Surgical Anatomy of the Uterus

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Introduction

A thorough knowledge of the anatomy of the uterus and its relationship to neighboring organs is of immense importance to both gynecologic oncologists and radiation oncologists. A good surgical dissection can only be accomplished by an in-depth understanding of the anatomy of the pelvis and retroperitoneum. Laparoscopy and robotic surgery have improved anatomic perception by excellent optics and a 3D depth of vision. The importance of surgical anatomy of the uterus, its blood supply, lymphatic drainage, innervation, and proximity to vital structures such as the bladder and rectum cannot be overemphasized.

Embryology

The uterus develops by fusion of the bilateral paramesonephric ducts. The upper parts remain separate and eventually become the fallopian tubes. Malunion and nonunion of the paramesonephric ducts can lead to various congenital malformations of the uterus like bicornuate uterus, uterus didelphys, etc.

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Anatomy of Uterus

The uterus is a hollow, thick-walled, fibromuscular organ situated in the true pelvis between the urinary bladder and rectum. The shape, weight, and dimensions vary considerably with estrogenic stimulation and previous parturition.

It is divided into two main parts: upper two thirds form the body, which is mainly muscular, and the lower third forms the fibrous cervix. In the reproductive years, the body is considerably larger than the cervix. In the premenarcheal and postmenopausal years, the ratio of the size of body to cervix is 1:1 or even 1:2. The area where the fallopian tubes enter the body of the uterus is the vascular cornual end. The round ligament of the uterus and ovarian ligament are also attached to the cornua inferior to the fallopian tube, the former anteriorly and the latter posteriorly. The part of the uterus superior to the entry point of the uterine tube is the fundus. The body of the uterus extends from the fundus to the cervix. Within the body or corpus, there is a triangular-shaped potential space, the endometrial cavity. Nearly half of the cervix is inserted into the vagina through the uppermost part of its anterior wall and is called portio vaginalis. The supravaginal part of the cervix joins the body at the isthmus.

The cervix contains dense fibrous connective tissue with a small amount of muscular tissue (about 10 %). The scanty smooth muscle is distributed at the periphery of the cervix and is

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continuous with the body of the uterus and the vagina. It is into this layer that the cardinal, uterosacral ligament and the pubocervical fascia are inserted. This layer is easily stripped off while doing an intrafascial hysterectomy.

Relations and Position

Anteriorly, the uterus is separated from the urinary bladder and uterovesical space by loose connective tissue.

Posteriorly, it is related to the rectum and rectouterine pouch.

Laterally, it is continuous with the broad ligaments.

Axis

Long axis of the uterus is at right angle to that of vagina which is called anteversion.

The uterus is bent on itself at the isthmus anteriorly and is called anteflexion.

Uterine Ligaments

They are mostly composed of fibrous tissue and provide support to the uterus. Sometimes few muscle bundles may be found interspersed in the condensed connective tissue.

Round Ligaments

They are extension of the uterine musculature and are mostly composed of smooth muscle and are homologous to the gubernaculum testis. They begin as a broader structure on each lateral side of the corpus, anterior and inferior to the tubes, and assume a more rounded shape before they enter the extraperitoneal space lateral to the deep inferior epigastric vessels. After entering into the internal inguinal ring, they traverse the inguinal canal, through the external inguinal ring, and fuse with the subcutaneous tissue of labia majora. There is less evidence that it acts as a uterine support. Round ligaments are quite stretchable and attain great lengths as the uterus enlarges. It is accompanied by a constant artery on its inferior aspect which needs to be cauterized or ligated when round ligaments are divided.

Uterosacral Ligaments

These are thickening of the endopelvic fascia that form the medial margin of the parametrium and border the pouch of Douglas. It is composed mainly of smooth muscle, autonomic nerves of the pelvic organs, connective tissue, and blood vessels. Transection of these ligaments disrupts the nerve supply to the bladder and rectum leading to bladder atony and constipation. More recently, it has been found that the uterosacral ligaments merge with the rectal fibers on the lateral sides instead of being inserted into the sacrum (Fig. 13.1). Dissection of these during radical hysterectomy calls for a more careful approach in a nerve-sparing surgery (Fig. 13.2). With improved survival rates in cancer endometrium, quality of life issues now take a precedence. The inferior hypogastric plexus and hypogastric nerve are intimately related to the uterosacral ligament. Saving these structures as far as possible and of course with-

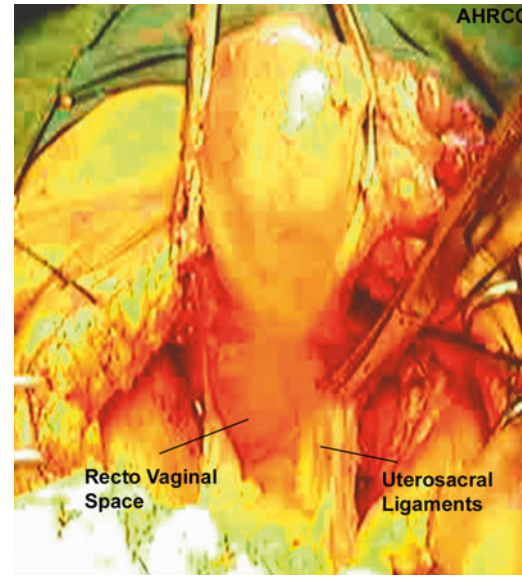

Fig. 13.1 Uterosacral ligaments (AHRCC)

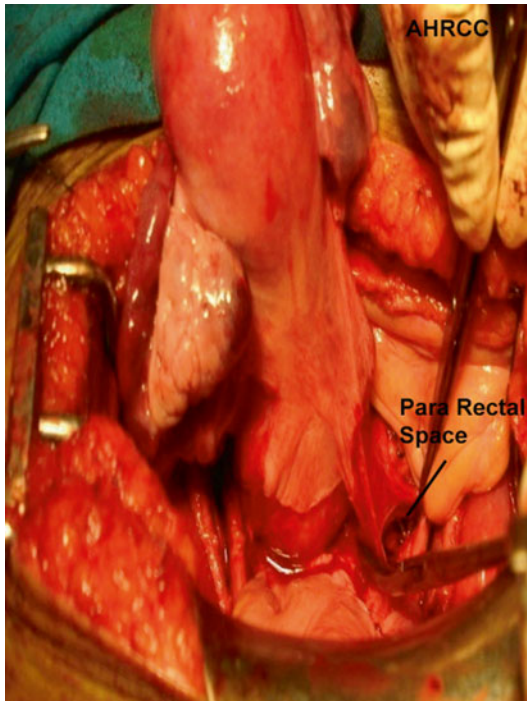

Fig. 13.2 Uterosacral ligaments removed from attachment

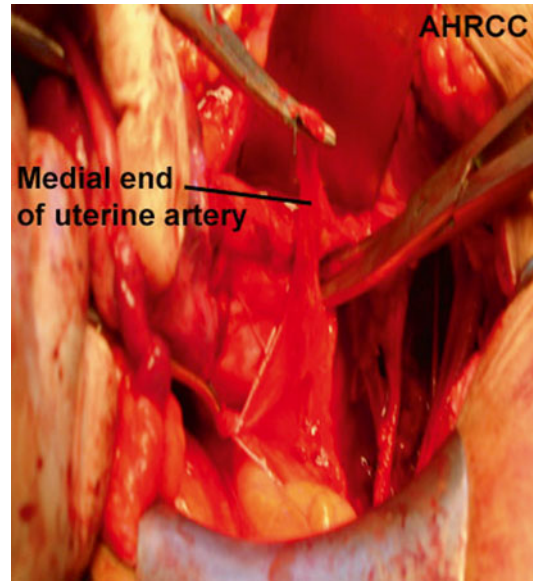

Fig. 13.3 Ureteric tunnel dissection

out sacrificing oncological clearance is of importance [2]. The inferior hypogastric plexus (named after Lee Frankenhauser) gets fibers from the superior hypogastric plexus via the hypogastric nerve and from the roots of S2 to S4 via the splanchnic nerves. It is placed in a sagittal plane and measures about $3 \times 4 \times 0.5$ cm and is a dense triangular neural network with base lying posteriorly. It stretches from the anterolateral wall of the rectum, lateral to the cervix and vaginal fornix, to the lateral vaginal wall and base of the bladder. Its upper limit is in close proximity to the deep uterine vein that serves as a landmark to identify the plexus [3]. Thus, it runs in close proximity to the pelvic connective tissues.

Transverse Cervical (Cardinal/ Mackenrodt's) Ligaments

This serves as the main uterine support. They attach the lateral margins of the cervix and vagina to the pelvic wall. It is important that at the end of hysterectomy, the vault is fixed to these ligaments to prevent future descent of the vault. The cardinal and uterosacral ligaments are simply two parts of a single body of suspensory tissue. It consists mainly of perivascular connective tissue and pelvic vessels.

Though described as extending laterally, these ligaments assume vertical position in erect posture. Each ligament is well defined near the uterine attachment but fans out symmetrically with a broad area of attachment on the second, third, and fourth sacral vertebrae (Figs. 13.3 and 13.4). They help hold the uterus above the levator plate.

The uterosacral and cardinal ligaments provide the greatest support within the pelvis. Fortunately, they are infrequently involved in uterine cancer contrary to cervical cancer where they are frequently involved.

Rectal Pillars

The fibrovascular bundles running from the anterolateral aspects of the rectum to the posterolateral aspect of the vagina are the rectal

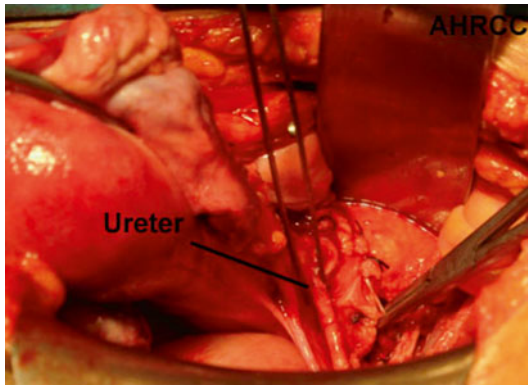

Fig. 13.4 Mackenrodt's ligament (AHRCC)

pillars. They are very vascular and contain the middle rectal arteries, and division may cause unexpected heavy bleeding from the uterine margin. Applying clamps on either side of the division is more esthetic in open surgery.

Bladder Pillars

They are paired fibrovascular bundles that form the lateral limit of the vesicovaginal space. They sometimes are continuous with paracolpos and paravaginal tissue. Condensation of tissue in this area forms the vesicouterine ligament. This houses the ureteric tunnel and is divided into anterior and posterior leaves by the ureter. These two layers have to be dissected off the ureter to visualize its entry into the posterolateral aspect of the bladder [4]. The vesicouterine ligament harbors the cervicovesical veins. Division of these ligaments allows de-roofing of the ureters, and it can be completely mobilized from its attachment to the posterior layer of broad ligament and ureteric tunnel. It is important to know the anatomy of the ureter so that mobilization without ureteric injury is achieved and at the same time preserving its mesentery and vascular supply. The secret to maintaining vascularity of the ureters is to dissect parallel to it and also along the big vessels. The whole purpose of mobilizing the ureter is to place clamps as lateral as required.

Microstructure

Endometrium (Mucosa)

Inside the uterus is a potential triangular cavity lined by endometrium. Endometrium is a unique mucosa. The epithelium is a single-layered columnar and is continuous with tubular uterine glands. The stroma consists of highly cellular connective tissue between endometrial glands and contains blood and lymph vessels. The superficial portion of this layer undergoes cyclic change with the menstrual cycle. Spasm of hormonally sensitive spiral arterioles causes shedding of this layer after each episode of menstruation. A deeper basal layer remains to regenerate a new lining. Separate arteries supply the basal endometrium which explains the preservation of this layer even after shedding.

Myometrium (Smooth Muscle Layer)

The myometrium is fibromuscular in character and makes up most of the uterine corpus. The arrangement of fibers in this layer is complex. This is because the uterus originates from paired paramesonephric primordia, with the fibers from each half crisscrossing diagonally with those of the opposite side. It is composed largely of smooth muscle fascicles mingled with loose connective tissue, blood, and lymph vessels and nerves.

They are arranged in four layers (inner to outer):

1. Submucosal layer (innermost), composed mostly of longitudinal muscles
2. Vascular layer, zone rich in blood vessels and longitudinal muscles
3. Circular muscle layer
4. Thin longitudinal muscle layer

Serosa

It is composed of peritoneum and covers the uterine body and supravaginal cervix posteriorly and only the uterine body anteriorly.

Microstructure of Cervix

Epithelium

The endocervical canal is lined by columnar secretory epithelium and the ectocervix by stratified squamous nonkeratinizing epithelium. The usual prepubertal location of the squamocolumnar junction is at the external os.

At puberty, the endocervical columnar epithelium responds to estrogenic stimulation and extends distally on the ectocervix. This area of columnar cells on the ectocervix is red and raw in appearance and called ectopy. It is then exposed to acidic environment of the vagina, and through a process of squamous metaplasia, a stratified squamous ectocervical epithelium effectively grows over the exposed area resulting in the transformation zone. Other hyperestrogenic states such as pregnancy and use of oral contraceptive pills can also result in ectopy. This area is the site of epithelial abnormalities that may progress to malignancy. In postmenopausal women, the squamocolumnar junction recedes into the endocervical canal.

Spaces Around the Uterus

Knowledge of spaces around the uterus is an absolute necessity to proceed with any kind of uterine surgery and more importantly radical surgery. Pelvic spaces have been created to help us, surgeons, accomplish adequate surgery without blood loss and injury to vital structures. These spaces have loose areolar tissue and are essentially avascular.

The anterior cul-de-sac separates the bladder from the uterus and the posterior cul-de-sac from the rectum. The loose peritoneum of the anterior cul-de-sac helps in filling the bladder without tension. It is this loose peritoneum that helps to create the space between the bladder and uterus during hysterectomy (Fig. 13.5). Posterior cul-de-sac extends lower as the peritoneum covers the upper part of the vagina, unlike anteriorly, where the vagina is bereft of peritoneum. This has to be kept in mind while opening the peritoneal cavity from below in a vaginal hysterectomy. Specialized dense connective tissue between the rectum and the posterior vaginal wall is called the fascia of Denonvilliers and serves as an important landmark while dissecting the rectovaginal space. While dissecting the rectovaginal space, it is also important to remember that the rectovaginal pad of fat should be kept along with the rectum to prevent inadvertent injury to the rectum.

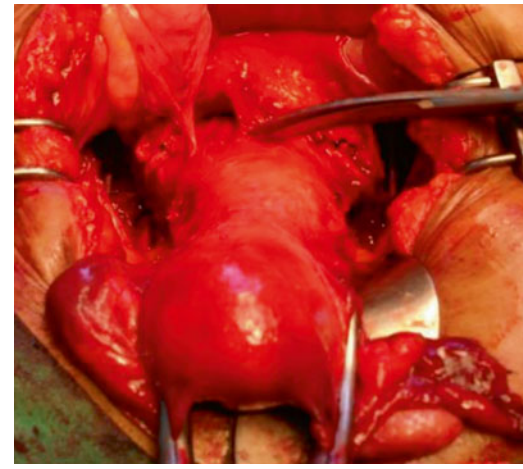

Fig. 13.5 Division of vesicocervical ligament (AHRCC)

Paravesical Space

These are potential spaces on either side of the bladder. The anterior boundary is the pubic arch that is continuous with the lateral pelvic wall as a lateral boundary. It is bounded medially by the bladder and obliterated umbilical artery and posteriorly by the cardinal ligament (Fig. 13.6).

Fig. 13.6 Developing the paravesical and pararectal spaces [1]

Pararectal Space

The cardinal ligament forms the anterior border of this space, the medial border is the rectum, and the lateral limit is the pelvic wall. Posteriorly, it is bound by the presacral fascia. The pararectal space is created easily by dissecting in between the ureter medially and the internal iliac artery laterally (Figs. 13.6 and 13.7).

Peritoneal Folds

These ligaments provide no support to the uterus and only consist of folds of peritoneum.

- Uterovesical fold.
- Rectovaginal fold.
- Broad ligament (mesometrium, mesosalpinx, mesovarium). These folds of peritoneum extend laterally from the uterus and cover the adnexal structures.

Infundibulopelvic ligament contains ovarian vessels.

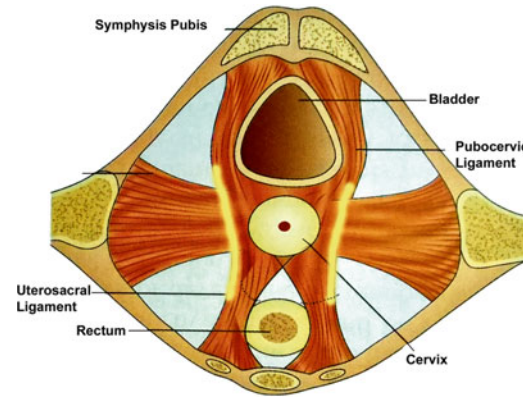

Fig. 13.7 Preserving the hypogastric nerves [3]

Artery Supply

The uterus is abundantly supplied with blood vessels. Uterine artery, a branch of anterior division of the internal iliac artery, supplies the uterus. It usually arises independently or may rarely have a common origin along with the internal pudendal or vaginal artery. It joins the uterus near the junction of the corpus and cervix but may be variable at times. On reaching the uterus, it divides into an ascending and a descending branch. Using injection micrographic and histologic technique to study the vascular anatomy of the uterus, Farrer-Brown et al. [5] showed that the uterine arteries run a tortuous course between the two layers of the broad ligament along the lateral side of the uterus (Fig. 13.8). They turn laterally at the junction of the uterus and fallopian tube, run toward the hilum of the ovary, and terminate by joining the ovarian arteries. At this point, the artery is closely related to the insertion of the uterosacral ligaments to the uterus. Brisk bleeding ensues on inadvertent injury to the vessels while dividing the uterosacrals from the uterus in a Type I hysterectomy. The ascending branch ascends with a tortuous course in the broad ligament and ends by anastomosing with a branch of ovarian artery. A continuous arterial arcade connects the ovarian, uterine, and vaginal arteries. This is a source of collateral circulation after uterine artery ligation done for postpartum hemorrhage.

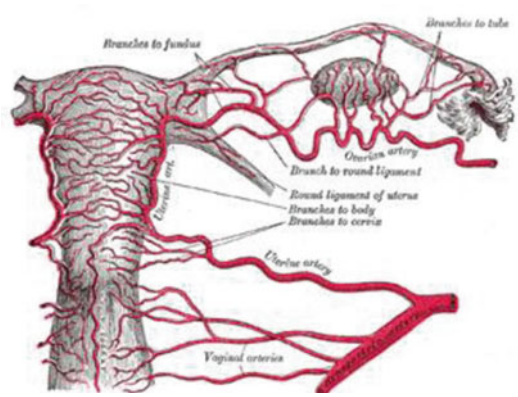

Fig. 13.8 Uterine vasculature [5] (with permission from Tripathy (2009) [13])

Accompanying each uterine artery are several large uterine veins. But uterine veins may not accompany the uterine artery always. Bleeding from uterine veins is low in pressure but high in volume. Attempts to take stitches may result in larger avulsions as uterine veins are very thin walled. Vascular clips would be a better alternative.

The uterine artery crosses the ureter anteriorly. Rotating the uterus and putting it on stretch makes the uterine artery taught and more visible. It is easier to identify the ureter in the posterior layer of the broad ligament, and the entire course may be visible in thin women. Excess of retroperitoneal fat in obese women, adhesion due to inflammation or previous surgery, and needless to say a very deep pelvis and big uterus can sometimes make it difficult to trace the uterine artery and ureter. Exact knowledge of anatomy helps to identify these structures in such difficult situations. Double ureter is another entity that should be kept in mind, and preserving the mesentery is of paramount importance. Each uterine artery gives off numerous branches which enter the uterine wall, divide, and run circumferentially as groups of anterior and posterior arcuate arteries. The arcuate arteries of both sides approach and anastomose at the anterior and posterior midline (Fig. 13.8). Many tortuous radial branches arise from the arcuate arteries and pass centripetally through the deeper myometrial layer to reach the endometrium.

Venous Drainage

Uterine veins are multiple and large. They run in the broad ligament with the uterine artery and drain into the internal iliac vein.

Lymphatic Drainage

Data on the lymphatic vessels of the uterus have been coordinated by Reynolds [6]. The entire uterus has a rich capillary bed as extensive as the blood capillary system. The lymphatic capillary bed is arranged in four zones: (1) the lower uterine segment with its rich supply of fine capillaries, (2) the subserosa of the corpus with a few lymphatics, (3) a deep subserosal network, and (4) a plentiful supply in the muscularis proper. These vessels increase greatly in number and size during pregnancy. The collecting system of the uterine lymphatics is formed from anastomoses of a lateral-uterine descending network of lymph vessels which unites with collecting vessels from the utero-ovarian pedicle and the external iliac area. Lymphatic drainage of the uterus and upper two thirds of the vagina is primarily to the obturator and internal and external iliac nodes. The direction of lymph flow from the uterus tends to follow its attachments, draining along the cardinal, uterosacral, and round ligaments.

Lymphatics from Cervix

The primary cervical drainage is to the paracervical lymph nodes located at the point where the uterine vessels cross above the uterus and then laterally to the external iliac nodes.

Lymphatics from Lower Part of Uterine Body

They drain mostly into internal iliac nodes along the cardinal ligaments and to the presacral and lateral sacral nodes along the uterosacral ligaments. Free communication to the external iliac

nodes leads to further dissemination. The parametrial lymph vessels draining the middle and lower part of the corpus tend to spread in the base of the broad ligaments toward the lateral pelvic side walls and drain into nodes located in the obturator fossa and the internal iliac nodes. Posterolaterally, they drain to internal iliac node, posteriorly to rectal and sacral nodes, and some may drain to obturator or gluteal nodes.

Lymphatics from Upper Part of Body, Fundus, and Tube

Lymph from the fundus drains toward the adnexa and infundibulopelvic ligaments. From there, they drain into lateral aortic and preaortic nodes. Grossly, lymphatics in this region can be divided into left para-aortic, right paracaval, and the aortocaval group of lymph nodes. But Winter and Benedetti-Panici have divided them into more groups: pre-, para-, and retro-aortic; pre-, para-, and retrocaval; and superficial and deep cavo-aortic [7]. The great vessels are covered by the node bearing areolar tissue, and division of this layer exposes the adventitia of the vessels. Once the vessels are exposed, the remaining lymphatics can now be stripped off easily [7]. These ascending lymphatic channels eventually coalesce to form the thoracic duct. Lymphatic channels along the round ligaments may carry the metastatic deposits to the inguinal nodes. Vaginal metastasis in cancer endometrium occurs via lympho-vascular spread. They commonly occur without cervical involvement [8].

The anastomotic connections of the uterine and ovarian vessels have lymphatic connections between these two drainage systems, and metastases in either direction are possible.

Pelvic Blood Supply

A knowledge of the blood supply of the pelvis is essential, because a complete and systematic lymphadenectomy encompasses lymph nodes from the pelvis and para-aortic region up to the renal vessels. Lymphatic channels follow the pelvic vasculature; lymphadenectomy includes stripping off the lymph nodes, lymphatic channels, and fibro-fatty tissue lying along the pelvic vessels.

External Iliac Vessels

After dividing the round ligament and entering the retroperitoneal space, the external iliac artery and vein are seen on the lateral pelvic wall medial to the psoas major muscle (Fig. 13.9). They continue down as femoral vessels after passing under the inguinal ligament. Just before it passes below the inguinal ligament, the external iliac artery is crossed by the deep circumflex iliac vein that marks the lower limit of lymphadenectomy. During its course, it rarely gives out an aberrant obturator artery. It is important to go in between the artery and vein and sometimes behind the vessels to clear all lymphatics.

Internal Iliac Vessels

They remain posteromedial to the external iliac vessels. It divides into anterior and posterior divisions (Fig. 13.9). The pelvic ureter is a close medial relation of the internal iliac vessels. The posterior division supplies the pelvic and gluteal musculature and it's not necessary to trace. The internal iliac vein which follows closely is an important

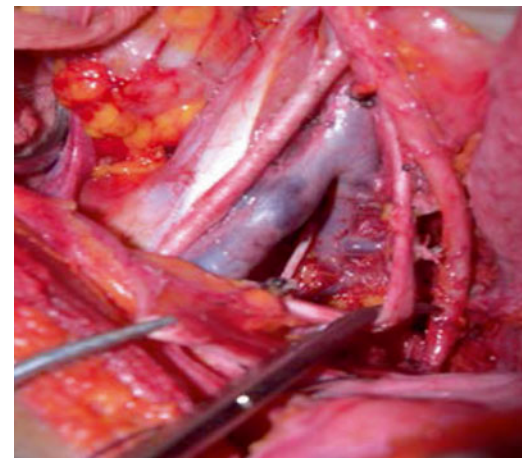

Fig. 13.9 Joining of external and internal iliac veins (AHRCC)

area that should be handled with care. Traction over this area causes avulsion of the vein which has a tendency to retract and cause brisk hemorrhage. The anterior division gives out the uterine artery from its medial aspect. It also gives off the superior and inferior vesical arteries to the bladder that need to be preserved. After giving out the internal pudendal, inferior gluteal, and obturator arteries, it continues as the obliterated hypogastric artery. This serves as an important landmark bordering the medial side of the paravesical space on either side.

Common Iliac Vessels

The external iliac vessels continue above as the common iliac arteries. They are devoid of any major branch except a constant ureteric branch. The common iliac vein lies medial to the artery on the left and lateral to it on the right [9]. The nodes in this area are flattened and hug the common iliac veins snugly. Careful dissection avoids rupture of the veins. Feeding vessels to the nodes bleed briskly as they arise from high-volume vessels. The ureters are a close relation to the common iliac vessels crossing from medial to lateral and need to be protected during lymphadenectomy.

Abdominal Aorta

The aorta divides into two common iliac arteries at the level of L4 vertebra toward the left side. Both common iliac veins join together at the same level to form the inferior vena cava on the right side of the aorta. Rarely, there may be double vena cavae on either side of the aorta necessitating bilateral paraaortic lymphadenectomy. The important anatomical detail to remember is the drainage of the infundibulopelvic vessels. On the left, the ovarian vein drains into the left renal vein, and on the right, it drains into the inferior vena cava. As is obvious, the lymphatics do follow these vascular channels. The ovarian arteries arise from the aorta at the level of L1 vertebra anteriorly just below the renal arteries. The single inferior mesenteric artery arises 3–4 cm above the bifurcation of the aorta and is easily identified as it passes toward the left into the sigmoid mesocolon

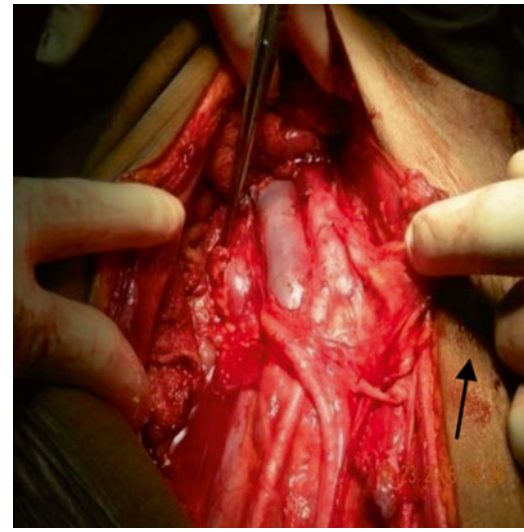

Fig. 13.10 Crossing of the left ureter, inferior mesenteric artery (AHRCC)

(Fig. 13.10). Sacrifice of this vessel may be required at times without much consequence. Destruction of nerve fibers that follow along the inferior mesenteric artery causes prolonged postoperative ileus. But the more important middle sacral artery arising from the V of bifurcation can cause troublesome bleeding if not dealt with care. The left renal vein crosses in front of the aorta to join the inferior vena cava (Figs. 13.11 and 13.12).

Venous Drainage of Pelvis

Veins in the pelvis are thin walled and get easily damaged if one is little careless. They have a tendency to retract and cause troublesome hemorrhage. Of these, the obturator vein in the obturator fossa and uterine veins in the ureteric tunnel need special attention. Sometimes the uterine vein may be difficult to visualize if the uterus is enlarged, and blind entry into the pelvic spaces may cause avulsion and torrential bleeding.

The right external iliac vein is a medial relation of the external iliac artery near the inguinal ligament. As it ascends, it goes behind and passes laterally at its cephalic end. However, the left external iliac vein remains medial to the left external iliac artery throughout its length. They are joined by the

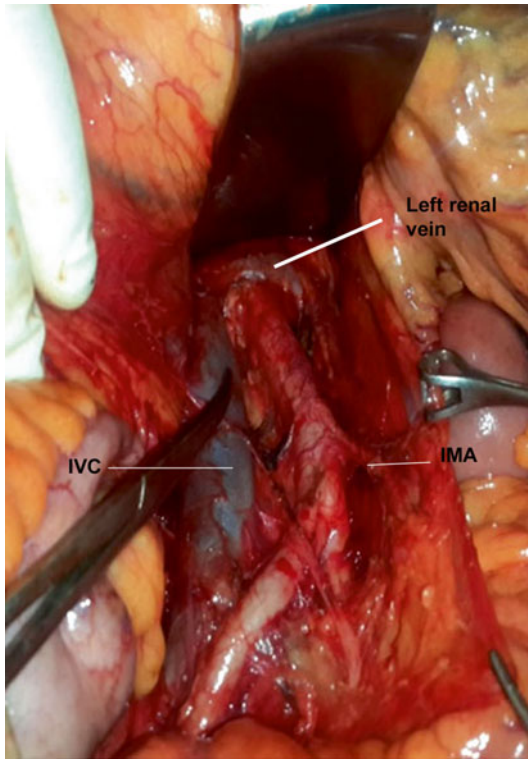

Fig. 13.11 After retro peritoneal dissection [10] (AHRCC)

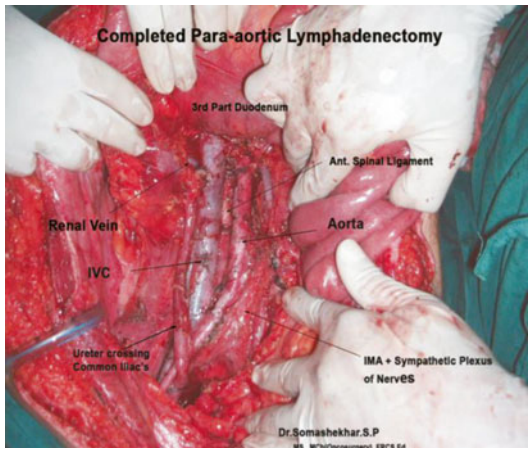

Fig. 13.12 Complete para-aortic lymphadenectomy [10] (with permission from Dr. S.P. Somasekhar)

internal iliac veins to form the common iliac veins on either side. The left common iliac vein crosses behind the left common iliac artery to join the right common iliac vein and form the inferior vena cava. The inferior vena cava ascends along the right side of the aorta (Figs. 13.13, 13.14, and 13.15).

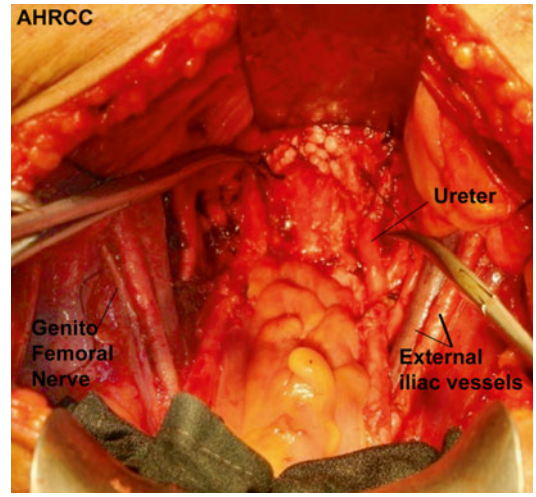

Fig. 13.13 External iliac vessels and ureter after surgery (AHRCC)

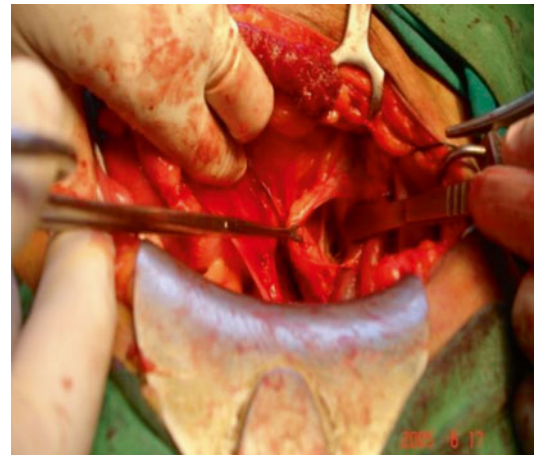

Fig. 13.14 Obturator lymphadenectomy (AHRCC)

Innervation

Knowledge of innervation and nerves running around the uterus during dissection is important to protect them from injury. Nerve-sparing surgery improves sexual and voiding functions. With improved survival rates, the focus is now on improving quality of life [11].

The uterus is supplied by inferior hypogastric plexus. It is a somewhat amorphous concentration of nerve fibers and ganglia. The sympathetic fibers originate in the thoracic and lumbar seg-

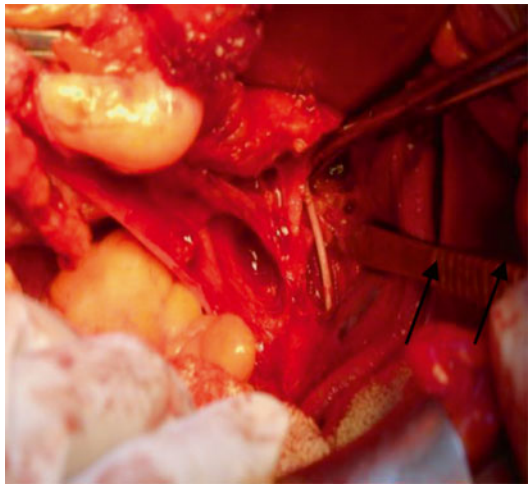

Fig. 13.15 Pararectal space and obturator nerve (AHRCC)

ments (T12 to L1) of the spinal cord and reach the uterus via the hypogastric plexus and are responsible for uterine contraction and vasoconstriction of vessels [12]. The parasympathetic fibers commence from S2, S3, and S4 nerve roots and join the inferior hypogastric plexus. They bring about uterine relaxation and vasodilatation. Inferior hypogastric nerves traverse through the uterosacral ligaments and need to be preserved to maintain smooth functioning of the bowel and bladder.

Genitofemoral Nerve

It arises from L1 and L2 and is a sensory nerve. It passes on the psoas muscle lateral to the external iliac vessels. Attempts must be made to preserve this nerve to avoid numbness of the thigh postoperatively.

Obturator Nerve

Motor nerve from L2, L3, and L4 supplies the adductor muscles of the thigh. It appears as a cordlike glistening structure in the obturator fossa when the external iliac vessels are retracted laterally. The lymphatic tissue in the obturator fossa is attached to the nerve and needs to be teased away gently. Inadvertent injury to the nerve can be repaired with 3–0 Prolene without much consequence.

Conclusion

Surgical anatomy of the uterus involves anatomical description of the uterus along with other pelvic and retroperitoneal structures that are relevant to surgery. Dissection along natural planes and correct development of pelvic spaces are an art to be learned and mastered. Identification of the bloodless planes allows bloodless dissection during simple as well as radical surgery. Knowledge of pelvic anatomy helps surgeons in avoiding injury to vital structures like the ureters, nerve plexuses, and vessels.

Key Points

1. Management of cancer endometrium requires a thorough understanding of the surgical anatomy of the uterus, pelvis, and retroperitoneal spaces.
2. Avoiding injury to ureters and major vessels and preserving the nerve plexuses require a proper and clear understanding of anatomic relationships.
3. Anomalies and variations of vital structures should be understood.
4. Stretching of the ligaments by pulling on the fundus in an opposite direction partially brings into view the paravesical and pararectal spaces.
5. Ureters are loosely attached to the posterior leaf of the broad ligament from where they can be traced upward and downward.
6. The ureteric tunnel is a part of the condensed pelvic connective tissue.
7. The uterine arteries cross the ureters on its superior aspect at almost right angles.
8. The deep uterine vein may not always accompany the uterine artery.
9. The inferior hypogastric plexus is an important relation of the uterosacral ligaments and needs to be identified before transection.

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