona mortis and obturator vessels is vital to perform safe oncological pelvic dissection or Burch colposuspension [2-4].

Accurate anatomical localization of the corona mortis and obturator vessels is vital to perform safe oncological pelvic dissection or Burch colposuspension [2,4,5]

There are different types of origins of the obturator artery from the external and internal iliac arteries. The majority of the obturator artery (OA) originates from the anterior division (PD) of the internal iliac artery (IIA) reported as 25% by Pai et al 2009, whereas 5% of OA originates from the posterior division (PD). The OA may arise as a separate branch from the posterior division of IIA reported as 2% of OA arise as a separate branch of the Posterior division, whereas 3% of OA arise from the Posterior division of IIA [6].



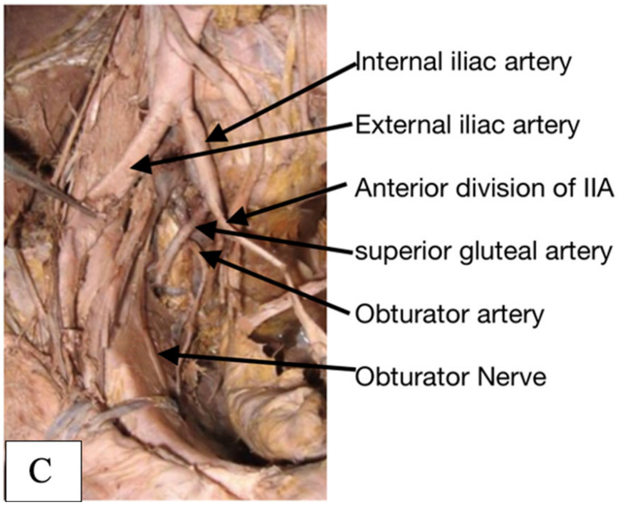


Figure 9: Image-A: The internal iliac artery's anterior division, where the right obturator artery (OA) originates. Image-B: The posterior division of the internal iliac artery (IIA), where the right obturator artery (OA) originates. Image-C: The iliolumbar artery (ILA) and the PD of the IIA, where the suitable OA originates [6]. Bergman et al 2018, reported 44% of OA arises from the common iliac or anterior division of the internal iliac artery [IIA] and only 10% arises from the superior gluteal artery [7].

The parietal branches of the OA are collaterals in aortoiliac and femoral arterial occlusive diseases. In cases of ischemic necrosis of the head of the femur following decreased blood flow through the OA, those patients require immediate placement of a bypass graft may to connect the posterior division to the distal end of the obstruction by vascular surgery (Figure 10).

Approximately, 21% of OA arising from EIA is 1-5% in females reported 25% [7, 8].

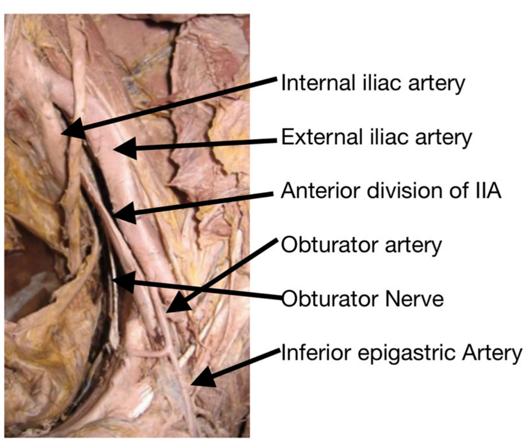


Figure 10: Left side of a pelvis showing the origin of the OA from the EIA with the inferior epigastric artery (IEA). IIA- Internal iliac artery, ON- obturator nerve [1].

Most of the articles recorded a fairly 20-47% variation in the origin of the inferior epigastric and obturator arteries. A dual origin was found in 6%.

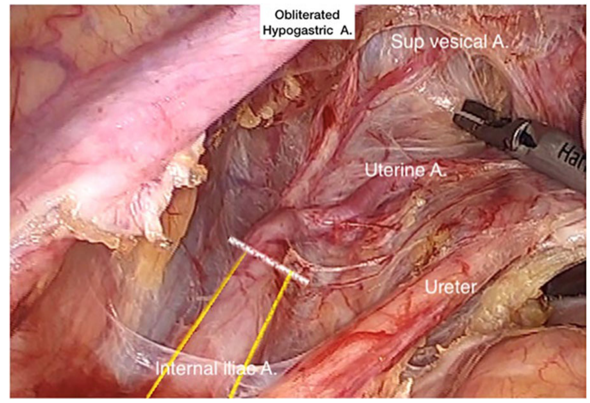


Figure 11: The internal iliac artery is medial to the ureter. Between the ureter and the external iliac artery is where the internal iliac artery is located. The superior vesical artery, which continues as the obliterated hypogastric artery or ligament, is the internal iliac artery's second branch after the uterine artery [5].

3.3. Nerves

The pelvic structures (uterus, rectum, vagina, urinary bladder) are supplied by the autonomic nervous system. The anatomy of the female pelvis is beyond the scope of this article. However, Fuji et al have discussed this topic in good detail. The inferior hypogastric nerve (T10–L2) provides sympathetic nerves and the pelvic splanchnic nerve (Figures-12) provides the parasympathetic fibers. The inferior hypogastric plexus supplies both the uterus and the urinary bladder. Nerve-sparing radical hysterectomy involves requires identifying the inferior hypogastric nerve and the plexus, dividing only the uterine branch, and preserving the bladder branches from the plexus. This helps better preserve urinary bladder function after surgery. injury of the Hypogastric nerve may lead to post-operative urinary retention, sexual dysfunction, and postoperative constipation.

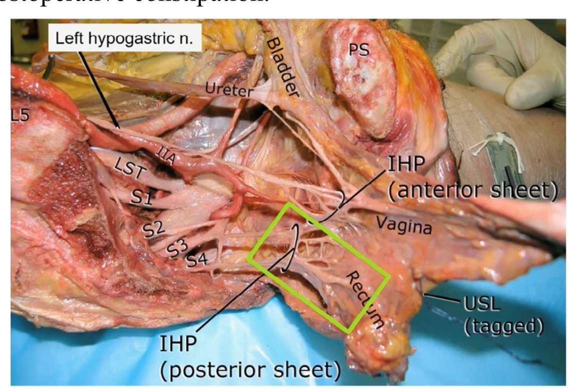


Figure 12: Inferior Hypogastric plexus (Cadaveric Image) [9].

The inferior hypogastric plexus is located at the level of the posterior pelvic floor and forms a triangular structure extending from the base of the sacrum extend along the sacral concavity

[Sienkiewicz-Zawilinska et al., 2018; Mauroy et al., 2003, 2007a, 2007b]. The plexus has three edges: a posterior superior or dorsal cranial edge parallel to the internal iliac artery, a posterior inferior edge in contact with sacral roots, and a caudal edge extending from the fourth sacral ventral rami to the ureter at its point of entry into the broad ligament [Sienkiewicz-Zawilinska et al., 2018; Mauroy et al., 2007a].

Identification of the deep uterine vein facilitates the identification of the hypogastric nerve. The hypogastric nerve is the nerve supply of the bladder. Injury of the hypogastric nerve leads to temporary urinary bladder dysfunction and overflow incontinence.

4. Avascular Spaces

The retroperitoneum is a space located under the parietal peritoneum and above the transversal fascia [10]. The peritoneum represents the roof of all retroperitoneal spaces and shares a common floor with the levator ani muscle. The retroperitoneal spaces are hollow pyramidal structures with the base lying on the levator ani muscle and the apex pointed medially toward the peritoneal cavity. These spaces are potential spaces, which means are normally consist of two peritoneal layers folded on each other and filled with areolar connective tissue. These spaces are created during surgical dissection to access the content anatomical.

The retroperitoneal spaces of the pelvis are named based on the location of the nearest organs. Each space has its importance. These pelvic spaces are classified as follows [11].:

A. Lateral spaces:

i. Paravesical (divided by umbilical artery into lateral and medial spaces)
ii. The fourth space (Yabuki space)
iii. Pararectal (divided by ureter into lateral and medial spaces)

B. Median spaces:

i. Retropubic (Retzius) space
ii. Vesicocervical/Vesicovaginal spaces
iii. Presacral or retro rectal space
iv. Rectovaginal space

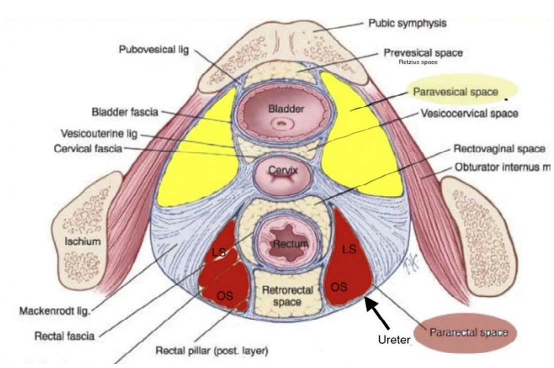


Figure 13: Avascular spaces in the female pelvis Obliterated umbilical artery (UA), Ur-Ureter, Latzko's space (LS), Okabayashi's space (OS), Retzius space (RS), paravesical space (PVS), Rectovaginal space (RVS), and retrolental (presacral) space are some of the terms used to describe these structures. Source: Reproduced after permission from Dr Schwab. Video Presentation 04 use of methylene blue for detection of sentinel lymph nodes in cervical cancer g. menderes; c. l. schwab. https://vimeo.com/156356506

4.1. Paravesical space (Figure of Pararectal space)

Paravesical space boundaries: Anteriorly-superior pubic ramus, arcuate line of the os ilium; Posteriorly –cardinal ligament including parametrium, ureter, paracervix, uterine artery and vein; medially-vesico-uterine ligament, bladder; laterally–obturator internal medial muscle, external iliac artery and vein (Figure 14). The paravesical space is covered by the the peritoneum of the anterior leaf of the broad ligament. Its floor is the iliococcygeus muscle and pubocervical fascia as it inserts into the arcus tendinous fascia pelvis [2,3,13, Peters et al. 2016]. Some authors described the paravesical space as a lateral compartment of the Retzius space [13].

Paravesical space contains the umbilical artery, superior vesical artery, and the obturator neurovascular bundle [3]. The obliterated umbilical artery (obliterated hypogastric artery) divides the paravesical space is divided into medial (MPS) and lateral paravesical spaces (LPS) [14,15] (Figure14).

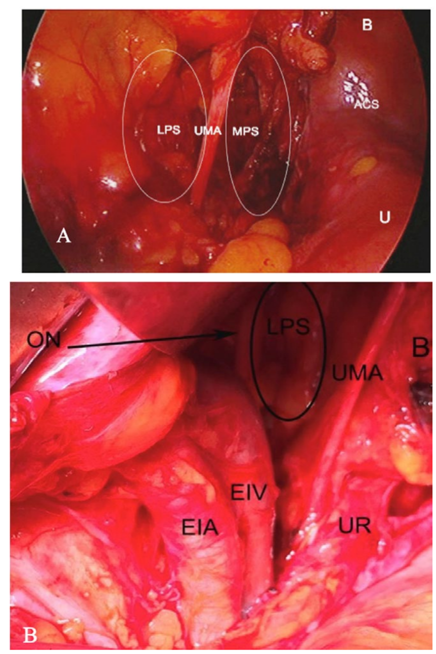


Figure 14: Image A: External iliac vein (EIV), External iliac artery (EIA), ureter (UR), left paravesical space (LPS), obturator nerve (ON), obliterated umbilical artery (UMA), bladder (B), and anterior cul-de-sac (ACS). Lateral Paravesical Space (LPS), Image B Source: Reproduce with Dr. Kostov's permission. Source: Reproduced after permission from video presentation with the title "Anatomic and Vascular Considerations in Laparoscopic uterine artery ligation during Hysterectomy." by the Society of gynecologic surgeries (SGS). ttps://vimeo.com/156356513

The space within the LPS is known as obturator space. This space has the exact boundaries as the paravesical space, except for a medially–superior vesical artery. The obturator space contains an obturator artery, obturator never, obturator vein, loose areolar, and lymphatic tissue [13].

The paravesical space is dissected by transecting the round ligament and cutting the anterior leaf of the broad ligament anteriorly and laterally to the obliterated umbilical artery [16]. Kostov et al., stated that it is unnecessary to transect the round ligament when performing laparoscopic pelvic lymphadenectomy [17,18]. The limit of dissection for the MPS is the floor formed by the levator ani muscle. For the LPS, the limit of posterior dissection is the obturator nerve [2,15,14].

From a gynecology oncology point of view, the paravesical space is dissected laterally. In contrast, in benign gynecological surgeries, the paravesical space is dissected medially to enter the space [Peters et al., 2016].

In urogynecology, Burch colposuspension requires access through the LPS [Selcuk et al. 2018, Kadar et al. 1997]. The paravaginal defect can be repaired through the LPS. After opening the LPS, the dissection is extended to the levator floor, which is the upper limit of the LPS [Kadar et al., 1997]. MPS is dissected in cases of ureteric anastomosis [15].

In gynecology oncology, LPS is dissected for pelvic lymphadenectomy, whereas MPS allows for managing bladder or ureteric endometriosis or anterior exenteration. Although rare, the paravesical space is dissected through an extraperitoneal approach during extraperitoneal pelvic lymphadenectomy in gynecology oncology cases. Twelve centimeters away from the midline incision in the lower abdomen, the space between the rectus abdominis sheath and the parietal peritoneum is developed toward the left inguinal region to identify the external iliac artery and vein. (Figure 14). The paravesical space is exposed after the separation of the peritoneal sac. Paravesical space contents are the external iliac artery/vein [19,20].

Dissection during sentinel lymph node detection due to cervical or endometrial cancer requires access through the paravesical space (Figure-14) [21].

In obstetrics, a paravesical space is developed during a cesarean hysterectomy for placenta percreta to clip uterine arteries and identify the ureter [Ansari et al. 2018]. Then, Vesicouterine and paravesical spaces are exposed for minimally invasive (laparoscopic/robotic) or open (laparotomy) cerclage. Whittle reported 65 patients who underwent laparoscopic cervico-isthmic cerclage. Whittle's surgical technique includes the development of paravesical and vesicouterine spaces and the creation of broad ligament peritoneal windows due to the identification of the uterine vessels at the cervicoisthmic junction [Ansari et al., 2018].

4.2. Prevesical space

The prevesical space lies between the bladder and the anterior abdominal wall. It extends on both sides with the paravesical space. It ends laterally by the lateral umbilical ligament, which continues the obliterated hypogastric artery (or anterior division of the internal iliac artery) onto the abdominal wall. (Figure 15)

The prevesical space contains the bladder, neck, and urethra, a critical space for urogynecologist for placement of the sling procedures and management of stress urinary incontinence. In addition, the anterior exenteration of localized recurrent cervical cancer also requires access to the prevesical space.

4.3. Rectovaginal space

The retroperitoneal space is enclosed anteriorly by the uterus and the posterior vaginal wall, posteriorly by the rectum, and laterally by the uterosacral and the Mackenrodt ligament (superiorly—peritoneal reflections of the pouch of Douglas; inferiorly—levator ani muscle [22,16,23] (Figure 17). The roof comprises the peritoneal reflections of the pouch of Douglas, and the levator ani muscle forms the floor. The roof comprises the peritoneal of the Douglas pouch, and the floor is the levator ani muscle.

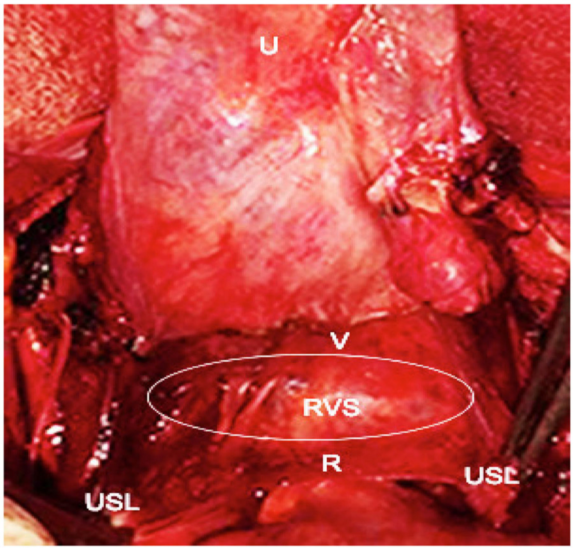


Figure 15: Rectovaginal space (RVS). Uterus (U); Uterosacral ligaments (USL) are cut for better visualization; R–anterior surface of rectum (R); posterior surface of vaginal (V).

The Denonvilliers fascia is a two-layered fascia present retroperitoneal to the uterus along its course tell the uretrovesical junction [24]. This space is lined by the cervicovesical fascia, which contains parasympathetic nerves innervating the bladder. Therefore, careful dissection during the nerve-sparing radical hysterectomy must be taken to preserve parasympathetic innervation.

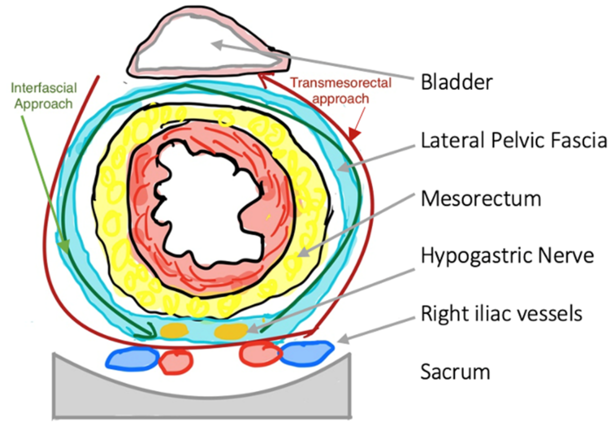


Figure 16: Trans-mesorectal approach (TMRA); Inter-fascial approach (IFA) to access the Rectovaginal Space.

There are two different approaches to the rectovaginal space; medial and lateral. The medial approach accesses the Denonvilliers' fascia by cutting through the rectouterine pouch.

There are many controversies in the literature regarding this fascia, as the appearance of the fascia during operations varies considerably [13]. Zhai et al. 2009, concluded that the rectovaginal septum was composed of two layers—the anterior layer (Denonvilliers' fascia) and the posterior layer (fascia propria of the rectum) [12]. According to Puntambekar et al, 2019, There are two layers of Denonvilliers' fascia—one covers the rectum and the other the posterior vaginal wall. Ceccaroni et al. 2018, described a different lateral approach for treating deep endometriosis [25]. The rectovaginal septum develops in latero-medial, Cranio-caudad, and dorsoventral directions after opening both pararectal compartments. After locating the ureter and hypogastric nerves, the lateral technique encircles the illness from the back [19].

After a vertical or transverse posterior vaginal incision at the intersection of the lower third or middle third of the posterior vagina, the vaginal route enters this location [5]. For rectocele repair, a vaginal technique is used to access the RVS area [26].

From the urogynecological perspective, to treat vaginal vault prolapse, the rectovaginal area is reached via laparoscopic sacrocolpopexy or uterosacral ligament suspension [Wattiez et al., 2003]. In addition, the rectovaginal area is exposed after a radical hysterectomy in gynecological oncology: pelvic adhesions, deep endometriosis resection, or rectovaginal fistula closure in gynecology.

For safe dissection, stay between two fascial layers to prevent vascular or rectal injury because, as we all know, "fat belongs to the rectum" [3].

4.4. Retrorectal or presacral space

Presacral (retro rectal) space boundaries: related anteriorly to the mesorectal fascia and rectum; Posteriorly is related to the longitudinal anterior vertebral ligament, sacral promontory, anterior aspect of the sacrum; laterally is related to the right (right common iliac artery and right ureter), left (left common iliac vein and left ureter), hypogastric fascia (medial fibers of the uterosacral ligaments); superiorly is related to the peritoneal reflection of the rectosigmoid colon; inferiorly is related to the pelvic floor (Figure 17) [24,26,27]. Vigorous dissection between the mesorectum and Denovillier fascia could lead to injury of presacral veins, which can lead to severe bleeding and postoperative retro rectal hematoma.

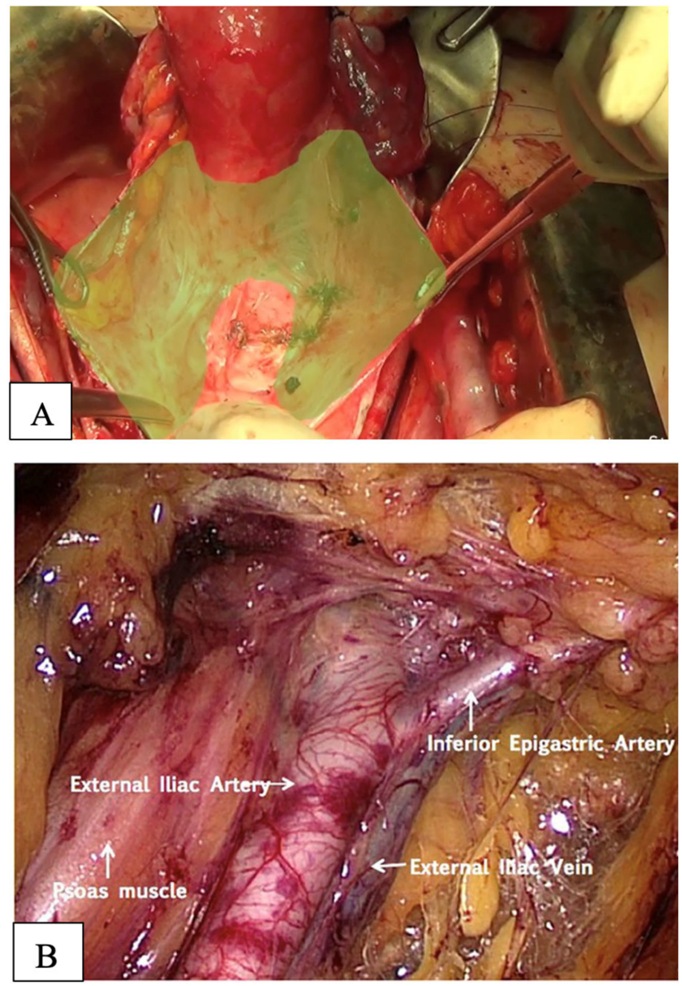


Figure 17: Presacral space, image A. Image B: The sacral promontory after dissection, with the ureter crossing over at the common iliac artery's bifurcation into the internal and external iliac arteries. Source: Reproduced after permission from Dr Puntambekar. Puntambekar S, Manchanda R. Surgical pelvic anatomy in gynecologic oncology. Surgical pelvic anatomy in gynecologic oncology. 11 October 2018 https://doi.org/10.1002/ijgo.12616.

The retro rectal space is helpful in posterior exenteration for complete mesocolic excision of the metastasized rectum in a patient with stage IV-A cervical Cancer or profoundly infiltrating endometriosis involving the rectum, presacral neurectomy, and sacrocolpopexy.

The retro rectal space is divided by Waldeyer's fascia into inferior and superior retro rectal space [Jin et al. 2011]. The presacral area has three fascial layers—presacral fascia, proper rectal fascia (mesorectal fascia), and Waldeyer's fascia.

Most authors describe Waldeyer's fascia as recto sacral fascia, which originates at the fourth portion of the sacrum, runs along sacral curvature, and fuses with the posterior leaf of fascia propria of the rectum. We conclude that the most critical aspect is to identify this fascial layer (either Waldeyer's fascia or retrorectal fascia) and failure to recognize and divide it can cause rectal perforation or severe presacral hemorrhage. Division of this fascia can provide access to the inferior portion of the retrorectal space, resulting in successful mobilization of the rectum during operations for bowel endometriosis or ovarian cancer infiltrating the rectal wall [Jin et al 2011, 21].

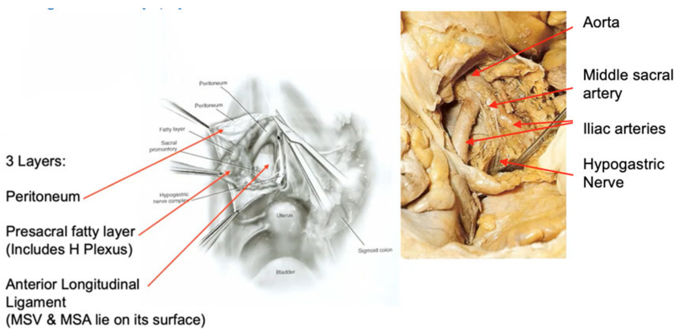


Figure 18: Anatomy of Sacral Promontory. Source: Reproduced after permission from video with title "Understanding Pelvic Anatomy and Optimizing Surgical Outcomes" the society of gynecologic surgeries (SGS). https://vimeo.com/user23887852

In gynecology oncology, the holy plane of dissection is an inter-fascial approach to differentiate between mesorectal fascia and presacral fascia (Figure 17). It is used for total mesorectal excision (TME). We use this procedure to resect for resection of ovarian cancer infiltrating the rectal wall or endometriosis of presacral fascia [28,29,19,26].

In gynecology, the trans-mesorectal approach is superior to the inter-fascial for managing endometriosis because the trans-mesorectal approach preserves the mesorectum. In addition, most studies reported that mesorectum preservation reduces nerves and ischemic vascular complications [Ledu et al., 2018; Mangler et al., 2008] [40].

The presacral space is dissected by two different approaches: the lateral traction of the rectosigmoid to the right side of the pelvis and incising the peritoneum vertically to the left sigmoid peritoneal attachment to the posterior pelvis or at the level of the promontory. The dissection starts at the level of aortic bifurcation and proceeds caudally. To get access to the presacral space, the surgeon should identify three structures at higher risk of injury during the dissection, including the Left common iliac vein right common iliac artery, and hypogastric plexus. The sacral promontory is covered with three layers: the peritoneum and two layers of connective tissue—peritoneum along with its attached areolar tissue and presacral fascia containing the superior hypogastric plexus. With the sacral promontory approach, the peritoneum incision starts from the promontory along the axis of the right common iliac artery. The underlying presacral fascia is dissected along the medial border of the right common iliac artery (Figure 17).

The prelumbar space can be accessed to identify the longitudinal anterior vertebral ligament. Presacral fascia contains middle sacral vessels, hypogastric nerves, and superior hypogastric plexus. In urogynecology, the prelumbar space is developed for sacrocolpopexy [19]. The hypogastric nerve is the most common structure to be injured in Sacrocolpopexy. The superior hypogastric plexus (SHP) carries both sympathetic and parasympathetic fibers for pelvic organs. It is located bilaterally along the fifth lumbar vertebral body and sacral promontory on the aortic bifurcation. Injury of hypogastric nerves is the most common complication of sacrocolpopexy. Injury of the Superior hypogastric plexus in females results in bladder dysfunction, Sexual dysfunction, and dyspareunia. Careful dissection of the presacral fascia anterior to the promontory, and avoidance of electrocautery in this region, may help prevent this complication.

In gynecology & gynecology oncology, the prelumbar space dissection is done for para-aortic sentinel lymphadenectomy [26,29]. The sentinel Lymphadenectomy can be identified after opening the peritoneum above the aorta. Sentinel Lymph nodes can be visualized lying between the aorta and IVC [Figure 18].

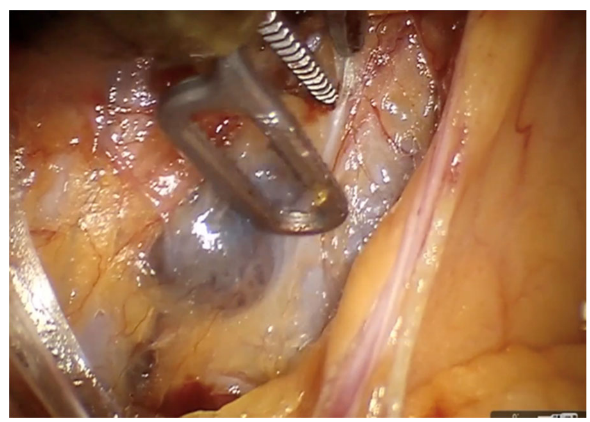


Figure 19: Sentinel Paraaortic Lymphadenectomy (with methylene blue). in stage IIA1 Cervical cancer during radical hysterectomy. Sentile Lympgnode lie between the aorta and IVC. Source: Reproduced after permission from Dr. Schwab. Videofest 21: Methylene blue for detection of sentinel lymph nodes in cervical cancer g. Menderes; C. L. Schwab. https://vimeo.com/156356506

Careful dissection of presacral or Prelumbar space is advised. Injury to middle sacral vessels will be challenging to control as these vessels are difficult to clamp or suture. The superior hypogastric plexus and nerves are parley visible by laparoscopy.

The operator should excise tissues when all the adjacent anatomic structures are visible [5,26].

4.5. Pararectal space

Pulling the ureter to the medial side will access the uterine artery in the lateral pararectal space (i.e., the Latzko space).

Pulling the ureter to the lateral side after dissecting the broad ligament, access to the Okabayashi space, and the para-sympathetic nerves. Access to Okabayashi space is helpful in nerve-sparing radical hysterectomy and surgical resection of endometriosis.

In the lateral approach, the incise of the peritoneum lateral to the infundibulopelvic ligament will access the external iliac vessels (vein and artery) and lymph nodes. The internal iliac artery lies below the external iliac vein. Once identified, it must be dissected free from the ureter to avoid vein injury during the rough manipulation. The lateral approach is the access to the lateral paravesical space for pelvic lymph node dissection (Figure 16). In gynecology oncology, LPS is dissected for pelvic lymphadenectomy, whereas MPS gives access to the management of bladder or ureteric endometriosis or anterior exenteration. Although rare, the paravesical space is dissected through an extraperitoneal approach during extraperitoneal pelvic lymphadenectomy in gynecology oncology cases. Twelve centimeters away from the midline incision in the lower abdomen, the space between the rectus abdominis sheath and the parietal peritoneum is developed toward the left inguinal region to identify the external iliac artery and vein. (Figure 16). The paravesical space is exposed after the separation of the peritoneal sac. Paravesical space contents are the external iliac artery/vein [19,30].

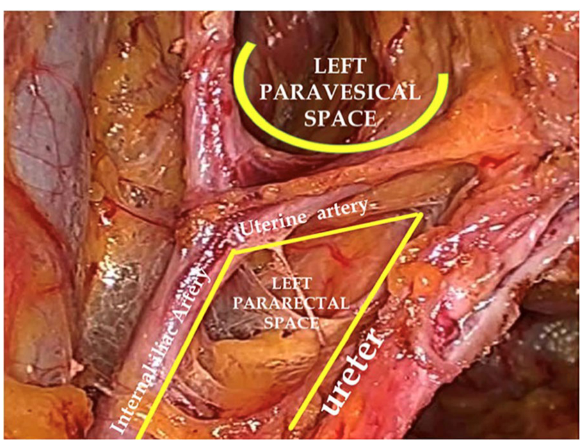


Figure 19: The pararectal and paravesical spaces are divided by the uterine artery. Source: Reproduced after permission from Dr Puntambekar. Puntambekar S, Manchanda R. Surgical pelvic anatomy in gynecologic oncology. Surgical pelvic anatomy in gynecologic oncology. 11 October 2018 https://doi.org/10.1002/ijgo.12616.

A medical approach is used to access the ureter. With further dissection, the ureter divides the pararectal space into medial (Okabayashi's space) and lateral (Latzko's space) pararectal spaces [16,11]. The HN is localized 2–3 cm Posteriorly to the ureter (Figures 20) [22].

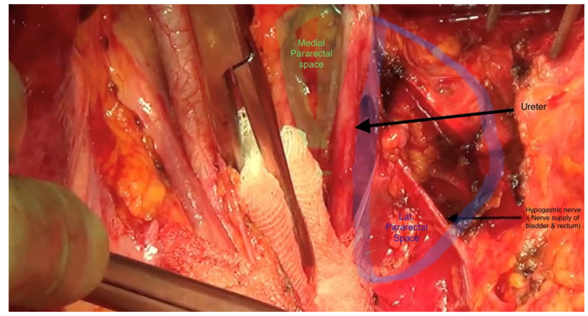


Figure 20: Pararectal space. Ureter divide the pararectal space to Medial and lateral Pararectal space. Hypogastric Nerve located in Medial Pararectal space.

By medial traction on the ureter, the lateral pararectal space (i.e., the Latzko space) is opened and dissected from its origin. The uterine artery can be easily identified and dissected here. By lateralizing the ureter from the fold of the peritoneum or the posterior leaf of the broad ligament, the Okabayashi space is opened clearly, and the para-sympathetic nerves (Figures) can be seen on gentle dissection. This is helpful in nerve-sparing radical hysterectomy. These principles are also applicable in surgery for endometriosis. In the lateral approach, the incision on the peritoneum is made lateral to the infundibulopelvic ligament, and the first structures visible here are the external iliac artery and vein. This area is the best place for easy lymph node dissection. The internal iliac artery lies below the external iliac vein. Once identified, it needs to be dissected free from the ureter. The lateral approach also helps in the easy opening of the lateral paravesical space for pelvic lymph node dissection (discussed later) (Figure 19).

The Okabayashi space contains nerve fibers of the superior hypogastric plexus that traverse from the rectum and join to form the hypogastric nerve, finally innervating the bladder. It has a significant surgical application of nerve-sparing radical hysterectomy and nerve-sparing fertility-preserving procedures in cases of endometriosis. The ureter passes through Okabayashi space; it can be accidentally ligated.

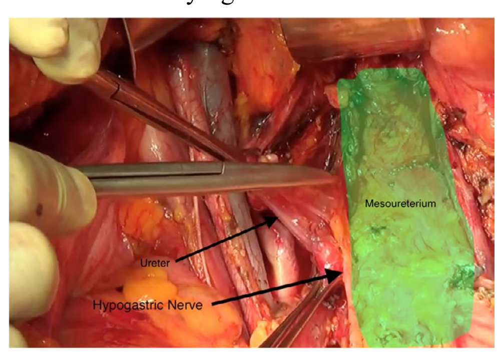


Figure 21: Hypogastric Nerve in Pararectal space after medial traction of the ureter. Hypogastric nerve lie within the mesoureter.

By medial traction on the ureter, the lateral pararectal space (i.e., the Latzko space) is opened and dissected from its origin. The uterine artery can be easily identified and dissected here. By lateralizing the ureter from the fold of the peritoneum or the posterior leaf of the broad ligament, the Okabayashi space is opened clearly, and the para-sympathetic nerves (Figures) can be seen on gentle dissection. This is helpful in nerve-sparing radical hysterectomy. These principles are also applicable in surgery for endometriosis. In the lateral approach, the incision on the peritoneum is made lateral to the infundibulopelvic ligament, and the first structures visible here are the external iliac artery and vein. This area is the best place for easy lymph node dissection. The internal iliac artery lies below the external iliac vein. Once identified, it needs to be dissected free from the ureter. The lateral approach also helps in the easy opening of the lateral paravesical space for pelvic lymph node dissection (discussed later) (Figure 19).

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Dietzik managed the limb ischemia with immediate placement of a Dacron aortobifemoral bypass extending from the infrarenal aorta to both deep femoral arteries was performed (Figure 21) with a resolution of all ischemic symptoms and healing of the left foot ulcer.

Figure 22: Diagram of arteriographic occlusions in patient 1, and (A) presumed compensatory collateral circulation to the lower extremities before radical cystoprostatectomy with bilateral hypogastric artery ligation (arrows); (B)revascularization with a right external iliac to left common femoral artery PTFE bypass and a reversed saphenous vein graft extension to the left anterior tibial artery. At a subsequent operation, a PTFE extension from the crossover bypass was performed to the right below-knee popliteal artery.

Okabayashi's space-related anteriorly to the cardinal ligament; Posteriorly to the presacral fascia and sacrum; laterally to the ureter and mesoureter; medially to the rectum [3,15,16,19,23,25,28]. In addition, Okabayashi's space can be accessed by blunt dissecting between the posterior leaf of the broad ligament and the ureter. This step allows lateralization of the ureter, mesoureter, HN and gives access to the uterosacral ligament [16,19,25].

Okabayashi's space is divided transversely by the lateral ligament of the rectum (LLR) and middle rectal artery (MRA). LLR is formed by the MRA and vein and surrounding tissue. LLR and MRA are stretched between the hypogastric vessels and the rectum. The LLR and MRA are significant during nerve-sparing procedures. LLR and MRA are led to the pelvic plexus, which is located under them. LLR and MRA transverse the pelvic plexus [22,19,23]. In gynecology oncology, Okabayashi's space is exposed during nerve-sparing radical hysterectomy or in cases with deep endometriosis to preserve nerves. The dissection of Okabayashi's space is essential for the identification and dissection of hypogastric nerves [3]. Fujii reported that during nerve-sparing radical hysterectomy, developing Okabayashi's space is not required, as the development of Latzko's space is enough [15].

Okabayashi's space is dissected during laparoscopic uterosacral nerve ablation (LUNA) to avoid ureteral injury during transection of uterosacral ligaments, or endometriosis resection that requires ureter mobilization, bowel management [19,20].

Pararectal space usually will be dissected during radical vaginal trachelectomy (Dargent's operation) or (Shauta's operation), vaginal sacrospinous ligament fixation, or laparoscopically assisted radical vaginal hysterectomy. The left Pararectal space is accessed by the extraperitoneal approach by incising the peritoneal depression in-between 3 o'clock and 5 o'clock positions of outward traction on the peritoneum using two Kohler forceps [14,32].

The pararectal space is dissected during sentinel lymph node biopsy. During dissection, avoid the deep dissection, as the deep vein might be lacerated. In addition, careful dissection of the caudal limit of PRS must be taken due to the risk of injury of the ureter, lateral sacral, and hemorrhoidal vessels [32].

4.6. Yabuki (Fourth) Space

The Yabuki space is located between the cranial portion of the vesicouterine ligament and the ureter. It is surrounded anteriorly by the ureter and posteriorly by the anterior surface of the uterus. The Yabuki space is accessed during nerve-sparing radical hysterectomy as it contains the pelvic splanchnic nerves for bladder innervation (Figure 23). The indication of dissection of Yabuki space is to gain access to the vesicouterine ligament and ureter (Figure 24) [3,21]. Concluded that the Yabuki space should be located between the lateral side of the vagina and the caudal portion of the vesico-cervical ligament [21]. Nerve-sparing techniques in oncologic pelvic procedures usually require the dissection of four avascular spaces (medial paravesical, Okabayashi, Latzko, Yabuki spaces) and four structures (the ureter, LLR, MRA, and the deep uterine vein) [2,22].

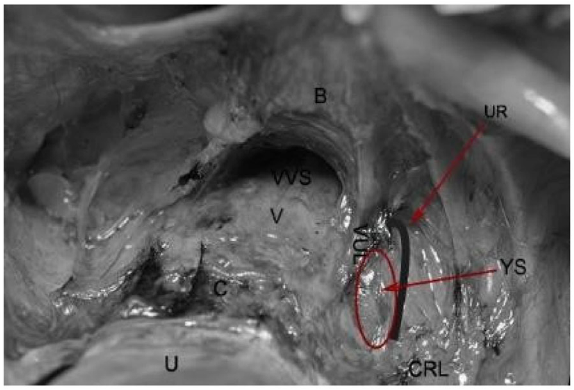

Figure 23: Yabuki space. Vesico-uterine ligament (VUL); vesicovaginal space (VVS); cardinal ligament (CL); Yabuki space (YS), uterus (U); cervix(C), vagina (V); bladder (B); ureter (UR);

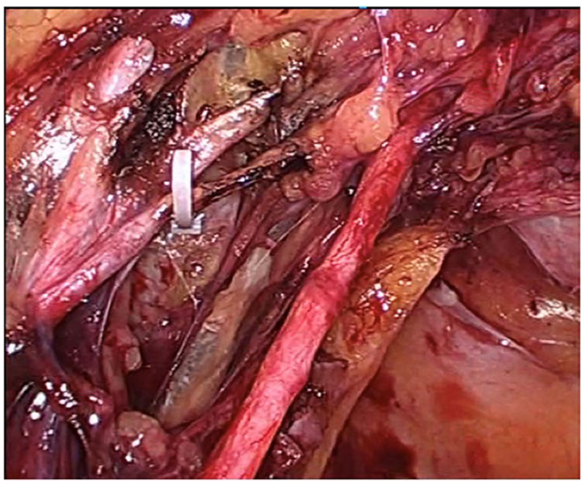

Figure 24: Yabuki space [18].

4.7. Retropubic (Retzius) Space

Retzius space (retropubic or prevesical) space is a retroperitoneal space made by the pubic symphysis anteriorly, Posteriorly by the parietal peritoneum and bladder. The transversalis fascia superiorly, while the urethra, pubocervical fascia, and bladder neck are related inferiorly. The arcus tendinous fasciae pelvis, which lies on the inner surface of the obturator internus, and the pubococcygeal and puborectalis muscles represent the lateral boundary of the Retzius space (Figure 25) [20,24,26,32].

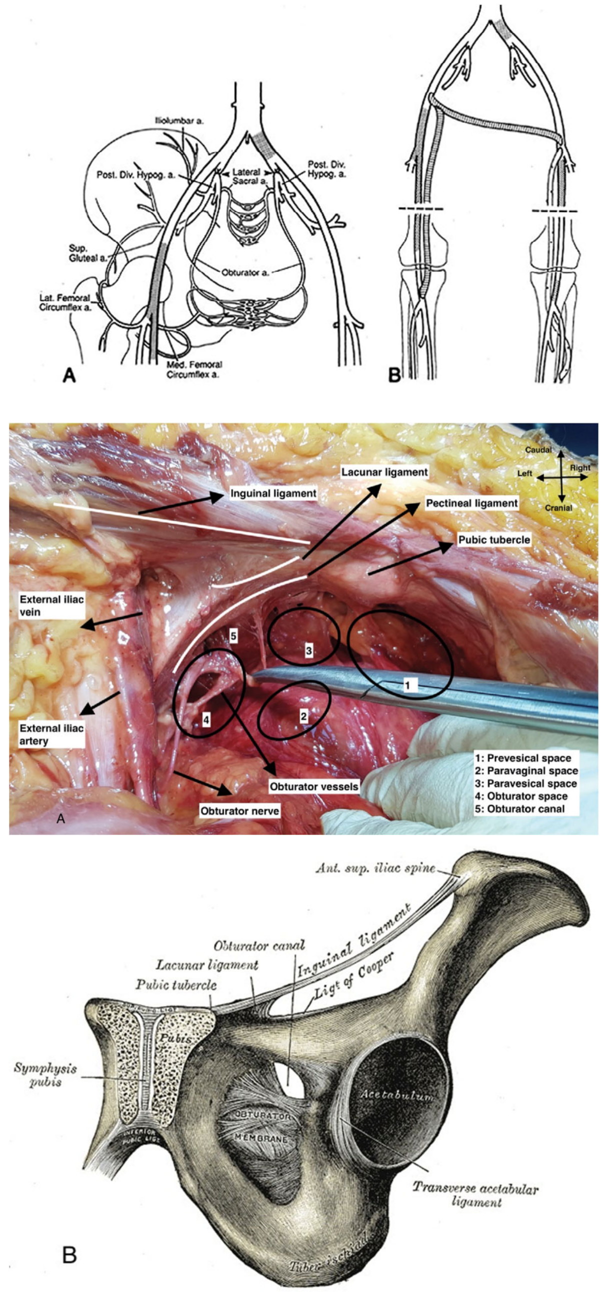

Figure 25: Image A: Retzius space (Prevesical) .Paravaginal space (2), Paravesical space (3), obturator space (4), Obturator canal (5).; Pubic tubercle; Pectineal Ligament, Lacunar ligament. Source: reproduced after permission from National Institute of health. Structure of pectineal ligament. https://bit.ly/3FT6toP. Image B: reproduced from Wikipedia- Pectineal Ligament.

The Retzius space is an extraperitoneal space related laterally to the paravesical bilaterally. The line of demarcation is the obliterated umbilical artery that divides the paravesical space into LPS and MDS [5,33,34]. The surgical application of dividing the Retzius space is part of laparoscopic nerve-sparing operations used to manage deep endometriosis and most gynecology oncology surgeries.

In urogynecology, Retzius space is a virtual space for Burch colposuspension, retropubic TVT, MESH removals, and anterior colporrhaphy [Ahmed et al. 2018]. In addition, Retzius space is accessed during the anterior exenteration and anterior pelvic peritonectomy in gynecology oncology.

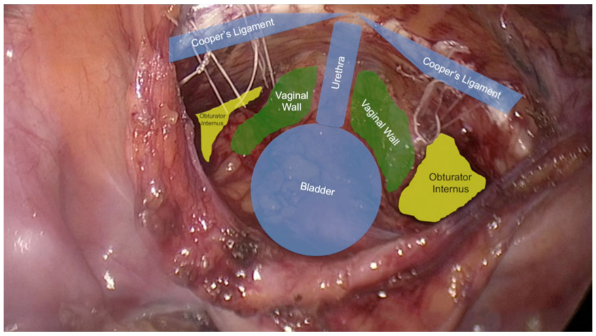

Figure-25: Burch Colposuspension. Reproduced after permission from Dr Garcia. From Video Cafe 30 Laparoscopic Burch Colposuspension B. A. Garcia; R. Elkattah; S. Mohling; A. Yilmaz; R. Furr. https://vimeo.com/156316464

In gynecology, it is developed for bladder endometriosis [31]. The urachus (median umbilical ligament) lies on the inner aspect of the anterior abdominal wall dorsal to the fascial layers (umbilical vesical fascia, umbilical prevesical fascia, transversalis fascia) (Figure-5).

To gain access to the Ritzus space, the site of the peritoneal incision is just above the bladder dome, included between the medial umbilical ligaments bilaterally [35,12]. After cutting the median umbilical ligament, proceed ventrolaterally to reach retropubic space.

During dissection, the surgeon has to be familiar with a prominent vascular plexus within the paravaginal space known as the veins of Santorini, which drains into the internal iliac vein. The dorsal vein of the clitoris drains into the plexus of Santorini [16,12]. In addition, Bladder injury may occur, If the surgeon misses the correct avascular plane of dissection.

4.8. Vesicocervical and Vesicovaginal Space

The vesicovaginal space is a continuation of the vesicocervical space, also known as the anterior cul-de-sac [16]. Vesicocervical space is related to the bladder anteriorly; and to the pubocervical fascia and cervix (upper part) posteriorly. It is related to the vesicouterine ligament laterally; and superiorly to the peritoneal reflection between the bladder and uterus. Inferiorly related to the urethra (Figure 26).

Multiple surgical applications may be applied to the vesicocervical/ vesicovaginal spaces.

In abdominal Hysterectomies, the uterovesical peritoneum is dissected centrally on the pubovesical fascia of the cervix and upper vagina [5]. Next, the anterior vaginal wall is incised transversely, and the dissection remains centrally on the cervix to incise the supravesical septum. Then cut the vesicouterine peritoneum to access the anterior cul-de-sac [5].

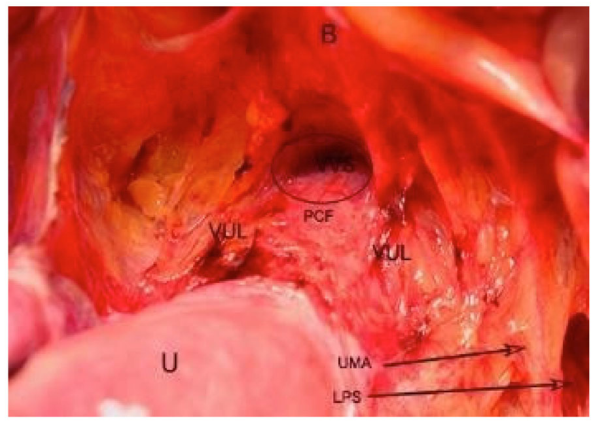

Figure 26: Vesicovaginal space dissected, bladder (B); uterus (U); Umbilical artery (UMA); paravesical space (PS); Vesico-uterine ligament (VUL); Pubocervical fascia (PCF); vesicovaginal space (VVS).

In urogynecology, the vesicovaginal space is dissected in urinary stress incontinence procedures, repair of a vaginally connected fistula, anterior corporaphy, and during laparoscopic sacrocolpopexy or hysterocolpopexy [24,34,27,26]. In addition, vesicovaginal and paravesical spaces are dissected during nerve-sparing radical hysterectomy or deep endometriosis.

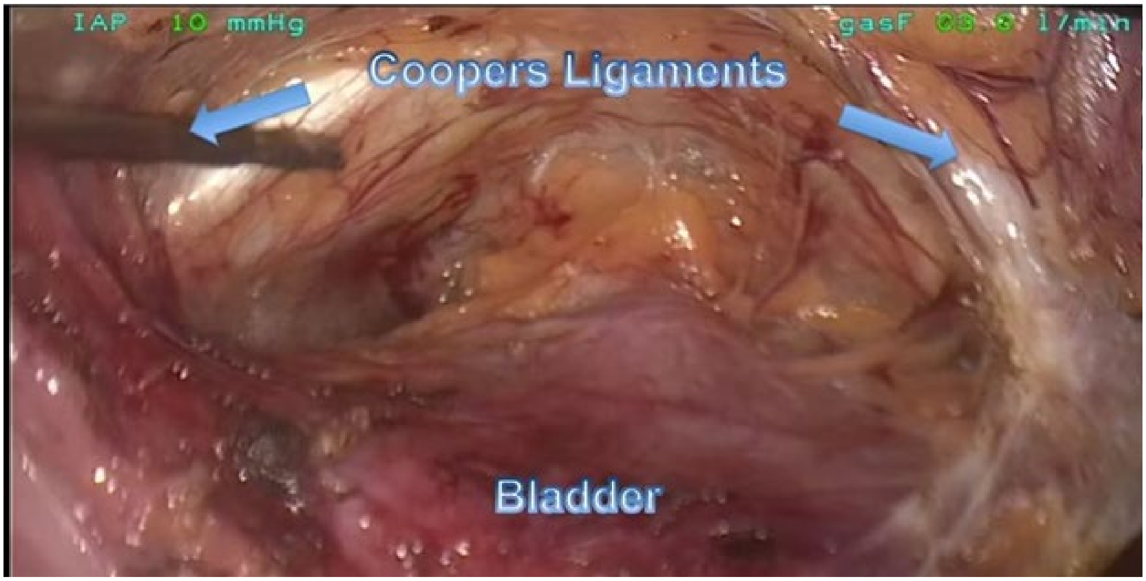

Figure 27: Burch Colposuspension. Source: Reproduced after permission from Dr Furr. From Video Cafe 30 LAPAROSCOPIC BURCH COLPOSUSPENSION B. A. Garcia; R. Elkattah; S. Mohling; A. Yilmaz; R. Furr. https://vimeo.com/156316464

In obstetrics, the dissection of the vesicovaginal space with exposure of the lower uterine segment is required in cesarean section, cesarean hysterectomy, and ectopic pregnancy in cesarean section scar minimally invasive surgeries, and laparotomy cerclage procedures [29].

It is essential to stay in the correct dissection plane, which is above the pubovesical fascia, to avoid bleeding. Remember the dissection rule is "fat belongs to the bladder" [3].

The vesicouterine ligament (lateral and caudal portions from the distal ureter). The paravaginal portion of the paracervix and the superficial layer of the vesicouterine ligament is the ventral parametrium (cranial and medial portions from the distal ureter). The lateral part of this ventral parametrium contains important vessels such as the uterine artery & vein, the ureteral branch of the uterine artery, and cervicovesical vessels [20]. The ureter travels between the cranial and caudal portions of the vesicouterine ligament.

The surgeon should maintain the medial side of the dissection of the vesicouterine and vesicovaginal space, as lateral dissection will lead to ureteric and vessel injury. In laparoscopic procedures, to access the vesicouterine and vaginal space, pull up the bladder. The surgeon should avoid pulling up the peritoneum only without pulling up the bladder, as this will lead to bladder injury (Figure 28) [36-43].

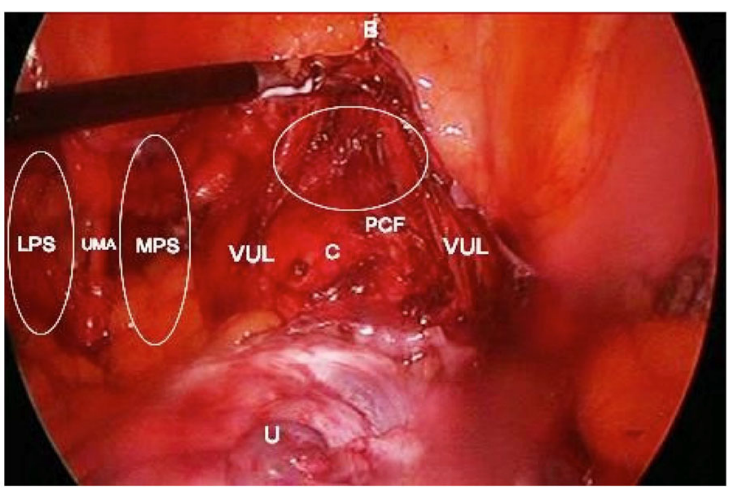

Figure 28: Development of vesicovaginal space during laparoscopic total hysterectomy. The bladder was dissected. bladder (B); uterus (U); medial paravesical space (MPS); lateral paravesical space (LPS); Cervix (C); umbilical artery (UMA); cranial portion of the vesico-uterine ligament (VUL); pubocervical fascia (PCF).

Conclusion

This article discussed the detailed surgical anatomy of female pelvic vasculatures and its clinical applications in obstetrics and gynecological surgeries. We discussed the significance of all avascular retroperitoneal spaces in the female pelvis. The surgeon should fully understand these spaces and related structures. Therefore, a thorough understanding of pelvic anatomy is essential in retroperitoneal pelvic surgery in the urogynecology and gynecology oncology fields.

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