ΚΕΦΑΛΑΙΟ

2

Laparoscopic Anatomy

Laparoscopy just like any operative procedure requires detailed knowledge of all anatomical relations among the several structures of the operative field. Such knowledge renders surgery both safer and faster.

This chapter does not aim to substitute anatomy textbooks but rather highlight principals of anatomy essential to carry out a laparoscopic procedure safely and underline potential pitfalls.

The pelvic floor consists of three muscle layers: the superficial layer (external anal sphincter, superficial transverse perinealis, ischiocavernosus and bulbocavernosus), the middle layer (deep transverse perinealis, sphincter urethrae) and the deep layer (levator ani, ischiococcygeal). It is important to keep in mind that in laparoscopy this sequence is reversed and the surgeon essentially encounters only the deep layer. The deep layer of the pelvic floor, essentially the two levator ani muscles, merge in the midline to form the pelvic diaphragm. The latter obstructs the pelvic floor and carries two openings: one between the anterior edges of the levators which is filled with loose connective tissue around the vaginal canal and the urethra and a posterior opening through which transverses

the rectum. The perineal body is inter-positioned between these two openings, dividing the vaginal introitus anteriorly from the anus posteriorly.

Anterior abdominal wall (Figure 1)

After incising the skin overlying the abdominal wall, the surgeon encounters the subcutaneous layer, which consists of fibro-adipose tissue of varying amount. Thickening of this tissue forms the most superficial Camper's fascia followed by a deeper fascial layer, the Scarpa's fascia.

The abdominal wall is formed by five muscles in each side (external oblique, internal oblique, transversalis, rectus abdominis and pyramidalis. The aponeuroses of the first three (external

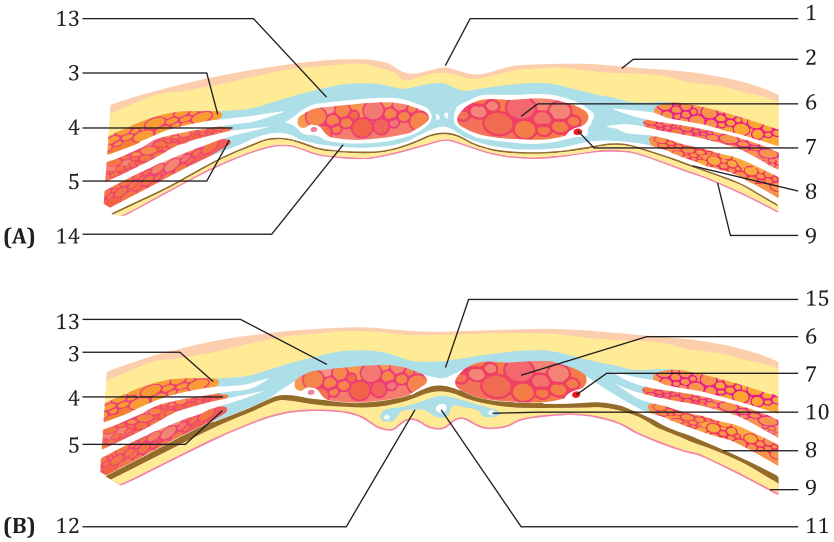

FIGURE 1 ■ Layres of the anterior abdominal wall **(A)** at the level of the umbilicus **(B)** bellow the umbilical level. The following structures are identified and numbered: 1: umbilicus, 2: skin, 3: aponeurosis fo the external oblique muscle, 4: aponeurosis of the internal oblique muscle, 5: aponeurosis of the abdominal transversalis muscle, 6: rectus abdominis muscle, 7: inferior epigastric artery, 8: fascia transversalis, 9: parietal peritomeum, 10: median umbilical ligament, 11: urachus, 12: perivascular umbilical fascia, 13: anterior sheath of the rectus abdominis, 14: posterior sheath of the rectus abdominis, 15: linea alba.

oblique, internal oblique and transversalis) form a fascial sheath, as they travel towards the midline, that contains the rectus abdominis muscle and the piramidalis. The aponeurosis of the external oblique runs anteriorly, whereas the aponeurosis of the internal oblique splits in two leafs (one anterior and the other posterior to the rectus muscle). The aponeurosis of the transversalis muscle runs posteriorly under the rectus muscle. Finally the aponeuroses or those muscles on one side merge with their counterparts of the other side to form the linea alba. This structure of the rectus sheath however, is modified at the lower abdominal wall (approximately 4 cm bellow the level of the umbilicus). At this level (Figure 1) the aponeuroses of the internal oblique and the transversalis muscle merge on the anterior surface of the rectus muscle together with the aponeurosis of the external oblique. In this manner the anterior wall of the rectus sheath is reinforced, whereas the posterior wall of the sheath is weakened, comprised only from the transversalis fascia and the parietal peritoneum (Figure 1). This transition is obvious by the presence of a horizontal line (**arcuate line of the abdomen**, **linea semicircularis** or **Douglas' line)** that demarcates the lower limit of the posterior layer of the rectus sheath, it is also where the inferior hypogastric vessels insert into the rectus abdominis muscle.

Even though the anatomy of abdominal wall layers might be considered of minor importance for laparoscopic surgery, the course of the abdominal wall vessels (Figures 1, 2 and 3) is extremely important and determines the trocar insertion sites.

Blood Supply: The vessels of the anterior abdominal wall can be divided in two groups; those supplying the skin and subcutaneous tissue (superficial vessels) and those supplying muscles and aponeuroses (deep vessels).

Superficial vessels (Figure 2)

- The superficial epigastric vessels follow an oblique course from a lateral-caudal towards a medial-cephalad direction (Figure 2): they originate from the femoral artery bilaterally as a single artery (superficial epigastric artery) which divides as it courses towards the umbilicus. Topographically, the site of the superficial epigastric artery can be defined in the middle

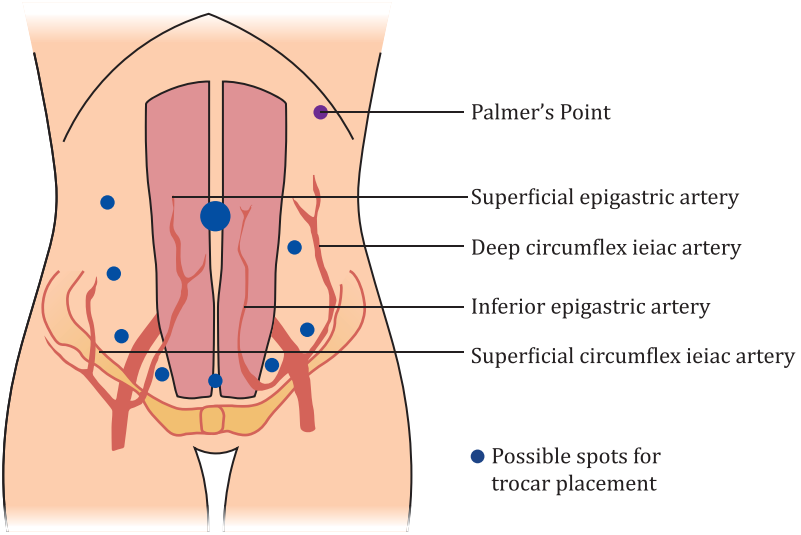

FIGURE 2 ■ Topographic location of deep and superficial vessels on the anterior abdominal wall in relation to trocar placement during laparoscopic surgery.

of a line drown between the umbilicus and the point where the femoral artery is palpated.

- The external pubendal artery originates from the femoral artery, courses obliquely towards the medial surface of the thigh and supplies the superficial layers of the external genitalia.
- The superficial circumflex iliac artery originates from the femoral artery and runs cephalad between the costal margin and the iliac crest.
- Respective veins are accompanying the named arteries

Deep vessels

The course of vessels supplying the deeper layers is parallel to that of their superficial counterparts.

- The deep circumflex iliac artery lies in-between the internal obligue and transversus abdominis muscles
- The superior epigastric artery, a branch of internal mammary, divides into several diaphragmatic and parietal brunches.

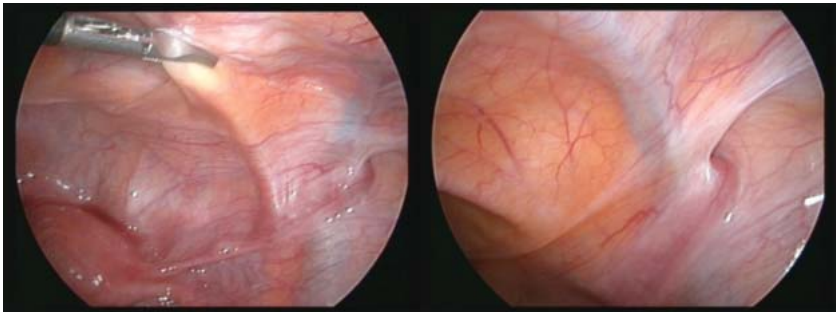

FIGURE 3 ■ Localization and grasping of the right obliterated umbilical artery. In the closer view the opening of the inguinal canal with the insertion of the right round ligament is visualized. The right inferior epigastric vessels are visible in the center of the screen running on the anterior abdominal wall.

- The inferior epigastric artery (Figures 2 and 3) originates from the external iliac artery and along with its respective veins runs on the inner surface of the anterior abdominal wall obliquely towards the umbilicus from an caudal -lateral to a medial-cephalad direction. Initially it runs lateral to the sheath of the rectus abdominis muscle. At the level of the semilunar line it penetrates the posterior sheath to enter into the rectus muscle. The inferior epigastric vessels are visible on the abdominal wall, as they run laterally to the medial umbilical ligament (obstructed umbilical artery) prior to entering to the rectus sheath.

Innervation

Innervation of the anterior abdominal wall originates from the inter-costal (T 7-11), sub-costal (T12), iliohypogastric nerves (T12-L1) and ilioinguinal (L1) nerves. The T10 neurotome is considered to be located at the level of the umbilicus. The main branches of the inter-costal nerves course between the internal oblique and the transversus abdominis muscles. All the above nerves course through or between muscles to reach the rectus sheath. The anterior cutaneous nerves perforate the rectus sheath close to the midline. Branches from T9-11 innervate the

skin above the umbilicus while T10 distributes around the umbilicus and T11-12 and L1 in the skin beneath the umbilicus.

Things to consider in laparoscopy

- Umbilical trocar insertion
  Umbilicus: Topographically it is located at the L3-L4 spinal disc level. It is in the midline only few cm above the aortic bifurcation. In slim patients, the distance between the umbilicus and major vessels is small, therefore special attention is needed upon insertion of the umbilical trocar. In addition, vascular supply of the umbilicus is provided mainly from the circumferential vascular network located in its right lateral side. It is therefore preferable to create the umbilical incision towards the patient's left side.
- Stomach and bladder
  Both should be empty prior to initiation of the procedure, so a Foley catheter and probably a nasogastric tube are placed so the chances of injury from the Verress needle or the trocars are minimized.
- Insertion of lateral trocars
  The surgeon should pay attention to the course of the abdominal wall vessels (inferior epigastric and superficial epigastric artery). Injury of these vessels at the entry points might cause significant hemorrhage. Note that these vessels are located 5.5 cm lateral to the midline at the level of the symphysis pubis; this distance is 4.5 cm at the umbilical level. Placement of the trocars laterally to the lines connecting these landmarks minimizes the risk of injury.

The pelvis during laparoscopy

Peritoneal and retroperitoneal anatomy (see related video)

The laparoscopic surgeon should become familiar with changes in the anatomical relationship between the structures of the operative field secondary to the pneumoperitoneum, the Trendelenburg positioning and the manipulation of the uterus. During laparoscopy the 3D structure of the operative field is projected as a two-dimensional picture on the monitor, a fact that may complicate matters further.

The inner surface of the abdominal wall and the avascular pelvic spaces

The inner surface of the anterior abdominal wall is layered by parietal peritoneum which forms several folds. These folds are commonly created by the presence of an underlying vessel or ligament.

The falx is a fold between the umbilicus and the liver enclosing the round ligament which is the remnant of the obliterated umbilical vein. Just beneath the umbilicus one can see three umbilical folds covering respective ligaments. The **median** umbilical ligament is formed by the peritoneal fold, overlying the urachus. The **medial** umbilical folds are formed by peritoneal folds covering the obliterated umbilical arteries bilaterally, lateral to which the inferior epigastric vessels are identified (Figure 2 and 3).

Several important structures are located in the lateral pelvic wall. These are closely related to each other and they should be recognized at the beginning of the procedure. These structures are: the ovarian vessels (Infundibulum pelvic ligament), the ureter, the bifurcation of the common iliac artery as well as the common iliac vein (Figure 4).

In addition, the laparoscopic surgeon should be able to recognize and develop the avascular spaces of the pelvis and their

FIGURE 4 ■ Visualization of the right ureter as is courses between the external and the internal iliac artery. The IP ligament is visualized lateral to the ureter. In the closer view the right round ligament is grasped.

landmarks. The term avascular implies the absence of major vessels; therefore access to these spaces can be considered safe and with limited blood loss. Three sets of ligaments define eight avascular pelvic spaces in the pelvis (Figure 5).

1. The **prevesical space** of Retzius is located between the pubic bone and the anterior wall of the bladder. It's anterior border is Cooper's ligament while it's posterior border is the anterior bladder wall. Lateral borders are formed by the obliterated umbilical arteries.

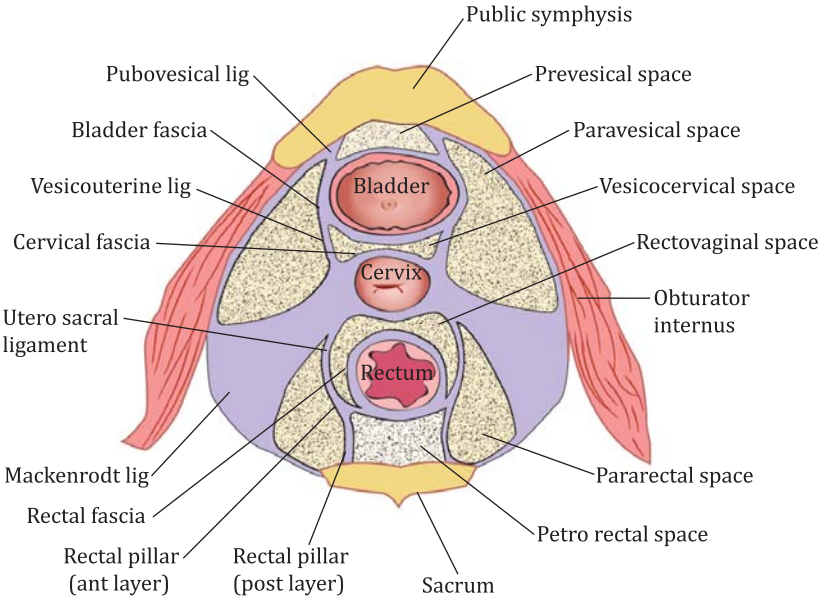

FIGURE 5 ■ The avascular spaces of the pelvis are delineated by the following ligaments: anteriorly the pubic bone is connected to the bladder by the two pubovesical ligaments, the bladder is connectd to the cervix the two vesicouterine ligaments, the cervix is attached to the lateral pelvic wall by the two cardinal ligaments. The cervic is also attached to the sacral bone by the two uterosacral ligaments. These ligaments define eight (8) avascular spaces. In the central section of the pelvis in an anterior posterior direction we encounter: the prevesical space, the vesicouterine space, the rectovaginal space and the retrorectal space. Bilaterally we encounter the two paravesical spaces and the two pararectal spaces.

2. **Paravesical spaces (Figures 6 and 7):** they are located bilaterally anterior to the base of the broad ligament. They are defined by the bladder and the obliterated umbilical artery medially, by the obturator internus and the iliococcygeus muscle laterally and the cardinal ligament with the uterine artery posteriorly.
3. **Pararectal spaces (Figures 6 and 7):** they are triangle-shaped spaces located bilaterally to the rectum. They are defined by the cardinal ligament and the uterine artery anteriorly, by the internal iliac vessels and the ureter laterally, and the rectal wall medially. The floor of the pararectal space is formed by the puborectalis muscle (which itself is a segment of the levator ani complex).

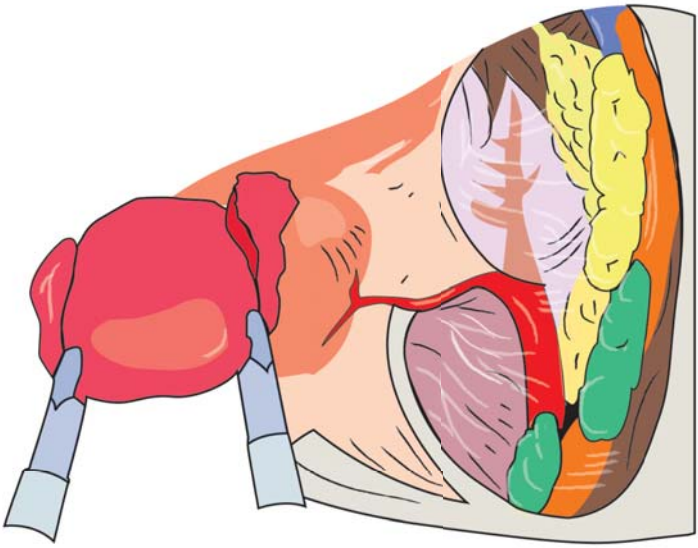

FIGURE 6 ■ The cartoon indicates the right paravesical (anteriorly) and the right pararectal (posteriorly) spaces. These spaces are separated by the uterine artery running within the cardinal ligament. During surgery these spaces become more obvious by retracting the uterus to the left side. The lateral borders of these two spaces are defined by the external iliac vessels (artery and vein). The external iliac (yellow) and the common iliac (green) lymph nodes are also demonstrated.

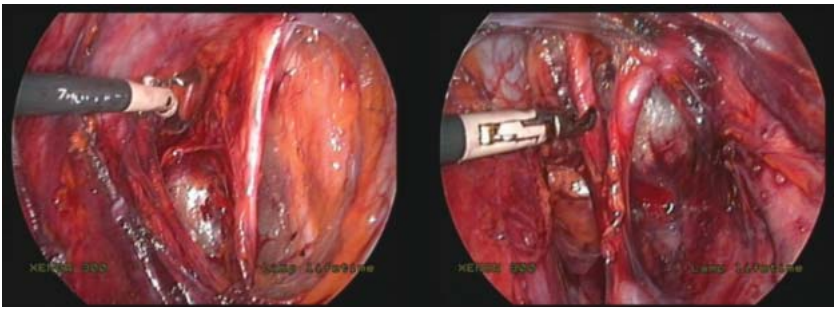

FIGURE 7 ■ Laparoscopic view of the right and the left paravesical and pararectal space. The uterine artery on the left is completely skeletonized and visualized. The left pararectal space is completely developed.

4. **Vesicouterine space or vesicovaginal space (Figure 8):** it is located between the posterior surface of the bladder and the anterior surface of the uterus, cervix and vagina. It includes the bladder trigone and the uterovesical fascia. Access to this space is accomplished by dissecting the uterovesical peritoneal fold.
5. **The rectovaginal space (Figure 9):** it is located between the posterior surface of the vagina and the anterior rectal wall. The surgeon can enter this space by dissecting the peritoneum

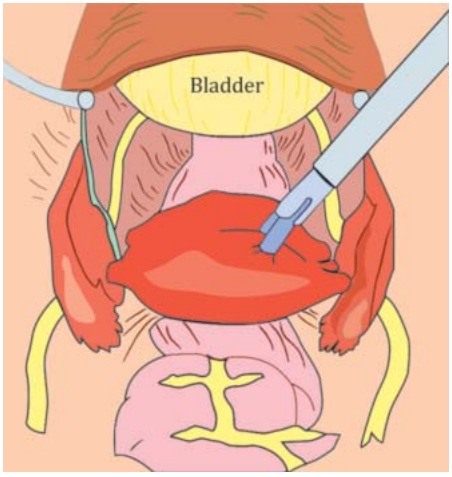

FIGURE 8 ■ Cartoon demonstrating the vesicouterine space after the peritoneum has been incised. The round ligaments are transected and the course of the ureters is indicated.

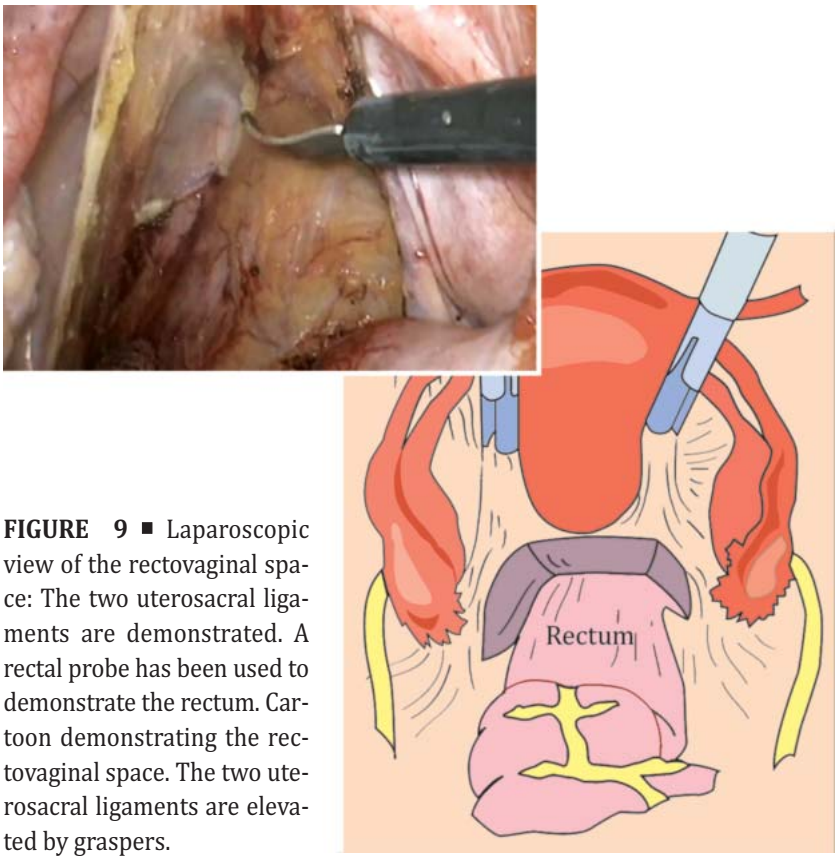

FIGURE 9 ■ Laparoscopic view of the rectovaginal space: The two uterosacral ligaments are demonstrated. A rectal probe has been used to demonstrate the rectum. Cartoon demonstrating the rectovaginal space. The two uterosacral ligaments are elevated by graspers.

overlying the posterior cul de sac between the uterosacral ligaments.

6. **The retrorectal space:** it is located between the anterior surface of the sacrum and the posterior surface of the rectum. Entry into this space can be accomplished by dissecting the mesentery or through the pararectal spaces.

Pelvic viscera of the female

Uterus and its ligaments (Figures 10 and 11)

The uterus is a pear shaped, hollow muscular organ located deep in the pelvis, between the rectum and the bladder. Its length is

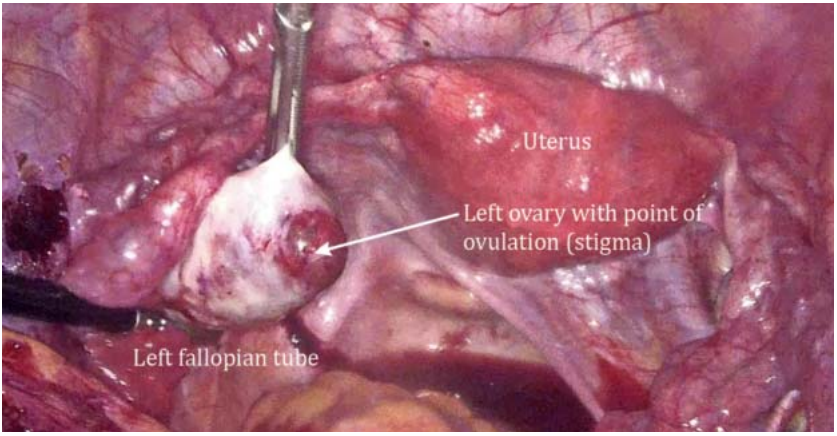

FIGURE 10 ■ Laparoscopic view of the uterus. A large posterior myoma is seen.

around 6-8cm, width 5cm and thickness around 2.5cm. It weighs 30-40gr in nulliparous women and around 70gr in multiparous patients. The body of the uterus is supported by the round ligament which runs trough the inguinal canal to the labia majora. The utero-ovarian ligament connects the upper portion of the uterus to the ipsilateral ovary. The broad ligament is a peritoneal fold layering the uterus and adnexa extending to the lateral pelvic wall. The body of the uterus is enclosed between the two leafs of

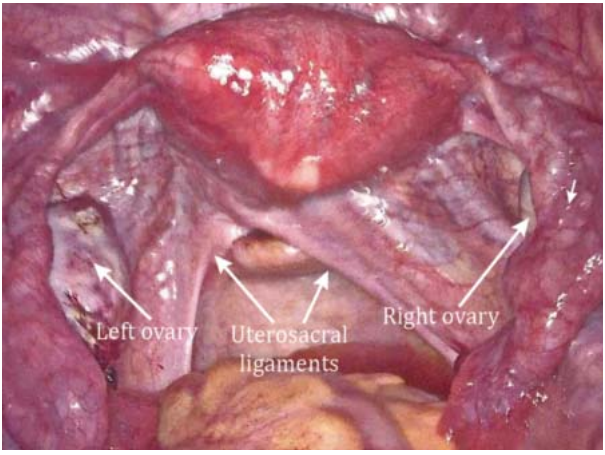

FIGURE 11 ■ Laparoscopic panoramic view of a normal uterus the fallopian tubes, the uterosacral ligaments and the ovaries are easily visualized.

the broad ligament and it can move freely. The two layers of the broad ligament surround the fallopian tube and form the mesosalpinx (Figure 12). Laterally and superior to the ovary these layers surround the ovarian vessels to form the infundibulopelvic

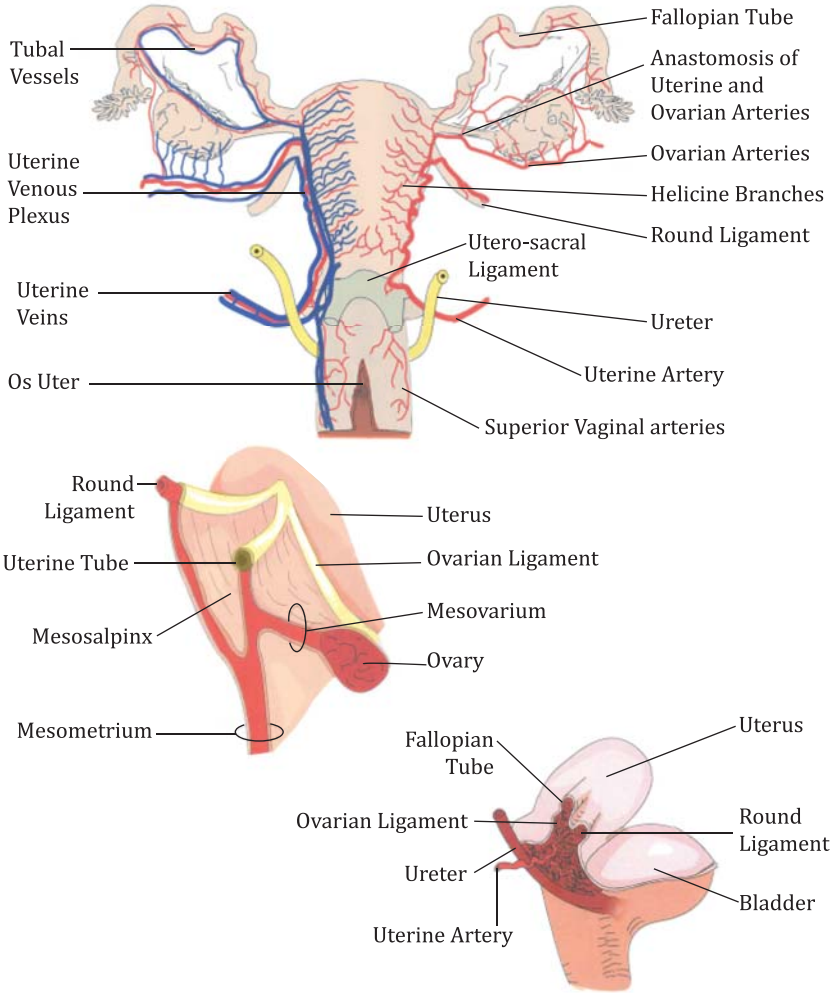

FIGURE 12 ■ The blood supply to the uterus and the anastomoses with the adnexal circulation. The peritoneal folds of the broad ligament creating the mesosalpinx and the mesovarium. The relationship of the uterine vessels to the ureters bilateral are indicated.

(IP) ligament. The cervix on the contrary to the uterus has limited mobility as it is supported by multiple ligaments-folds of the endopelvic fascia. The uterosacral ligaments support the cervix in relation to the sacrum. The cardinal ligaments extend from the side of the cervix and the lateral vaginal fornices all the way to the pelvic side-wall (Figures 5 and 11).

As the ureter is descending towards the bladder, it courses over the bifurcation of the common iliac artery at the level of the pelvic brim (Figure 4). It then descends attached to the posterior fold of the broad ligament, medially to the uterine artery, up to the level of the ischial spine where it crosses underneath the uterine artery approximately 1 cm from the lateral edge of the cervix (Figure 12). It then continues near the lateral edge of the vaginal fornices, especially on the left side, and enters the bladder at its posterior upper edge (Figure 16). The uterine venus network drains to the internal iliac veins while it anastomoses with the superior hemorrhoidal vein, thus creating an anastomosis between the systemic and portal circulation. Lymph from the uterus drains to the external iliac, internal iliac, para-aortic lymph nodes as well as to the superficial inguinal and sacral nodes.

Innervation of the pelvic viscera

The uterus, vagina, urinary bladder and rectum are innervated by a motor and sensory autonomic nerve supply, both of sympathetic and parasympathetic origin (Figure 13).

The sympathetic fibers originate from T11-L2 neurotomes to form the **superior hypogastric plexus**. The **superior hypogastric plexus** itself receives upper lumbar contributions from the intermesenteric plexus, as well as contributions from L3 and L4 splanchnic nerves. Located at the level of the bifurcation of the aorta, the superior hypogastric plexus descends into the pelvis and bifurcates as the right and left **hypogastric nerves (Figure 13)** Please note these "nerves" are more like meshworks than solid nerve trunks. These nerve meshworks diverge lateral to the rectum on either side and curve outward and backward as they make their way down about 7.5–10 centimeters into the pelvis. The **hypogastric nerves** convey the majority of the sympathetic contribution from

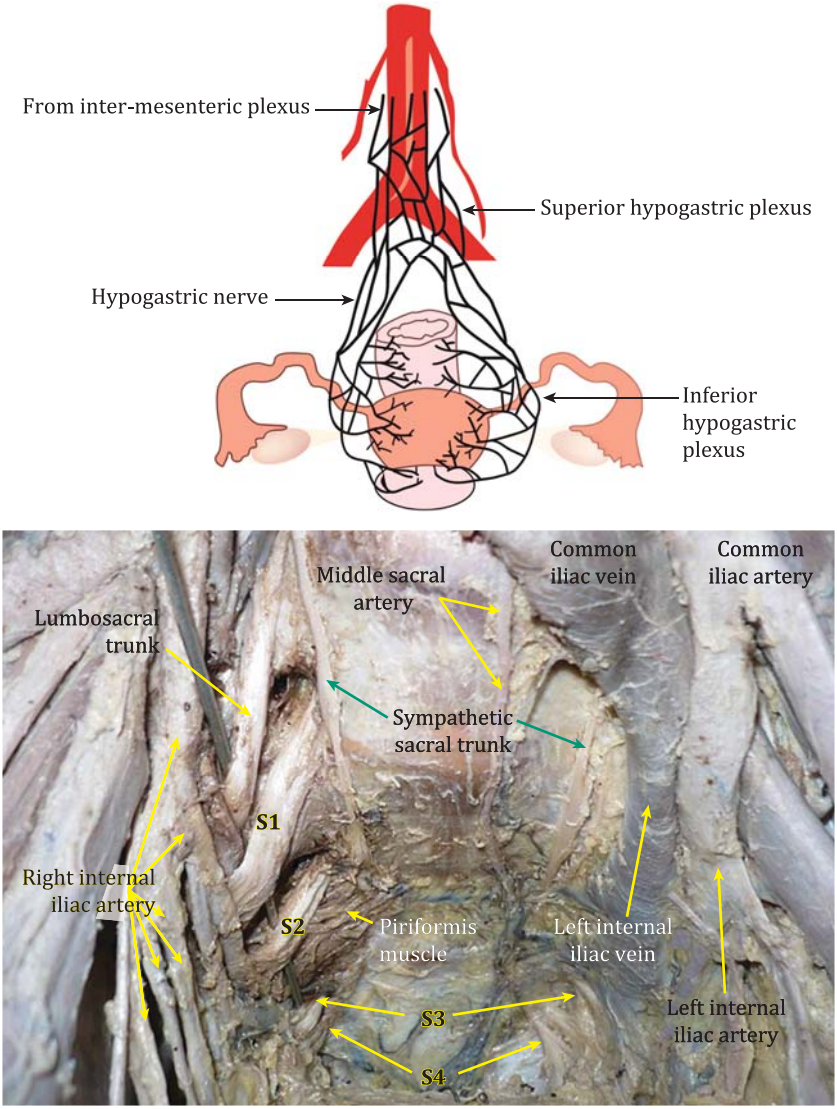

FIGURE 13 ■ The nerve supply of the pelvic organs in a schematic presentation. The superior hypogastric plexus receives mainly sympathetic fibers form the inter-mesenteric plexus. It splits into the right and left hypogastric nerves which follow the ureters into the medial leaf of the broad ligament. They receive sympathetic fibers from the ipsilateral sacral splachnic nerves and parasumpathetic fibers form the pelvic splachnic nerves to form the right and left inferior hypogastric plexuses which supply the rectum the bladder and the genital organs (uterovaginal plexuses).

the **superior hypogastric plexus** into the **inferior hypogastric plexuses (bilaterally).** Additional sympathetic contribution is provided by the **sacral splachnic nerves** arising from the sacral part of the sympathetic trunk.

The parasympathetic fibers regulate the emptying of the urinary bladder and the rectum as well as sexual functions like erection. They originate from the S2, S3 and S4 roots as the **pelvic splanchnic nerves.** The pelvic splanchnic nerves (parasympathetic) together with the sacral splanchnic nerves (sympathetic) merge with the hypogastric nerve to form the **inferior hypogastric plexus.** A subdivision of the hypogastric plexus located at the cardinal ligament (**the uterovaginal plexus)** provides nerve supply to the uterus, the vagina and the urinary bladder. The largest of the ganglia of this plexus is Frankenhauser's cervical ganglion which mediates motor fibers towards the uterus. Sensory fibers are located in sympathetic and parasympathetic plexuses, interconnected with the 2nd, 3rd and 4th sacral nerve.

The adnexae: Fallopian tubes and ovaries (Figure 10 and 11)

The Fallopian tubes are fibromuscular tubular structures approximately 10 – 12 cm in length. For descriptive reasons they are divided in four segments: the fimbriae, the ampulla, the isthmus and the corneal-interstitial segment. Except from the cornual segment, the tubes are located in the peritoneal cavity. They are supplied from the same vessels supplying the uterus and the ovaries and are innervated by the uterovaginal plexus. Their lymphatics are draining into the paraaortic nodes.

The ovaries have an ovoid shape, and they are 5-6 cm long and 1.5-3.5 cm wide. They are supported by the mesovarium (the peritoneal fold in continuation to the posterior leaf of the broad ligament) as well as the infundibulopelvic (IP), or suspensory ligament of the ovary (a peritoneal fold that which includes the ovarian vessels. The ovarian (or uteroovarian) ligament (figure 11) a band of connective tissue connects the ovary to the posterior uterine surface.

The ovarian arteries are derived from the abdominal aorta at the L2 level and are located at the posterior abdominal wall. At

the level of the pelvic brim they are crossing the external iliac vessels and elevate the peritoneum to form the IP ligaments. Within the broad ligament, the ovarian veins are forming the pampiniform vein plexus which communicates with the uterine vein plexus. On the right side, the ovarian vein is draining at the inferior vena cava (IVC) while the left ovarian vein at the left renal vein. The ovarian lymphatics follow the course of the vessels. On the right side they drain at the lumbar paraortic nodes while on the left they drain at the left renal nodes (Figure 16).

The vagina (Figures 14 and 15)

The vagina is a fibromascular cylinder 8-10 cm in length and 3-4 in diameter that penetrates the pelvic floor and extends between the cervix and the vulva. For descriptive purposes the vagina is divided into two segments. The intrapelvic (Supra-levator) segment located above the levator plate and the perineal or infra-

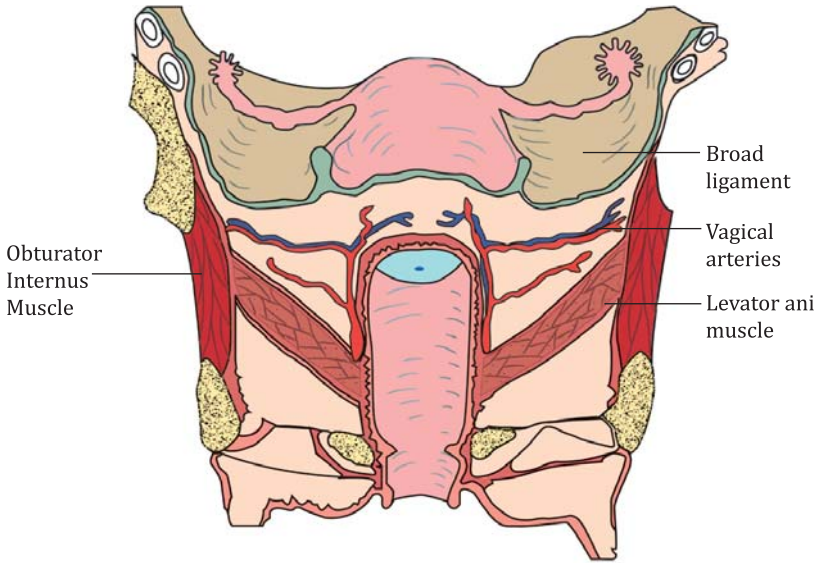

FIGURE 14 ■ Anatomy of the vagina: the relationship of the vaginal canal to the pelvic floor and the levator muscles is shown. The blood flow to the vagina is also shown.

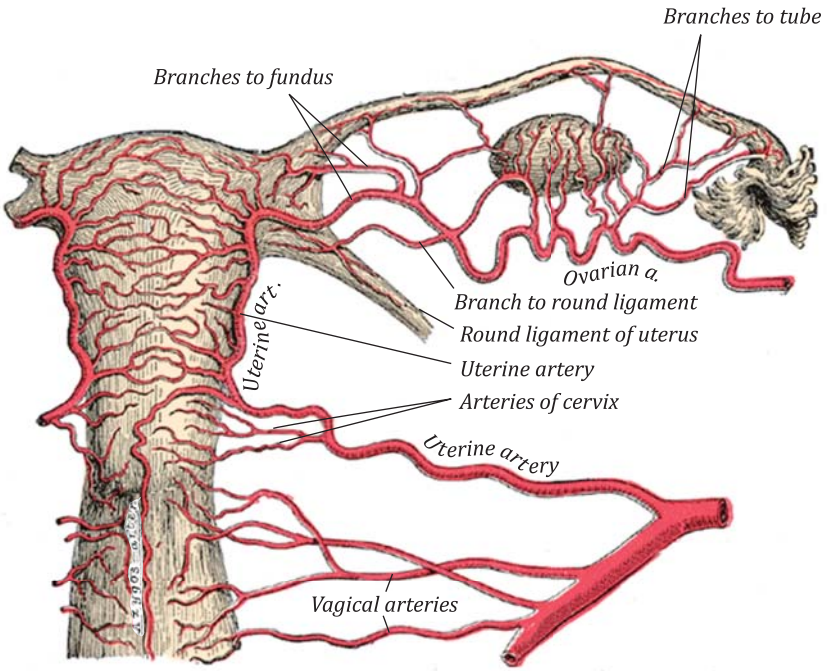

FIGURE 15 ■ The arterial supply of the vagina form the uterine as well as from the vaginal arteries directly from the internal iliac artery is shown. The anastomotic branches between the uterine and the ovarian artery are also demonstrated. The anterior azygos vaginal artery is also seen. (This faithful reproduction of a lithograph plate from Gray's Anatomy, a two-dimensional work of art, is not copyrightable in the U.S. as per Bridgeman Art Library v. Corel Corp.; the same is also true in many other countries, including Germany. Unless stated otherwise, it is from the 20th U.S. edition of Gray's Anatomy of the Human Body, originally published in 1918 and therefore lapsed into the public domain.)

levator segment. The blood supply is provided by the uterine artery for the upper portion of the vagina and from the vaginal arteries originating from the internal iliac artery (Figure 15). These vessels anastomose to form two median longitudinal vessels (the **azygos arteries of the vagina**) one of which runs down in the anterior and the other on the posterior vaginal wall. The veins of the vagina drain to the internal iliac vein and the lymph vessels drain to the external and internal iliac nodes as

well as to the inguinal nodes. The nerve supply of the vagina is provided by the uterovaginal plexus as described earlier. The **Utero-Vaginal Plexus** arises from the lower part of the inferior hypogastric plexus. It is distributed to the walls of the vagina, to the erectile tissue of the vestibule, and to the clitoris. The nerves composing this plexus contain, a large proportion of spinal parasympathetic nerve fibers.

Major vessels of the pelvis (Figure 16)

The anatomy of the pelvic vessels is of major importance since their laceration can have grave consequences. The aorta runs

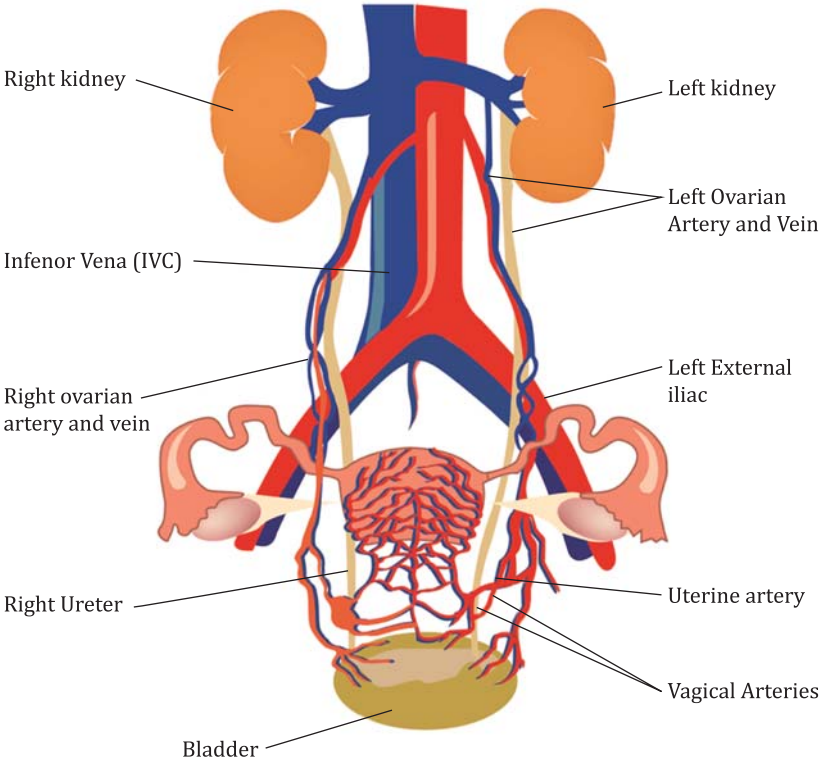

FIGURE 16 ■ Blood supply to the pelvis: The course of the ovarian vessels in relation to the ureters are seen. In addition the relationship between the aorta and the inferior vena cava before the bifurcation is also demonstrated.

anteriorly and slightly to the left of the anterior longitudinal ligament of the thoracic spine. The ovarian arteries are derived directly from the aorta at the L2-L3 level. At the level of the L4 the aorta bifurcates to the right and left common iliac arteries while at this level it generates the middle sacral artery. The latter is derived from the posterior surface of the aorta somewhat higher than its bifurcation. It courses anterior to the body of the two lower lumbar vertebrae, the sacrum and the coccyx and ends in several anastomoses.

The **common iliac artery** is about 5 cm long and divides into an internal and an external branch. The **external iliac artery** is longer and larger and courses through the inguinal canal continuing as the **femoral artery**. It provides small branches for the psoas muscle. Just before entering the inguinal canal it administers two major branches: the **inferior epigastric** and the **deep circumflex iliac** artery. Immediately after the inguinal canal it gives of the **superficial circumflex iliac artery** the **superficial epigastric artery** and the **external pudental** artery (Figure 2). These two vessels should be acknowledged while inserting accessory trocars under direct visualization. The **internal iliac artery** provides the main blood supply to pelvic viscera. Just after its origin from the common iliac artery it crosses under the ureter, continues posterior-medially and enters the true pelvis laterally to the common iliac vein. At the levels of the superior edge of the major sciatic foramen, the internal iliac artery bifurcates to an anterior and posterior division.

The **posterior division** supplies the lateral pelvic wall and pelvic muscles. After administering the iliolumbar and lateral sacral arteries, it exits the pelvis through the supra-opoiod foramen, in the major sciatic foramen and ends as **superior gluteal artery** to the gluteus maximus.

The **anterior division** of the internal iliac artery supplies the pelvic viscera. The main branches of the anterior division in order of origin are: obturator, umbilical, uterine, inferior vesical, middle rectal artery. The anterior division ends as the **internal pudendal artery** which exits the pelvis through the major sciatic foramen.

The obdurator artery passes antero-inferiorly (forwards and downwards) on the lateral wall of the pelvis, into the obdurator

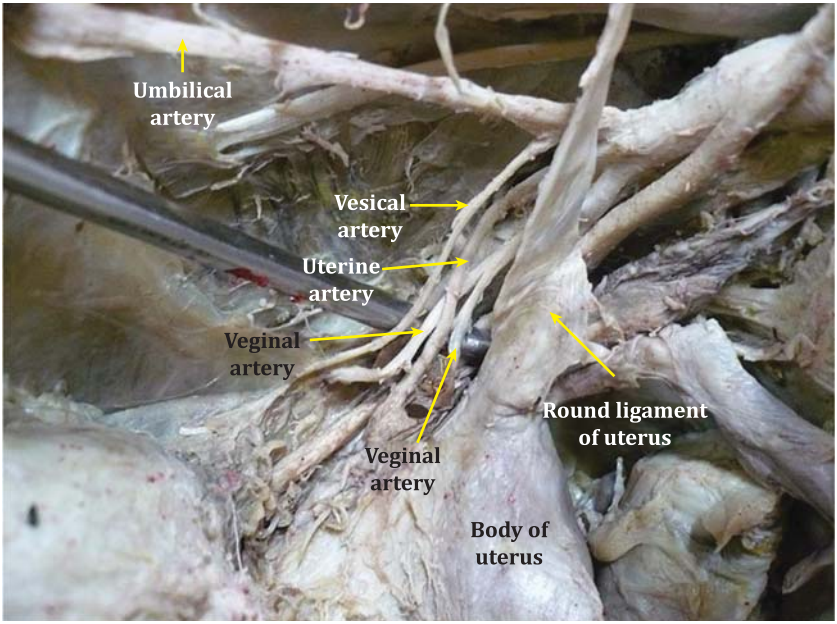

FIGURE 17 ■ Branches of the internal iliac artery. Note that there are frequent variations in the branching of the internal iliac artery. During radical hysterectomy the obliterated umbilical artery is used to identify the paravaginal space as well as to locate the origin of the uterine artery.

fossa together with the obdurator veins and the obdurator nerve. It passes trough the upper part of the obturator foramen to leave the pelvic cavity through the obturator canal.

The umbilical artery courses anteriorly and caudally between the bladder and the lateral pelvic wall. It ends to the anterior abdominal wall where it is obliterated creating the medial umbilical ligament. It administers the superior vesical artery which is distributed to the superior surface of the bladder.

The uterine artery originates from the anterior branch of the internal iliac artery. It courses to the lateral pelvic wall and enters the base of the broad ligament. It administers branches to the uterine corpus and fundus, the cervix and upper vagina. It also administers another lateral branch supplying the circulation of the ovary in addition to the ovarian artery.

The middle rectal artery courses laterally to the rectum and administers branches to the rectum and vagina.

The internal pudendal artery is the terminal branch of the anterior division of the internal iliac artery. It courses laterally and caudally, exiting the pelvis between the piriformis and coccygeal muscles, through the inferior division of the major sciatic foramen. It administers the inferior rectal and perineal arteries and in females the posterior vulvar branches, the urethral, vestibular and deep clitoral artery.

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