FIGO CANCER REPORT 2018

Surgical pelvic anatomy in gynecologic oncology

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Keywords: Gynecologic oncology; Hypogastric nerve; Laparoscopy; Pelvic anatomy; Predictive anatomy

Synopsis: Laparoscopic understanding of pelvic anatomy and its application in benign and radical pelvic surgery.

Abstract [Editing OK?]

Laparoscopy, with its many advantages, has revolutionized the field of pelvic surgery and enabled surgeons to gain a far greater understanding of pelvic anatomy. As technology evolves, our understanding is continuously improving. This article is a tribute to the anatomy of the pelvis, which itself has resisted evolutionary changes and remained the same, whereas our understanding of how to view and approach various organ structures has evolved.

In the text, please add place markers for the 10 figures either in brackets e.g. "(Figure 1)" or in a sentence e.g. "Figure 1 shows…". Please ensure that these markers appear in the most appropriate places and it is clear from the text and figure legend what is being illustrated. Please also add place markers in the text for the supporting information images e.g. "(Supporting information S1)"

1. Introduction

The science of anatomy is a systematic discipline that involves observation, understanding, and experimentation to obtain knowledge of the functioning of the human body. Surgery then is the practical application of this science to treat a disease, remove a tumor or simply minimize symptomatology, and improve function and quality of life. With advances in technology, our vision and ability to detail structures and organs have improved, and consequently so has our understanding. Lessons in anatomy that began with studies of cadavers transitioned to live and active anatomy lessons taught during surgery, moving from open surgery to the current status of learning anatomy via minimally invasive surgery. Minimally invasive surgery provides a magnified view of anatomic structures and is currently one of the best mediums to gain knowledge and improve our understanding of anatomy as we know it today.

Gynecologic malignancies manifest across the clinical spectrum, from localized tumors to locally aggressive tumors in the pelvic region to advanced metastatic spread through the abdomen, lungs, thorax, and even the brain. A thorough knowledge of pelvic anatomy is essential for the management of most gynecological malignancies and helps guide the surgeon toward achieving the required outcome.

Gross anatomy of the pelvis—namely the bladder, uterus, fallopian tubes, ovaries, rectum, and the muscles—has remained unchanged; however, knowledge of the anatomy of various structures that surround these organs has evolved over time. Much emphasis has been given to understanding the anatomy of the vicinity of these organs rather than the organs themselves; for example, their precise location and the approach to these locations, such as vessels, potential spaces, and nerves. The present article focuses on pelvic anatomy, which is discussed and explained using various supporting laparoscopic images.

2. Pelvic anatomy

2.1. Sacral promontory

The sacral promontory in its literal sense is the summit of the pelvis. Pathologic conditions of the pelvis may reach the abdomen and beyond; however, their origin always lies at a level below the sacral promontory. The sacral promontory is the most protuberant structure in the bony pelvis and can therefore be used as a fixed point of reference for various surgeries. (As shown in figure S1: the location of sacral promontory) It can also form a fixed reference point in conditions where the general anatomy of the pelvis seems scarred or distorted. Hence, orientation of structures in the pelvis should always begin with identification of the sacral promontory.

The sacral promontory is significant for the following reasons as shown in the figure (anatomy figure 1)

- The common iliac vessels bifurcate into the internal and external iliac vessels at this level.
- The ureter crosses over from the lateral to the medial side at this level over the bifurcation of the iliac vessels.
- The superior hypogastric nerve plexus, as a parasympathetic nerve plexus, unites to form the left and right hypogastric nerves at this level. At this level the

nerve fibers of the plexus are seen and, when traced inferiorly, form the hypogastric nerves.

- The sacral promontory forms the initiation point for transperitoneal para-aortic lymph node dissection.

Following identification of the sacral promontory, careful and skillful dissection performed lateral to the sacral promontory opens the pararectal retroperitoneal space. The same landmark is also achieved by beginning the dissection medial to the infundibulopelvic ligament. This approach to the retroperitoneal space is also called the endometriotic approach or the medial approach. The lateral approach is also known as the oncological approach, which will be discussed later in the article.

The line of the small bowel mesentery crosses the sacral promontory on its way to the right sacroiliac joint. This is significant because reflection of the small bowel along this line helps clearly delineate pelvic organs from abdominal organs.

2.2. Vessels

The arbor vitae of the pelvis begin at the L1 level where the aorta bifurcates into the common iliac vessels. (FigureS2: bifurcation of aorta) 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 figure S4: right pelvic wall structures. The internal iliac vessels are the main blood supply to the pelvis and its organs; however, as we go further into the peripheral and deeper regions, anastomosis of the finer vessel of the external and internal iliac vessels supplying common areas is seen.

2.2.1. External iliac vessels

The external iliac artery travels along the iliopsoas muscles on its way to supply the lower limbs. The significance of the external iliac artery here is that it has no branches on the anteromedial aspect of the vessels, which facilitates safer and easier ilio-obturator lymph node dissection as shown in Anatomical figure 2: external iliac artery along with inferior epigastric artery and also figure S3:external iliac artery for lymph node dissection. The inferior epigastric artery arises from the anterior aspect of the external iliac artery, which travels above the transversalis fascia under the anterior abdominal wall. During port placement in laparoscopy, utmost care should be taken to prevent damage to the vessel since this will lead to significant bleeding. Also, retraction of the vessels under the transversalis fascia also makes it difficult to achieve hemostasis. The origin of the inferior epigastric artery or the deep circumflex iliac vein inferiorly adjacent to it is considered the caudal limit of the ilio-obturator lymph node dissection.

While dissecting the pararectal spaces using the lateral approach, the first structure to be visualized after dissecting the peritoneum is the external iliac vessels. This identification assists in what is known as “predictive anatomy” and helps traverse deeper into the pelvis during dissection.

2.2.2. Internal iliac vessels

After bifurcation of the common iliac vessels at the sacral promontory, the internal iliac artery originates and then divides into anterior and posterior divisions. The anterior division of the internal iliac artery is the main blood supply to the vital organs of the pelvis, namely the bladder (superior vesical artery) and uterus (uterine artery).figure S6: relationship of internal iliac artery branches .The posterior division is of less significance as it pierces the presacral fascia and supplies the gluteal region.

The anterior division of the internal iliac artery travels parallel to the ureter. The first branch of the anterior division is the uterine artery, after which the internal iliac artery branches again as the superior vesical artery at a plane higher than the uterine artery and then continues as the obliterated hypogastric artery to the anterior abdominal wall. 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 as shown in Anatomical figure 4: Internal iliac artery and branches. According to the rules of dissection, dissection of tubular structures is done in a parallel direction to the long axis of the structure. Thus, the first structure to obstruct during the dissection of the ureter is the uterine artery.

Since the uterine artery arises much further along from the division of the internal iliac artery, this gives a length of approximately 5–6 cm of internal iliac artery devoid of any branches. This can be useful for ligation of the internal iliac vessels in cases of severe bleeding figure S8: relationship of internal iliac artery branches .

There is no direct blood vessel from the internal iliac artery supplying the ureter, which dispels the myth of segmental supply of the ureter. The ureter has its own mesentery and can be completely separated from the major vessels of the pelvis, thus aiding better dissection during radical hysterectomy.

The internal iliac veins also lie parallel to the artery; hence caution must be taken to carefully ligate only the internal iliac artery and not the vein. This can be done by tracing it in a retrograde manner 2–3 cm from the origin of the uterine artery where a cleavage can safely be created to separate the internal iliac artery from the vein.

The only lateral branch of the internal iliac artery is the obturator artery, which lies in the lateral paravesical space (discussed later). As shown in figure S7: obturator vessel The obturator vessels lie exactly underneath the obturator nerve. Thus, the lower limit of obturator lymph node dissection is the appearance of the obturator nerve Anatomical figure 3. Dissection beyond this leads to damage to the obturator vessels and significant bleeding.

2.2.3. Uterine artery

The uterine artery is the first branch to arise from the anterior division of the internal iliac artery. Figure S9: uterine artery branches It crosses over the ureter horizontally and anteriorly then divides into descending and ascending cervical branches before piercing the substance of the uterus. The uterine artery is best visualized in the pararectal space (discussed later).

Since the ascending cervical branch is formed a few millimeters away before entering the uterus, this allows easy access to clamp and coagulate the vessel during intrafascial hysterectomy. The descending cervical branch can be avoided as it helps in formation of the stump post coagulation.

The uterine artery lies anterior to the ureter, whereas the uterine vein lies posterior to the ureter as shown in figure S10 and Anatomical figure 5. Consequently, the ureter lies in the fork between the uterine artery and the uterine vein. This helps distinguish bleeding in the pararectal area. In cases of arterial bleeding, lifting the ureter to close the opening of uterine artery stops the bleeding; with venous bleeding, lifting the ureter will not cease the bleeding but will give access to catch the uterine vein.

On occasion, a small branch from the uterine artery may supply the ureter near the ureteric tunnel. This needs to be identified and coagulated during tunnel dissection to prevent bleeding and obscuration of the field.

2.3. Nerves

The pelvic structures (uterus, rectum, vagina, urinary bladder) are supplied by the autonomic nervous system. They are innervated by motor and sensory sympathetic and parasympathetic nerves. The inferior hypogastric nerve (T10–L2) provides sympathetic nerves and the pelvic splanchnic nerve (S2–S4) provides the parasympathetic fibers. Together these fibers merge and form the inferior hypogastric plexus, which supplies both the uterus and the urinary bladder. Fujii [1] described the anatomy of the inferior hypogastric plexus in great detail. The pelvic splanchnic and inferior hypogastric nerve form a cross-shaped plexus. Nerve-sparing radical hysterectomy involves 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.

3. Spaces

Classical anatomy describes pelvic spaces as coelomic in form or a manifestation of spaces lined by folds of the peritoneum that later led to formation of cavities not occupied by organs and fully lined by peritoneal tissue. It also describes the organs lying outside the peritoneal cavity and folds of peritoneum as ligaments. However, the latest updates on surgical anatomy have focused on understanding retroperitoneal spaces. These spaces lie beyond the peritoneum and are approached by dissection of the peritoneum at various places in the pelvic cavity.[2] Since the peritoneal cavity itself is devoid of any vessels and nerves, the spaces have gained importance in providing access to the vessels for dissection and nerves for surgery. The retroperitoneal spaces of the pelvis are named based on the location of the nearest organs. Each space has its own importance. The retroperitoneal spaces of the pelvis are classified as follows:

(1) Bilateral:

- Pararectal space
- Paravesical space

(2) Unilateral/midline:

- Prevesical space
- Rectovaginal space
- Retrorectal or presacral space

The peritoneal epithelial lining roofs all retroperitoneal spaces and the common floor is the levator ani muscles. If these spaces were to be pictographically explained, they would appear as hollow avascular pyramidal structures with the broad base lying over the levator ani muscle and the apex pointed inward toward the peritoneal cavity.

The retroperitoneal spaces of the pelvis can also be described as peritoneal depressions formed by reflections of the peritoneum between the organs and the pelvic walls. These spaces are virtual spaces, which is to say that they are not naturally present but are created or easily developed by dissection to access vital structures underneath or to separate or retract the organs during dissection.

3.1. Pararectal space

The retroperitoneal space lying lateral to the rectum on either side is known as the pararectal space. Pararectal spaces take the shape of a curve of sacrum bone[3]. The roof of the pararectal space comprises the posterior leaf of the broad ligament. Its medial borders are formed by the rectum and laterally are bound by the internal iliac artery. Cranially the space terminates at the uterine artery and the levator ani forms its floor.

The ureter further divides the pararectal space into the medial and lateral pararectal spaces. The medial pararectal space is known as the Okabayashi space, whereas the lateral pararectal space is known as the Latzko space Anatomical figure 7: pararectal space. The Okabayashi space is named after the famous Japanese surgeon Hidekazu Okabayashi who demonstrated the first nerve-sparing radical hysterectomy in Kyoto Imperial Hospital in 1921.

The Okabayashi space contains nerve fibers of the superior hypogastric plexus that traverse from the rectosigmoid junction and combine to form the hypogastric nerve, and then further at the level of the uterovesical junction form a plexus finally innervating the bladder. It holds clinical and surgical significance for nerve-sparing radical hysterectomy, as well for nerve-sparing fertility preserving procedures in cases of endometriosis. The nerves can be seen on careful dissection of the Okabayashi space. The approach to the pararectal space is defined by two approaches, namely the endometriotic approach and the oncological approach—medial and lateral approaches, respectively (medial and lateral with respect to the infundibulopelvic ligament).

In the medial approach, the incision on the peritoneum is made medial to the infundibulopelvic ligament. The first structure to be visualized here under the peritoneum is the ureter. The ureter then needs to be separated from the internal iliac artery. Following the rules of dissection, the space is dissected further—parallel and lateral to the ureter—until the apex of the uterosacral ligament is reached. During this process the uterine artery is encountered and dissected.

By medializing the ureter, the lateral pararectal space (i.e. the Latzko space) is clearly opened and dissected from its origin. The uterine artery can be easily identified and dissected here. By lateralizing the ureter from the fold of peritoneum or the posterior leaf of the broad ligament, the Okabayashi space is opened clearly and the parasympathetic S2, S3, S4 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 by using the same principles of dissection. The lateral approach also helps in easy opening of the lateral paravesical space for pelvic lymph node dissection (discussed later). Figure S 12: limit of dissection

3.2. Paravesical space

The paravesical space is the retroperitoneal space that lies lateral to the urinary bladder and anterior and superior to the pararectal space. It is enclosed medially by the bladder, laterally by the pelvic walls, and inferiorly by the uterine artery. Anatomical figure 6: pararectal and paravesical space. The pararectal and paravesical space can mutually communicate with each other, and also with the prevesical space. Dissection of these spaces ensures easy and complete removal of the uterus and its attachments during radical hysterectomy.

The paravesical space is divided into medial and lateral paravesical spaces by the obliterated hypogastric artery or the lateral umbilical ligament. While medial paravesical space dissection is performed to achieve optimum oncological clearance, the lateral paravesical space contains in itself the obturator and pelvic lymph nodes, which need to be dissected during radical hysterectomy.

The limit of dissection for the medial paravesical space is the floor formed by the levator ani muscle. For the lateral paravesical space, the limit of posterior dissection is the obturator nerve. The medial paravesical space also provides access for bladder dissection in conditions of adherent uterovesical fold due to previous cesarean delivery and sometimes for mobilization of the bladder during exenteration or ureteric reanastomosis.

3.3. Prevesical space

The prevesical space is a small midline retroperitoneal space that lies between the bladder and the anterior abdominal wall. It communicates with the paravesical space on both sides and is enclosed laterally by the lateral umbilical ligament, which is the continuation of the obliterated hypogastric artery onto the abdominal wall.

The prevesical space primarily exposes the bladder neck and urethra, making it more significant in urogynecology for the management of stress urinary incontinence and sling surgeries. However, it is also useful in anterior exenteration, for example in selected cases of localized recurrent cervical (or other gynecologic) cancers.

3.4. Rectovaginal space

The retroperitoneal space lining the outside of the pouch of Douglas is known as the rectovaginal space. It is enclosed anteriorly by the uterus and the posterior vaginal wall, posteriorly by the rectum, and laterally by the uterosacral and the Mackenrodt Anatomical figure 9: rectovaginal space The roof comprises the peritoneal reflections of the pouch of Douglas and the floor is formed by the levator ani muscle. The Denonvilliers fascia is a two-layered fascia present retroperitoneally yet between the rectum and the vagina: one layer covers the rectum and the second layer covers the vagina. The vaginal veins are present underneath the Denonvilliers fascia, covering the vagina as seen in figure S14: rectovaginal space Hence, the avascular plane is created exactly between the two layers of Denonvilliers fascia to dissect the rectovaginal space. This gives rise to the dictum: the “fat belongs to the bladder and fat belongs to the rectum.”

Rectovaginal space dissection is done until the levator ani is reached. This facilitates taking a larger cuff of vagina in radical hysterectomy. It also helps in symmetric dissection of the vagina anteriorly as well as posteriorly as dissection anteriorly is done below the level of ureter insertion. It is also helpful in posterior slings in urogynecology.

3.5. Retrorectal or presacral space

A thin, small retroperitoneal space lying behind the rectum is covered by the mesorectum anteriorly and Waldeyer fascia posteriorly. The presacral veins lie posterior to the Waldeyer fascia. If careful avascular dissection is not done between the mesorectum and the Denonvilliers fascia there could be severe bleeding from the injured presacral veins.

The retrorectal space is useful in posterior exenteration for complete mesocolic excision of the involved rectum. It is also useful in deep infiltrating endometriosis involving the rectum, sacrocolpopexy, and presacral neurectomy.

3.6. Yabuki space

The Yabuki space, unlike other pelvic spaces, is not lined by peritoneal epithelial lining. The Yabuki fourth space, as it is also called, is a midline small retroperitoneal space confined within the anterior surface of uterus and the ureter inserting into the bladder[4] . Anatomical figure 8: yabukis space This space is lined by the cervicovesical fascia and contains parasympathetic nerves innervating the bladder. Careful dissection at this space helps in nerve-sparing radical hysterectomy.

The cervicovesical fascia splits into anterior and posterior leaves. The anterior leaf allows the ureter to insert into the bladder. Figure S 15: cervicovesical fascia. The fascia here wraps around the ureter to form bladder pillars, while the posterior leaf further communicates with the endopelvic fascia at the level of the levator ani. FigureS 16: endopelvic fascia

4. Conclusion

This article has discussed the newer concepts of pelvic spaces, ureter and its own mesentery, and details of pelvic vasculature. These new concepts will continue to help shape our understanding of pelvic anatomy.

Author contributions

SP and MR wrote the manuscript and reviewed the final version.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Figure legends **[Note to typesetter: Please delete the figure legends from the image files]**

Figure 1 Structures seen at the level of the sacral promontory. Bifurcation of the common iliac artery into internal and external iliac artery, with the ureter crossing over at the bifurcation.

Figure 2 External iliac artery and vein remain parallel while travelling along the border of the pelvis, remaining medial to the psoas muscle and branching into the inferior epigastric artery branch.

Figure 3 The obturator nerves and vessels are the lower limits of dissection of pelvic lymph nodes and lie between the external and internal iliac vessels. The obturator artery is the only artery arising *laterally* from the internal iliac artery.

Figure 4 Relationships: The ureter always lies medial to the internal iliac artery. The internal iliac artery always lies between the ureter and the external iliac artery. The first branch of the internal iliac artery is the uterine artery, followed by the superior vesical artery, after which the vessel collapses to form the obliterated hypogastric artery or ligament.

Figure 5 The ureter lies in the fork between the uterine artery and the uterine vein.

Figure 6 The pararectal and paravesical spaces are divided by the uterine artery. The boundaries of the pararectal space are the uterine artery (anterior), internal iliac artery (lateral), and the ureter (medial).

Figure 7 The pararectal space is divided by the ureter into the medial and lateral pararectal spaces. The medial pararectal space contains the superior hypogastric nerve for performing nerve-sparing radial hysterectomy, while the lateral pararectal space is the best place for dissection of the uterine artery.

Figure 8 Yabuki space: The retroperitoneal space under the uterovesical fold of peritoneum. It is bordered by the ureter anteriorly and the anterior surface of the uterus posteriorly. It also contains nerves passing along the ureter to supply the bladder.

Figure 9 Rectovaginal space: A retroperitoneal space lying between the rectum and the uterus under the Pouch of Douglas. It is covered by two layers of Denonvilliers fascia. Dissection performed between the two layers creates an avascular plane and completely separates the uterus from the rectum in radical surgeries.

Supporting information figure legends **[Note to typesetter: Please delete the figure legends from the image files]**

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Figure S1 Sacral promontory: Summit of the pelvis. In conditions of obscuration of anatomy, dissection can begin from here are a fixed start point for the purpose of orientation and safety. The structure under the harmonic is the ureter.

Figure S2 Bifurcation of the aorta. The aorta bifurcates into the left and right common iliac artery on either side. Mild traction has been given to the right common iliac artery exposing the sacral promontory underneath. This is done during para-aortic lymph node dissection.

Figure S3 External iliac artery vessels. From their origin, the external iliac artery and vein travel in a parallel fashion. Neither one has branches on the anterior or lateral side for the first 6–8 cm. This is useful in lymph node dissection. The first branch is the inferior epigastric artery and vein.

Figure S4 Structures on the right lateral pelvic wall and pararectal space, seen from lateral to medial: external iliac artery; external iliac vein; internal iliac artery; ureter. The first structure to cross the ureter from the internal iliac artery is the uterine artery.

Figure S5 Structures on the left lateral pelvic wall and pararectal space, seen from medial to lateral: ureter; internal iliac artery; external iliac vein; external iliac artery. The external iliac artery gives the uterine artery branch and continues as the obliterated hypogastric artery.

Figure S6 Internal iliac artery and its branches with the ureter.

Figure S7 Obturator artery and its relationships.

Figure S8 Left uterine artery and its relationships.

Figure S9 Uterine artery.

Figure S10 The uterine artery–vein–ureter complex.

Figure S11 Uterine vein.

Figure S12 Lateral limit of lymph node dissection. Pelvic lymph node dissection is done until the pubic bone is exposed. Anteriorly, when the traced along the bone, the corona mortis can be seen; this is the only communication between the external and internal iliac veins.

Figure S13 Correlation between the ureter and the uterosacral ligament. The distance between them is shown with the help of a PDS suture.

Figure S14 Relationship of veins to the Denonvilliers fascia.

Figure S15 Cervicovesical fascia.

Figure S16 Endopelvic fascia.