Ibrahim Alkatout
Liselotte Mettler
Editors

Hysterectomy

A Comprehensive Surgical Approach

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Ibrahim Alkatout • Liselotte Mettler
Editors

With the Assistance of Dawn Rüther

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A Comprehensive Surgical Approach

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Dedicated to all patients placing their trust in us.

Foreword 1

The most common gynecological surgeries performed in the world are hysterectomies which date back to ancient time and were mainly associated with noncancerous conditions. The Italian anatomist Berengario da Carpi of Bologna carried out the first authenticated vaginal hysterectomy in 1507. In Manchester, England, Charles Clay performed the first recorded abdominal hysterectomy in 1843, and in 1853, by accident Walter Burnham performed the first successful abdominal hysterectomy in Lowell, Manchester. The early hysterectomies, either vaginal or abdominal, were performed without anesthesia, and with a fatality rate ranging from 70 to 90 %. In the absence of an alternative management of cervical cancer, the radical hysterectomy was introduced. The first radical hysterectomy was performed by John Clark at Johns Hopkins in 1985, and in 1898, Ernst Wertheim of Vienna performed the first extended radical hysterectomy. The more radical extension of vaginal hysterectomy was developed by Karl Schuchardt of Gottingen, and in 1901, Friedrich Schauta described radical vaginal hysterectomy in detail. With the advent of antiseptics, anesthesia, antibiotics, blood transfusion, new technologies, and advances in surgical techniques, by the 1940s, total abdominal hysterectomy had become the norm, and hysterectomy had become a safer surgical procedure for women worldwide. The fatality rate dropped significantly.

As science and technology advanced, Kurt Semm, in Kiel, Germany, in 1984, was the first to describe a technique for laparoscopic assistance in vaginal hysterectomy, thereby laying the foundation for all endoscopic procedures. Laparoscopic hysterectomy is increasingly performed in many countries in the world; however, conservative and less invasive operative managements, such as hysteroscopic surgery and the application of ulipristal acetate, may reduce the traditional indications for hysterectomy. The limitations of conventional laparoscopy and advances in robotic surgery have led to the increased use of robotic techniques in hysterectomy. Diaz-Arrastia reported the first series of successful robotic laparoscopic hysterectomies in 2002, and surgeries using robotic techniques for hysterectomy are now rapidly expanding.

The indication and performance of hysterectomies in general have changed with the change in techniques and procedures and have been adapted to the request of women to retain their uterus; therefore, the need for a comprehensive textbook on hysterectomy to improve the knowledge, skills, and competencies of surgeons has become very evident.

Ibrahim Alkatout and Liselotte Mettler have compiled the very first comprehensive medical textbook of its kind, *Hysterectomy*: *A Comprehensive Surgical Approach*, dealing with all surgical techniques of hysterectomy (vaginal, abdominal, laparoscopic, and robotic-assisted) and their extended operations, such as lymphadenectomy and omentectomy, with excellent illustrations. This textbook contains 132 chapters contributed by over 100 renowned international authors. This book is an important addition to the literature on hysterectomy techniques, accessible to gynecologists worldwide, and thereby contributing towards the global improvement of healthcare for women.

I believe this textbook will be very valuable and find extensive use in developed and developing countries. I am honored and privileged to write this foreword.

Windhoek, Namibia

Prof. Quazi Monirul Islam, MBBS, MPH, FRCOG
WHO Representative to Namibia

Foreword 2

Hysterectomy ranks among the most frequently performed procedures in gynecology. Since modern surgical techniques have allowed the reduction of intra- and postoperative complications to a considerable degree, it has become a well-established option in the treatment of a wide variety of conditions, including cancers of the reproductive system, certain types of endometriosis and adenomyosis, uterus myomatosus, chronic pelvic pain, or uncontrollable bleeding.

The range of procedures used is broad, not only in regard to surgical techniques – laparoscopic, robotic-assisted, vaginal, abdominal – but also in regard to the extent of the surgery, depending on which organs are included, in addition to the uterus itself, e.g., the cervix, the vagina or parts of it, the parametrium, the lymph nodes, the fallopian tubes, the ovaries, or the omentum.

With its comprehensive overview of all surgical techniques and its illustrated step-by-step descriptions, this book will provide not only a valuable decision aid for surgeons in their choice of method but also a training guide for surgeons at every level of education and experience. It can be considered an additional advantage that this book also covers anatomical and diagnostic aspects of hysterectomy, including questions of when hysterectomy is indicated.

This book is the successor to Liselotte Mettler's *Manual of New Hysterectomy Techniques* (2007), an indispensable handbook on vaginal and laparoscopic hysterectomy. This new volume, edited by a team, Ibrahim Alkatout and Liselotte Mettler, benefits in a similar way from the high standards of the Kiel School of Gynaecological Surgery, of which Liselotte Mettler is one of the distinguished protagonists. Along with Kurt Semm, she initiated the "minimally invasive revolution" of laparoscopic hysterectomy, thus establishing the foundation of today's procedures in the field.

This book's widened scope, now including all available techniques, diagnostic guidance, and in-depth background information, puts itself forward as a standard reference in the field of gynecological medicine.

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Foreword 3

It is with great pleasure that I write a forward for this book edited by Ibrahim Alkatout and Liselotte Mettler. Liselotte Mettler has lived on the cutting edge of advanced laparoscopic surgery from its beginning, and by beginning, I mean 1985 when we presented together at AAGL, known previously as a tubal ligation society. The next year, we were both teaching the advanced course at the AAGL. She has continuously worked as a leader to advance the surgical care of women and still does. She is active as a teacher worldwide, especially concerning hysterectomy, and was a founder of the Kiel School of Gynaecological Endoscopy, one of the first training centers in this specialty.

I have known and worked with Liselotte Mettler for over 30 years. Her work with Kurt Semm progressed along parallel paths with mine until we met in 1985–1986. Kurt and Lilo called me Mr. Electrosurgery at that time as Kurt used sutures for oophorectomy, while I pioneered the use of bipolar desiccation for large vessel hemostasis. It was then that Kurt told me, “If I learned to suture, I would be king.” So I learned how to suture!

Somewhat lost in these discussions is that I started as a vaginal surgeon. Vaginal surgery was my passion! Abdominal mutilation was our common enemy. After 10 years of doing vaginal hysterectomy surgery with the occasional use of the laparoscope for salpingo-oophorectomy, I began to do the whole operation using laparoscopic visualization with desiccation of both the uterine arteries and the ovarian arteries in 1988. Laparoscopic supracervical hysterectomy came soon thereafter by Kurt and Lilo.

Now, Lilo and her associates from the Kiel School of Gynaecological Endoscopy have put everything about hysterectomy together with this textbook describing different techniques in a relatively comprehensive manner. I must admit that my favorites are both the vaginal and the laparoscopic approaches. So, I look forward to reading those sections to determine if the difference between a colpotomy and a culdotomy has been finally resolved.

I believe that this is a much-needed textbook, and I am sure that most gynecologists will benefit from reading it.

Harry Reich, MD, FACOG, FRCOG
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Foreword 4

Hysterectomy is the most common major surgical procedure in modern gynecology. In the USA alone, approximately 600,000 hysterectomies are performed each year. All gynecologists will, at some stage of their training, learn how to perform the hysterectomy procedure independently. What is so special about a hysterectomy, compared to most other surgical procedures, is that there is such a variation of methods and surgical routes for this surgery. More than 90 % of all hysterectomy procedures are performed for benign indications. Thus, there are special needs concerning safety, efficiency, and cost-effectiveness in relation to this nonvital, quality of life-enhancing surgery.

A hysterectomy procedure can take anytime from 15 min to several hours. However, a hysterectomy that spans several hours may be as rewarding for the patient and the surgeon as a quick hysterectomy. I personally have probably performed the longest hysterectomy procedure. In a series of nine abdominal total hysterectomies that took place in 2013, the surgical duration was between 10.5 and 13 h. What is also so special is that these nine abdominal hysterectomies were performed to increase the quality of life of another woman and not the operated woman herself.

My co-surgeon, Pernilla Dahm-Kähler, and I performed the surgery through a midline incision and apart from the uterus also long extensive vascular pedicles, including the uterine and internal iliac arteries and veins, were harvested. The hysterectomy specimen was flushed and cooled ex vivo, before transplantation into the pelvis of the recipient (in most cases the daughter). Up until today, five healthy babies have been born from these transplanted uteri, and three out of these five recent mothers also grew themselves inside the same uterus as their babies.

Dr. Dahm-Kähler and I would never have been able to conduct these successful hysterectomies and uterus transplantations without a structured training in several different hysterectomy procedures during our early years of surgical training and more importantly, without the parallel acquisition of a great understanding of the anatomy of the pelvis. All these important aspects are covered in this comprehensive book. Another important point is that a prolonged duration of surgery does not necessarily equate with inadequate surgical skills. During my early training, I would closely record the time and would not be satisfied by a long duration of a seemingly easy hysterectomy. Today, I try to teach the residents in training that they should strive for minimal bleeding and follow the natural anatomic layers to minimize the tissue damage and thereby shorten the recovery time of the patient.

The editors, Ibrahim Alkatout and Liselotte Mettler, have been able to recruit a large number of absolute top clinicians/scientists in the field of gynecology and surgical hysterectomy to contribute chapters to this book. The impressive list of authors guarantees the readers not only up-to-date information on each aspect of hysterectomy but also that the opinions and surgical tips have passed the critical eyes of world-renowned doctors in academic medicine. Notably, this book covers not only the surgical techniques of all various hysterectomy procedures but also the important aspects of indications and presurgical diagnostics.

I am convinced that *Hysterectomy: A Comprehensive Surgical Approach* will become one of the classic books in the field of gynecology.

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Preface

This comprehensive surgical approach to hysterectomy rests on the pillars erected by the great masters in our specialty. The first hysterectomy was performed as a vaginal hysterectomy and dates back to ancient times. The procedure was performed in the time of Soranus of Ephesus, 120 years after the birth of Christ. There were many reports of its use in the Middle Ages, nearly always for the extirpation of an inverted uterus, and the patients rarely survived. Hysterectomy became safer with the introduction of anesthesia, antibiotics and antisepsis, blood transfusions, and intravenous therapy. During the 1930s, Richardson introduced the total abdominal hysterectomy to avoid serosanguinous discharge from the cervical remnant and the risk of cervical carcinoma developing in the stump.

Apart from this innovation, and the transverse abdominal incision introduced by Johannes Pfannenstiel of Kiel in the 1900s, there was little advance in hysterectomy techniques until the advent of endoscopic surgery and the performance of the first laparoscopic hysterectomy by Kurt Semm in Kiel in 1984 and Harry Reich in Kingston, Pennsylvania, in 1988. With his never-ending dedication to the teaching of laparoscopy, Kurt Semm stimulated his coworkers in Kiel and courageous followers around the world to move forward with laparoscopic total and radical hysterectomy.

Thoralf Schollmeyer was a pupil of Semm and head of the Kiel School of Gynaecological Endoscopy from 2007 until his early death at the age of 52 in 2014. He continues to inspire us and was the driving force behind the decision of the Kiel School to go ahead with the second edition of the *Manual of New Hysterectomy Techniques* (2007).

In this age of global communication, it is a great privilege to publish a specialist surgical book on hysterectomy which features the leading surgeons, researchers, and teachers as contributing authors. With the assistance of over 200 multidisciplinary authors, we have been able to compile a book that hopefully meets the requirements of a broad base of readers.

This book brings into balance theoretical background, clinical experience, and scientific findings in a readily comprehensible form with numerous illustrations and tables. For the beginner, this book could become a reliable companion, providing background information and assistance for all procedures associated with hysterectomy. This includes abdominal, vaginal, conventional laparoscopic, and robotic-assisted surgical procedures. But also the experienced surgeon will be able to broaden his spectrum and learn experimental and innovative surgical approaches as this is the first textbook on hysterectomy including traditional, up-to-date, and innovative surgical methods.

Additionally, the book contains a large proportion of interdisciplinary aspects, and we believe it will make a substantial contribution to meeting the growing requirements of interdisciplinary medical treatment. It offers related disciplines (especially general surgery and urology) the opportunity to describe the areas of common overlap and how these can be treated. This multidisciplinary approach is of advantage not only for gynecologists but also for general surgeons and urologists.

The wide range of the contents developed in the course of the conception of the book. Extended hysterectomy procedures cannot be separated from procedures on the internal genital organs or those involving the anatomical and functionally relevant surrounding area.

Finally, we would like to thank Joni Fraser for her continuous support and valuable assistance in preparing the book for production. Special thanks also go to Lizzy Raj, Julia Megginson, and Melissa Morton at Springer International Publishing for allowing us the freedom to design a book according to our ideas and supporting us in the realization of what turned out to be a mammoth project. Tribute is also due to the illustrators for their creative visual implementation of complex issues.

The editors are conscious of the privilege of having access to the most advanced treatment concepts of our time. In an unstable world, our foremost intention is to share the greatest good, the ability to cure one's fellow human beings.

Kiel, Germany, 2017 Ibrahim Alkatout and Liselotte Mettler

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Topographical Anatomy for Hysterectomy Procedures

3

Thilo Wedel

Compartments of the Female Pelvic Cavity

The female pelvic cavity is divided into an anterior, middle and posterior compartment (Fig. 3.1). In contrast to the male pelvic cavity which is confined to two compartments and contains parenchymatous organs (e.g. prostate and seminal glands), all three female compartments consist of hollow visceral organs resting upon the pelvic floor:

- Anterior compartment: urinary bladder and urethra
- Middle compartment: uterus with uterine adnexa and vagina
- Posterior compartment: rectum and anal canal

The peritoneum covers the organs contained in these pelvic compartments from above. While the urinary bladder and rectum are only partially lined by peritoneal serosa, almost the entire uterus and the complete adnexa including the ovaries and uterine tubes are wrapped by peritoneum and, thus, readily accessible by transperitoneal approach. The peritoneum reflects from the uterine body anteriorly on to the fundus of the urinary bladder forming the vesicouterine pouch delimited laterally by the vesicouterine folds and posteriorly on to the rectal wall forming the rectouterine pouch delimited laterally by the rectouterine folds. Except for the posterior vaginal fornix directly facing the rectouterine pouch, the vagina is located extraperitoneally. Both peritoneal pouches are often filled with small intestinal loops, sigmoid colon or greater omentum, thus requiring proper exposure by moving the content upwards.

The pelvic compartments are separated by septa mainly composed of connective tissue and intermingled smooth muscle tissue. Between the anterior vaginal wall and both the urinary bladder and urethra extends the vesico−/urethrovaginal septum, between the posterior vaginal wall and the anterior rectal wall extends the rectovaginal septum. The connective tissue septa are devoid of major blood vessels and serve as separating gliding layers between the three pelvic compartments reflecting the different ontogenetic origins of the urinary, genital and digestive tract. Thus, if surgical dissection follows these self-opening planes between the pelvic compartments, the uterovaginal complex can be readily delineated from the urinary bladder and urethra anteriorly and the anorectum posteriorly without relevant bleeding risk [1–3].

Female Pelvic Floor

The female pelvic floor (Fig. 3.2) is of larger dimension than in males displaying a wider urogenital opening, although its muscle strength is generally lower and its nerve supply less developed. These peculiar features allow vaginal delivery, but also predispose to an higher susceptibility for structural and functional insufficiency and pelvic organ prolapse.

The pelvic floor is composed of a pelvic diaphragm consisting of the levator ani muscle and a urogenital diaphragm comprising the transverse perineal muscles. The levator ani muscle corresponds to a flattened and funnel-shaped muscle closing most of the lower pelvic aperture. However, along the ventral midline openings are left for the urethra and vagina (urogenital hiatus) and the anal canal (anal hiatus).

The largest portion of the levator ani muscle are the ileococcygeal muscles extending from the pelvic side walls to a midline raphe. The rather thin muscle layer originates at the tendinous arc of the levator ani muscle formed by condensed

Note In regards to the nomenclature of anatomical structures, eponymes although commonly used in medical literature (e.g. Lee/Frankenhäuser ganglion, Poupart ligament, Mackenrodt ligament, Cooper ligament, Denonvillier fascia, Waldeyer fascia, Sampson artery, Richard fimbria, Latzko and Okabayashi spaces, etc.) are avoided to prevent confusions frequently resulting from misinterpretation of the historical descriptions.

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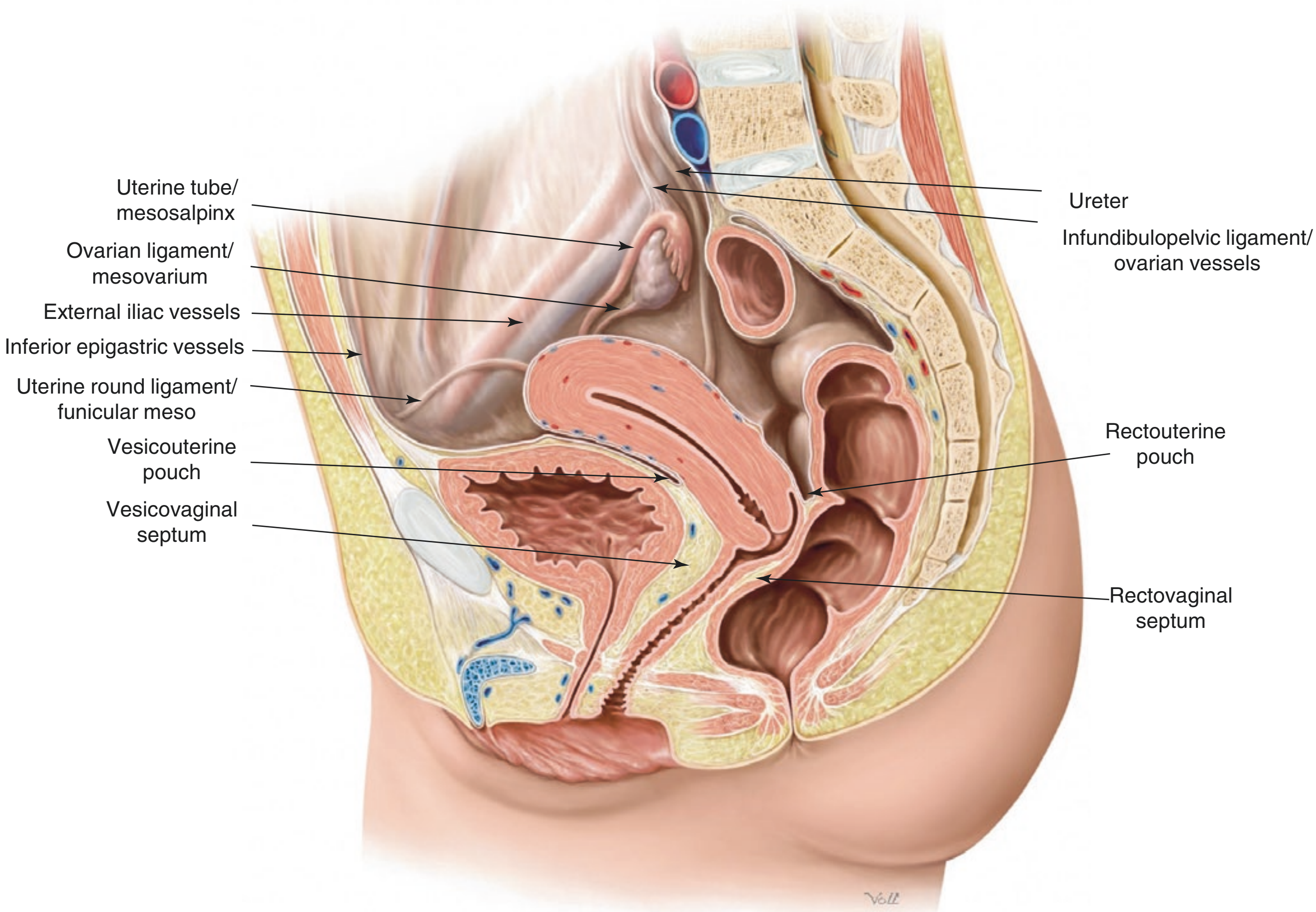

Fig. 3.1 Female pelvic cavity. Midsagittal section, view from left side (Reproduced from Schünke et al. [24])

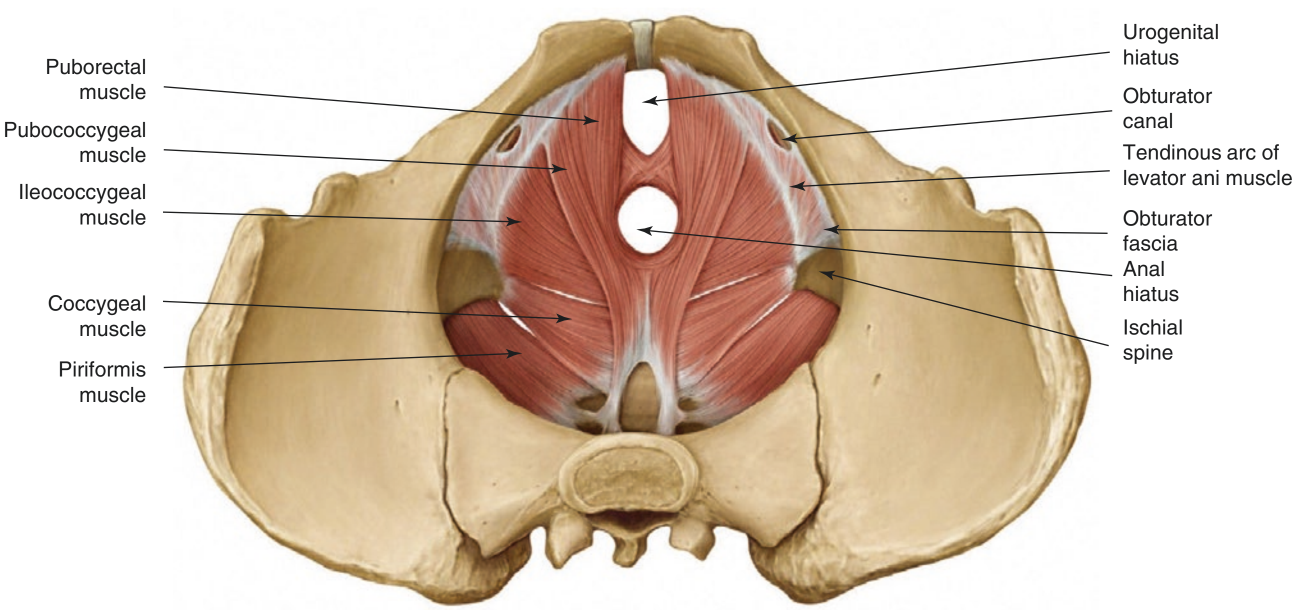

Fig. 3.2 Female pelvic floor. Cranial view. Content of pelvic cavity removed (Reproduced from Schünke et al. [24])

connective tissue of the obturator fascia ("white line"). The hammock-shaped pubococcygeal muscle originates from the pubic bone and extends towards the coccygeal bone, whereas the sling-shaped puborectal muscle bends arround the anal canal to produce the anorectal angle.

Innervation of the pelvic floor muscles is mainly provided by infralevatory branches of the pudendal nerve. In addition, also direct nerve branches the from sacral spinal nerves S3–S4 contribute and extend from the sacral concavity to reach the levator ani muscle from above. Thus, when exposing the pelvic floor muscle during extended deep lymphadenectomy, care must be taken to preserve these direct supralevatory nerve branches [1–3].

Uterus

The uterus (Fig. 3.3) is a pear-shaped hollow muscular organ of 7–9 cm length with its long axis nearly at right angle to that of the vagina (anteversion of uterine cervix plus anteflexion of uterine corpus) depending on the filling state of the urinary bladder. The anteroposteriorly flattened uterine corpus narrows caudally and continues into the cylindrical uterine cervix. The convex upper part of the uterine corpus is defined as the uterine fundus. On either side, a uterine cornu is formed to receive the uterine tube. Anterior to the uterine cornu inserts the uterine round ligament, posteroinferior to it attaches the ovarian ligament. The uterine cervix is 2–3 cm long, far less mobile than the uterine corpus due to its fixating ligaments and divided into a supravaginal and vaginal portion. Posteriorly the uterine cervix is covered by peritoneum, laterally it is in close relationship to the uterine arteries and the ureters flanking the uterine cervix at a distance of ca. 1–2 cm. The uterine cervical canal connects the uterine cavity with the vaginal lumen [3].

Uterine Adnexa

The uterine adnexa comprise the ovaries, ovarian tubes and ligaments adjacent to the uterus on both sides (Figs. 3.1 and 3.3). The ovaries lie in the ovarian fossae posterolateral to the uterus and medial to the external iliac vessels. They are attached to the uterus by the ovarian ligaments extending from the uterine pole of the ovary to the uterine cornu. The peritoneal fold raised by the ovarian ligament corresponds to the mesovarium containing the ovarian branch of the uterine artery (Figs. 3.5 and 3.8).

The tubal pole of the ovary is connected to the fimbriated end of the uterine tube. Between the tubal pole and the dorsolateral pelvic wall extends the infundibulopelvic ligament corresponding to a peritoneal fold raised by the ovar-

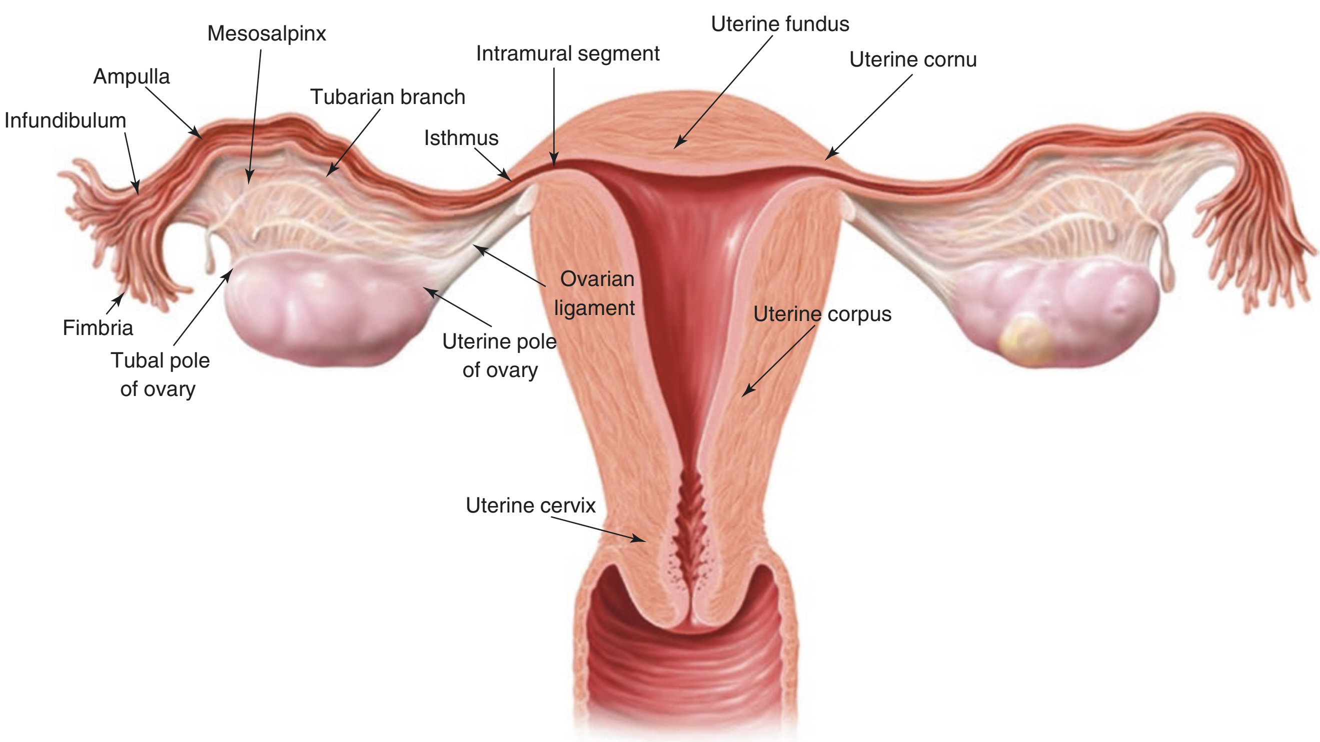

Fig. 3.3 Internal female genital organs. Frontal section, dorsal view. Broad ligament, parametrium and paracolpium removed (Reproduced from Schünke et al. [24])

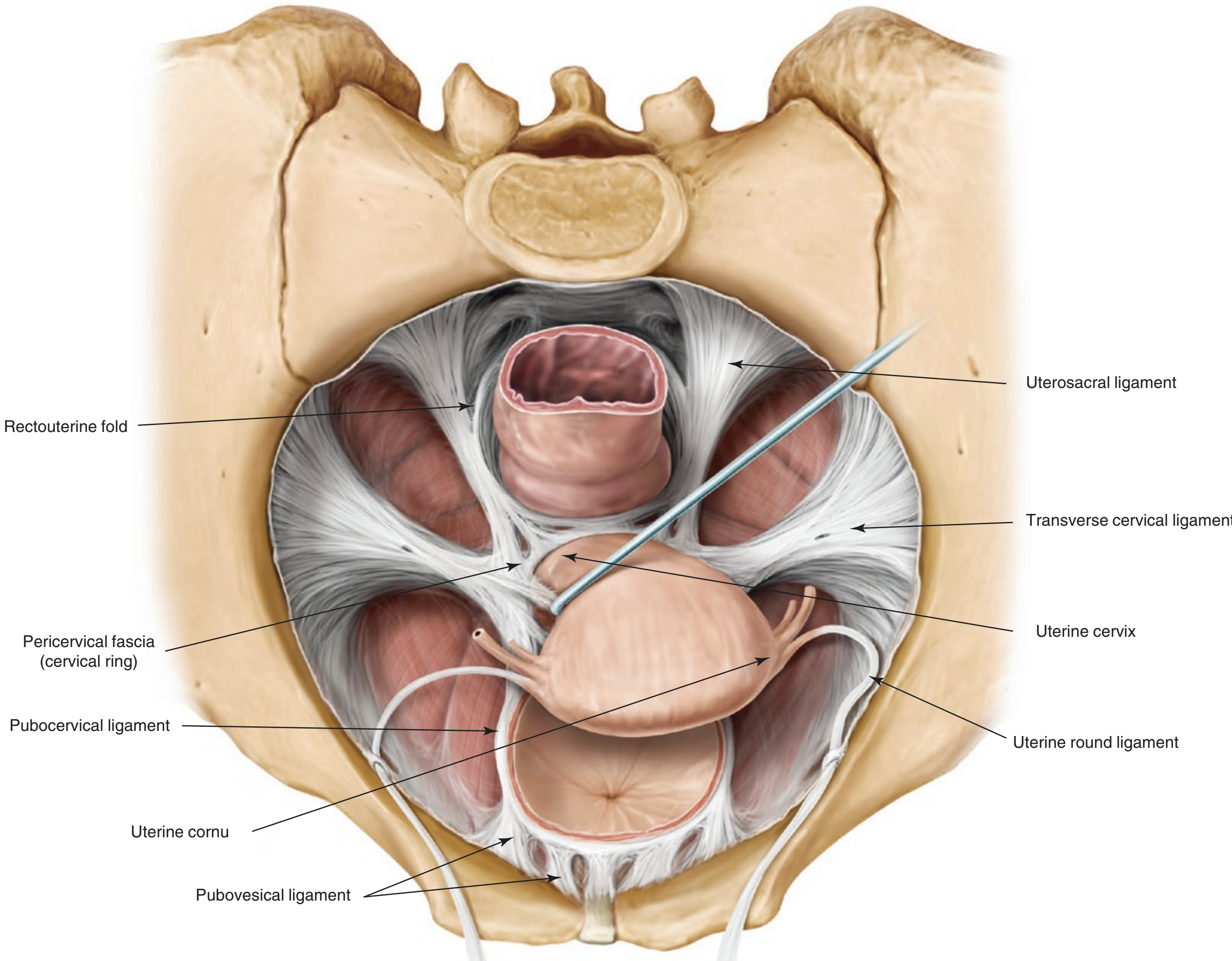

Fig. 3.4 Uterine ligaments. Cranial view. Rectum and urinary bladder are cut transversely, the uterus is shifted to the left side (Reproduced from Schünke et al. [24])

ian blood vessels. The synonym "suspensory ligament of the ovary" is inadequate, as the ovary is not substantially suspended by this peritoneal duplicature. When mobilizing the uterine adnexa, attention should be paid to the fact that the infundibulopelvic ligament together with the ovarian blood vessels cross the external iliac blood vessels ca. 1–2 cm anterolateral to the ureter. Moreover, due to its considerable intraperitoneal mobility the ovary may come into close proximity to both the external and internal iliac vessels and the ureter at the pelvic brim (Figs. 3.1, 3.5, 3.6, 3.9, and 3.7).

The uterine tube is ca. 9–11 cm long and connects the tubal pole of the ovary with the uterus. The infundibulum of the uterine tube is funnel-shaped and displays several fimbriae of which the ovarian fimbria is attached to the tubal pole of the ovary. The widened ampulla shows a luminal diameter of up to 10 mm and narrows at the isthmus to 0.1–0.5 mm. The uterine or intramural portion of the uterine tube is ca. 10 mm long and opens into the uterine cavity via the uterine os located at the uterine cornu. The peritoneal fold raised by the uterine tube corresponds to the mesosalpinx and contains the tubal branch of the uterine artery (Figs. 3.3, 3.5, and 3.8) [3].

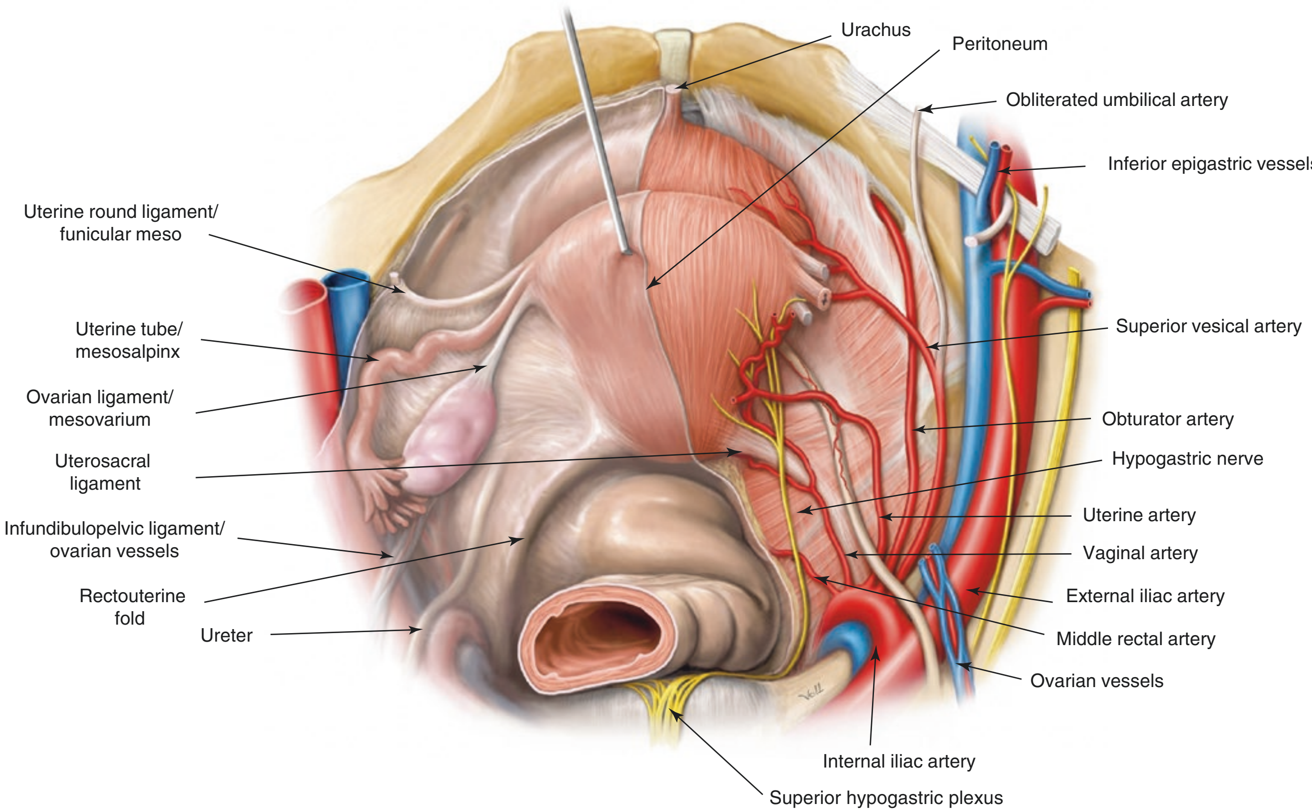

Fig. 3.5 Female pelvic cavity. Cranial view. The peritoneum, uterine adnexa and parametrial tissue are removed on the right side to expose the pelvic arteries and the ureter (Reproduced from Schünke et al. [24])

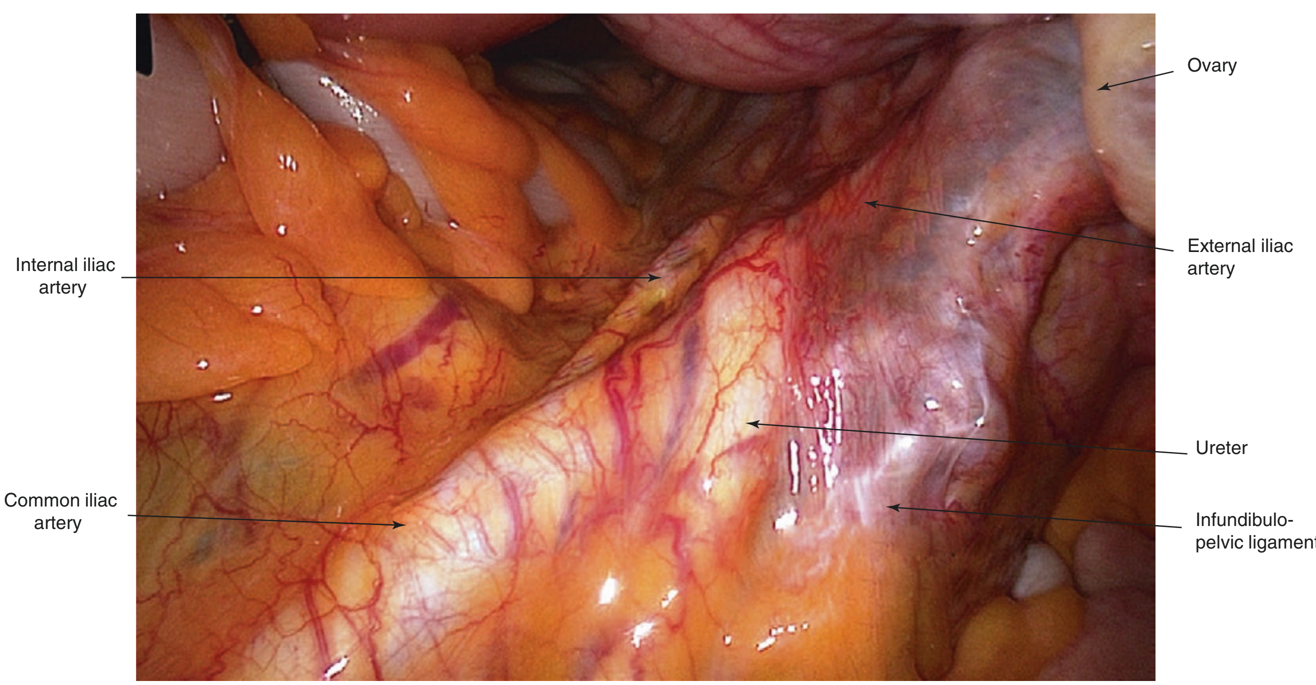

Fig. 3.6 Iliac vessels at the entrance into the right-sided female pelvis. Laparoscopic cranial view. The ureter crosses the pelvic brim running over the external iliac artery and medially to the infundibulopelvic ligament and the ovary

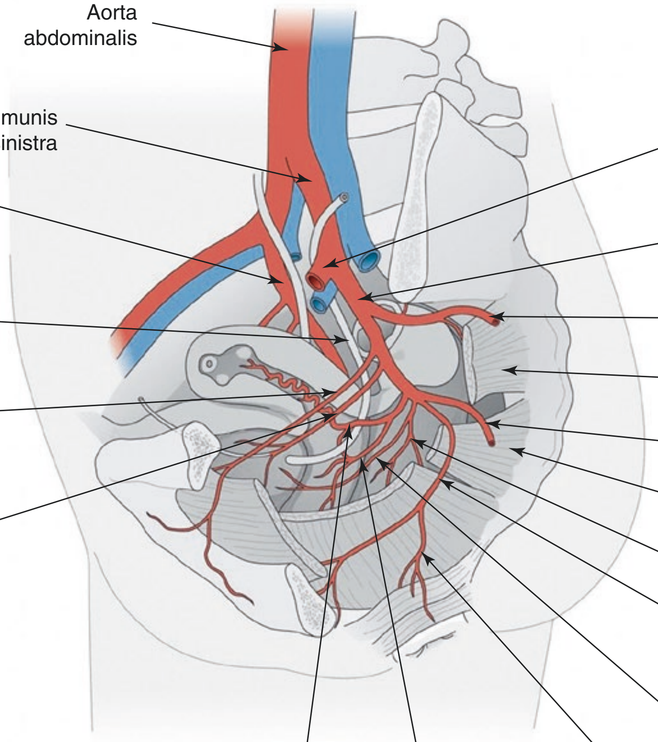

Fig. 3.7 Branches of the internal iliac artery in a female pelvis. Parasagittal section, view form left side. The left broad ligament is sectioned (Reproduced from Schünke et al. [24])

Uterine Ligaments, Parametrium and Mesometrium

Fixation of the uterovaginal complex is achieved on the one hand by the support of the pelvic floor (Fig. 3.2), on the other hand by uterine ligaments providing connections either to other pelvic organs or to the pelvic wall (Fig. 3.4). There is still an ongoing discussion about the exact tissue composition, topographic anatomy, functional relevance and terminology of these ligamentous, parauterine structures [1, 2, 4–7].

Broad Ligaments

The broad ligaments are named according to the fact that they provide a wide-stretched and ample connection between the middle pelvic compartment and the pelvic side walls. The peritoneal covering is lifted up by the broad ligaments and descends anteriorly to cover the paravesical space (anterior leaf) and posteriorly to cover the pararectal space (posterior leaf) on both sides. When viewed from above, the broad ligaments display three peritoneal folds on each side converging from different origins of the inner abdominal and pelvic walls towards the uterine cornu (Fig. 3.5):

- Funicular meso (anterior fold)
- Mesosalpinx (middle fold)
- Mesovarium (posterior fold)

The funicular meso corresponds to the peritoneal fold raised by the uterine round ligament extending from the uterine fundus below and lateral to the uterine cornu to the deep inguinal ring. The fibromuscular bands pass along the paravesical fossa and are accompanied by a branch from the uter-

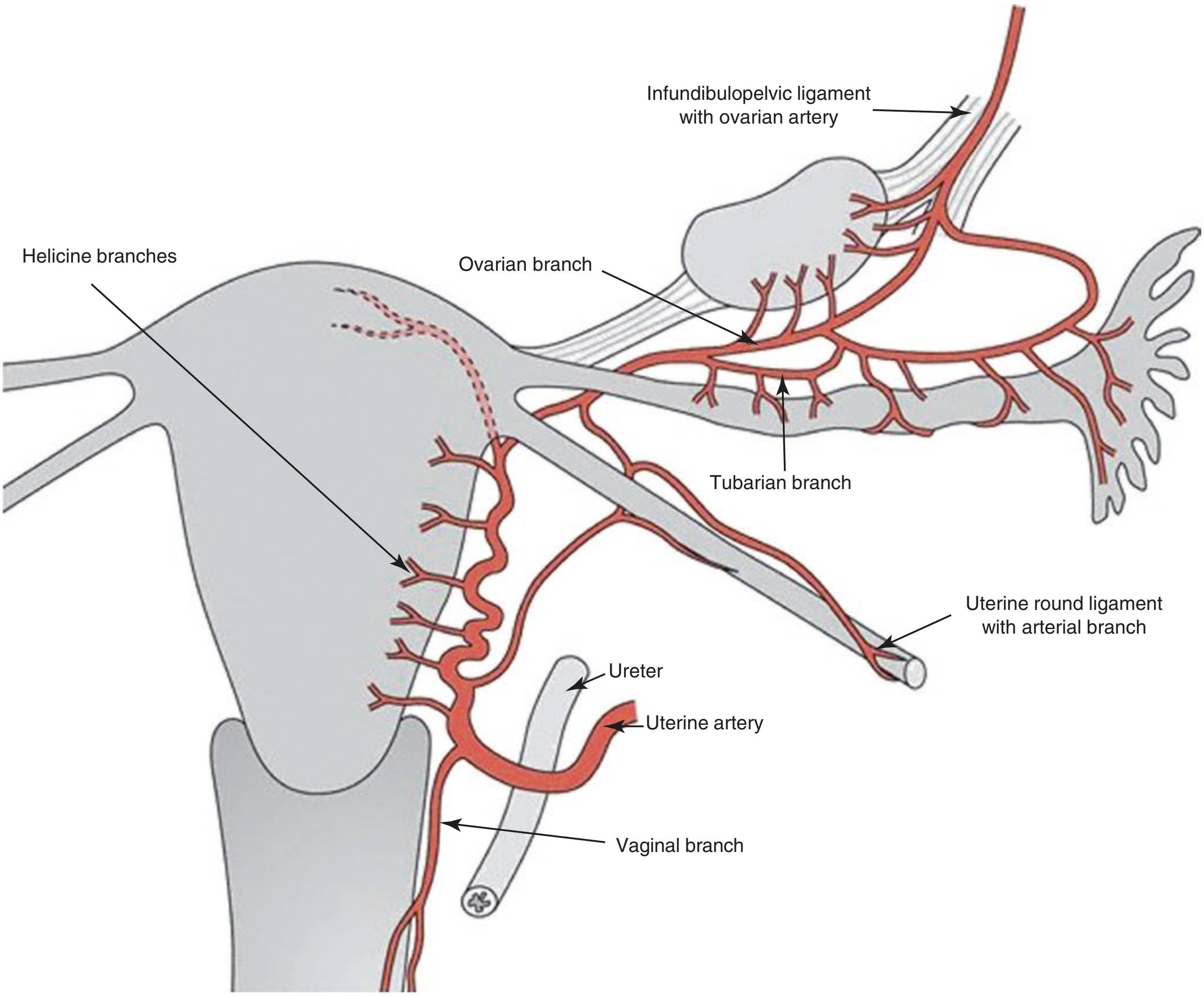

Fig. 3.8 Arterial supply of internal female organs. Ventral view. Branches of the left ovarian and uterine artery (Reproduced from Schünke et al. [24])

ine artery and lymphatic vessels draining to superficial inguinal lymph nodes. The mesovarium and mesosalpinx have been described previously (see section "Uterine Adnexa").

Parametrium and Transverse Cervical Ligaments

Beneath the peritoneal covering the broad ligaments consist of condensed connective tissue connecting the pelvic side walls with the uterus (parametrium) and the vagina (paracolpium) – comparable to those densifications of connective tissue extending lateral to the urinary bladder (paracystium) and rectum (paraproctium). The fibrous tissue contained within the parametrium/paracolpium corresponds to the transverse cervical ligaments (cardinal ligaments) which predominantly attach to the uterine cervix and vaginal fornix. Although composed of connective tissue providing a certain degree of mechanical suspension, the transverse cervical ligaments primarily resemble a mesentery-like structure serving as main routes of vascular, lymphatic and nervous supply of the uterus. The transverse cervical ligaments and parametrial tissue compartment are ca. 10 cm long and traversed by the ureter at its intermediate segment (Figs. 3.3, 3.4, 3.5, 3.10, 3.11, and 3.12) [4–6].

Uterosacral Ligaments

The uterosacral ligaments (Figs. 3.3, 3.4, and 3.5) attach to the uterine cervix and upper vagina and are often confluent with the uterine insertion site of the transverse cervical ligaments.

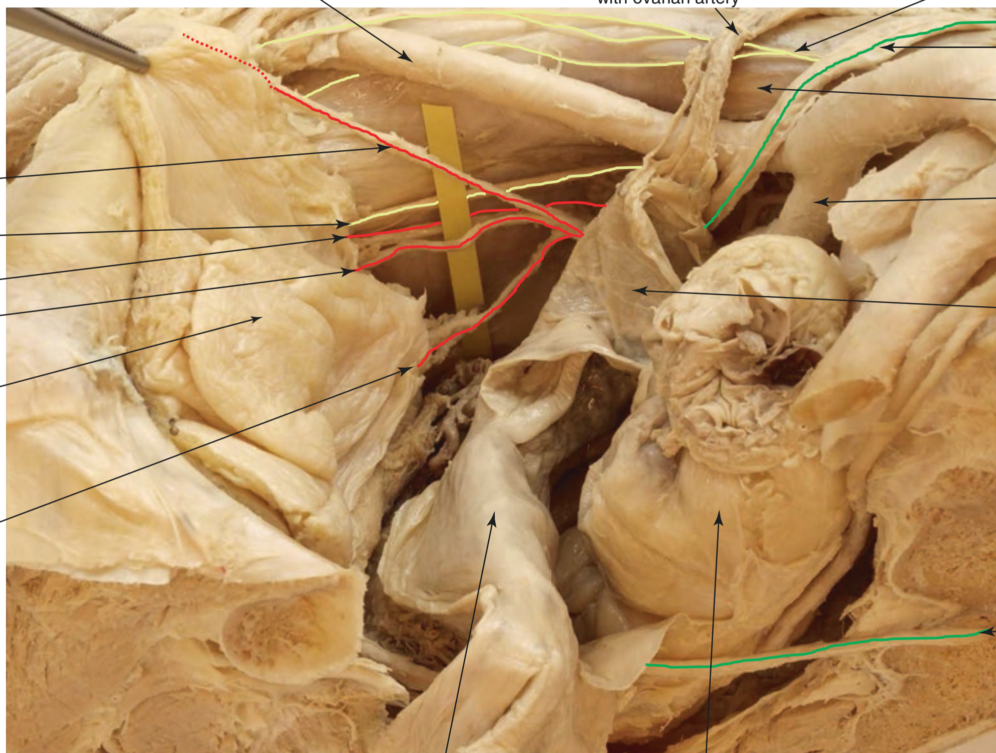

Fig. 3.9 Female right-sided hemipelvis. Parasagittal section, view from left side. The peritoneum is partially removed and incised, the anterior leaf of the right broad ligament is reflected dorsally, the urachus and the bladder roof are pulled upwards by a forceps, the obturator artery and nerve are marked by a yellow plastic strip. Arteries are highlighted by *red lines*, nerves by *yellow lines*, the ureter by *green line*. Formaldehyde-fixed specimen (same specimen also displayed in Fig. 3.10)

The fibrous bands extend dorsally along the rectal sidewalls to reach the sacrum. On their way to the sacrum they create the rectouterine folds and fan out before inserting at the sacral vertebrae S2–S4. The uterosacral ligaments serve as suspension of the uterine cervix and the vaginal tube ensuring the craniodorsal orientation of its long axis. In close proximity extend autonomic nerve fibers of the inferior hypogastric plexus passing immediately lateral to the uterosacral ligaments [4, 7–9].

Pubocervical Ligaments

The pubocervical ligaments (Fig. 3.4) connect the back side of the pubic bone with the uterine cervix. On their way to the uterus the pubocervical ligaments diverge around the urethra and bladder neck. In fact, all uterine ligaments – transverse cervical ligaments from both sides, uterosacral ligaments from behind, and pubocervical ligaments from front – insert at the uterine cervix. The insertion site is reinforced by a connective tissue condensation radially running around the uterine cervix termed cervical ring or pericervical fascia.

Mesometrium

The term mesometrium refers to the embryologically defined tissue compartment of the middle pelvic compartment that contains the neurovascular supply and major lymphatic drainage routes of the uterus – comparable to the mesorectum wrappend around the rectum in the posterior pelvic compartment. The mesometrium actually corresponds to the parametrial tissue, however further emphasizing its mesentery-like function provided by the lymphofatty tissue and accompanying uterine blood vessels and its clear delineation by fascial envelopes preventing early tumor transgression [6, 10].

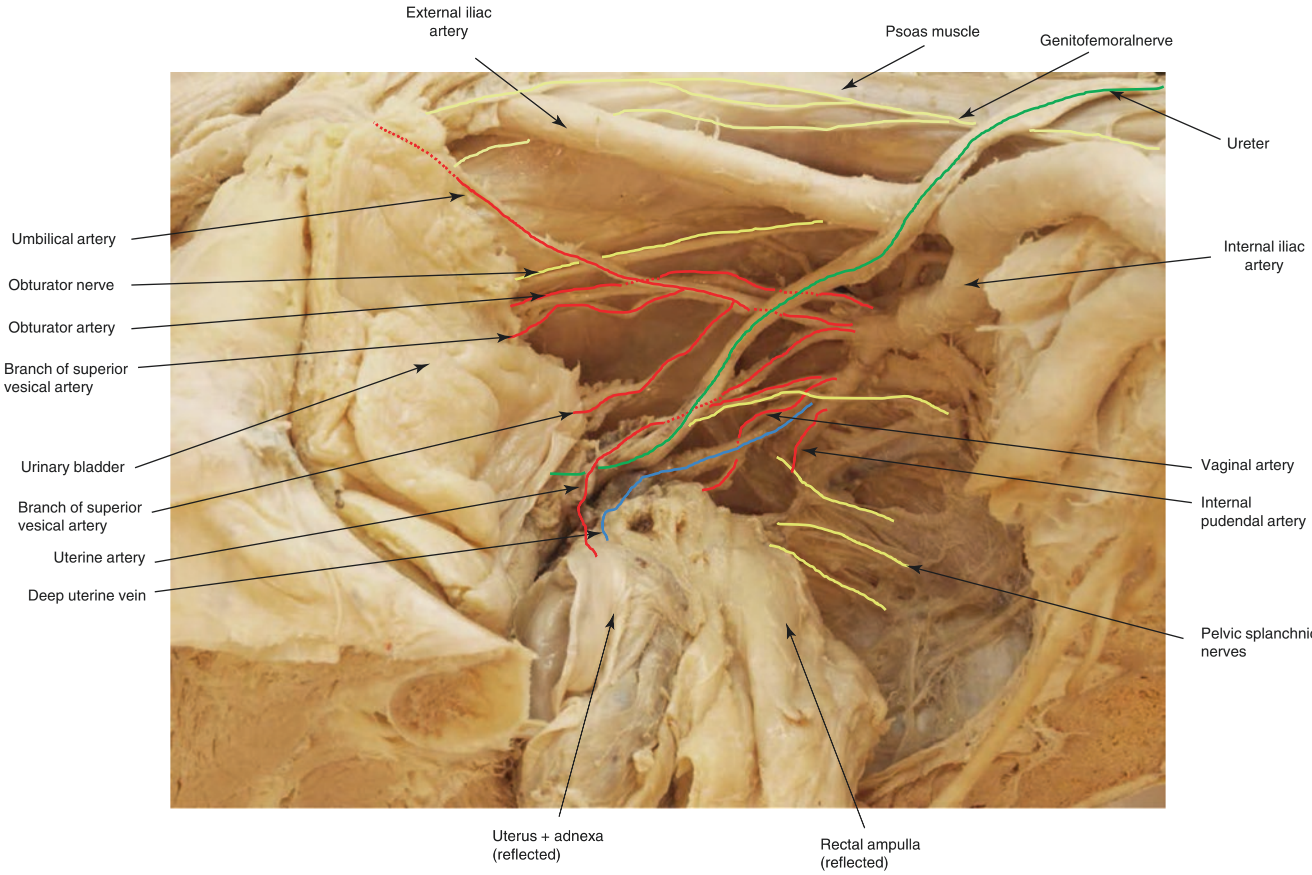

Fig. 3.10 Female right-sided hemipelvis. Parasagittal section, view from left side. The peritoneum is partially removed and incised, uterus and rectum are shifted to the left side to expose the blood vessels, nerves and ureter at the right pelvic sidewall. Arteries are highlighted by *red lines*, veins by *blue lines*, nerves by *yellow lines*, the ureter by *green line*. Formaldehyde-fixed specimen (same specimen also displayed in Fig. 3.9)

The clinical significance of the mesometrium has received special attention after the introduction of total mesometrial resection (TMME) for uterine cancer – in turn comparable to total mesorectal excision (TME) [11] carried for rectal cancer or complete mesocolic excision (CME) [12] recently introduced for colon cancer. All these surgical approaches are commonly based on the concept that tumor spread is initially confined to permissive ontogenetic compartments and its corresponding lymh node basins, so that complete removal of these embryologically defined packages will result in both optimal tumor control and low morbidity, if the resection margins are properly respected [10, 13, 14].

The uterine tubes, uterus and upper vagina are derivates of the paramesonephric ducts (Müllerian ducts). The distal fusion of the Müllerian ducts induces the development of the uterovaginal canal and the formation of the broad ligaments and the mesometrial tissue. According to Höckel the mesometrium can be subdivided into a vascular mesometrium containing the uterine vessels and surrounding lymphofatty tissue with mesometrial lymph nodes and a ligamentous mesometrium corresponding to the uterosacral ligaments and rectovaginal septum [10].

Blood Vessel Supply of Female Pelvic Viscera

The female pelvic viscera are mainly supplied by the internal iliac arteries (Figs. 3.5, 3.6, and 3.7) [3] The common iliac arteries originate at the aortic bifurcation in front of the left side of the fourth lumbar vertebra. They pass along the medial borders of the psoas major muscle without giving off branches and diverge into external and internal iliac arteries. Whereas the external iliac arteries follow the psoas major muscle until traversing the lacuna vasorum through the femoral ring to reach the lower limb, the internal iliac arteries descend into the pelvic cavity in posterocaudal direction over ca. 4 cm and then divide into an anterior and posterior trunk. To expose the inter-

Fig. 3.11 Female right-sided hemipelvis. Midsagittal section, view from left side. The peritoneum is partially removed and shifted to the left side to expose the blood vessels, nerves and ureter at the right pelvic sidewall. The ureter is marked by a green vessel loop, the pelvic autonomic nerve plexus by yellow plastic strips, the uterine artery by a red plastic strip, the uterine vein by a blue plastic strip. In addition, arteries are highlighted by *red lines*, veins by *blue lines*, nerves by *yellow lines*, the ureter by *green line*. Formaldehyde-fixed specimen

nal iliac artery the adjacent and sometimes overlying infundibulopelvic ligament and ovary have to be shifted upwards. The common, external and internal iliac veins are located medially or dorsomedially to their arterial counterparts.

The anterior trunk or division of the internal iliac artery comprises the following branches:

Superior Vesical Artery

The superior vesical artery (Figs. 3.5, 3.7, 3.8, 3.9, 3.10, 3.11, and 3.12) is the first visceral branch and corresponds to the proximal, patent segment of the fetal umbilical artery. The artery follows the pelvic sidewall medially to the obturator vessels and nerve and craniolaterally to the urinary bladder. Before reaching the urinary bladder the superior vesical artery splits into various branches mostly for the vesical fundus and corpus but also for the distal ureter. The obliterated segment corresponds to the medial umbilical ligament ascending from the vesical fundus along the anterior abdominal wall to the umbilicus thereby forming the medial umbilical fold underneath the parietal peritoneum (Figs. 3.20 and 3.21). Gentle traction applied to the medial umbilical ligament allows easy identification of the superior vesical artery and usually thereby also of the uterine artery, as both arteries originate either from a common trunk or close to each other.

Uterine Artery

The uterine arteries supply (Figs. 3.5, 3.7, 3.8, 3.10, 3.11, 3.12, and 3.13) the entire uterus including the uterine tubes and uterine round ligaments and also the upper third of the vagina. The uterine artery originates from the internal iliac artery either as a separate branch or as a common trunk together with the superior vesical artery. Although the superior vesical and uterine arteries supply different pelvic compartments, vesicovaginal anastomoses are often observed, in particular regarding the corresponding veins.

The uterine artery runs through the parametrial tissue covered by the broad ligament towards the uterine cervix. The ureter crosses underneath the uterine artery ca. 1–2 cm lateral to the uterine cervix and lateral vaginal fornix and receives a supplying branch. Whereas in most of the cases one single uterine artery is present on each side, multiple uterine veins of different sizes can be observed which drain the uterine venous plexus. The uterine veins often do not directly follow the course of the uterine artery, but often pass underneath the ureter. The most caudally located vein is also termed deep uterine vein.

The main branch of the uterine artery ascends lateral to the uterus in meander-like course towards the uterine cornu where it gives off an ovarian branch running within the mesovar and a tubal branch running within the mesosalpinx. These branches establish anastomoses with the ovarian artery. An additional branch originates at the uterine cornu to follow and supply the uterine round ligament.

From the tortuous segment of the uterine artery multiple helicine branches enter in the uterine wall, divide into arcuate arteries and supply the myometrial and endometrial layers by giving off radial and spiral branches. The right and left uterine arteries establish extensive intramural anastomotic connections across the midline, so that the uterine blood supply is not seriously compromised after unilateral ligation. At the level of the uterine cervix branches descend to the vagina and anastomose with branches of the vaginal artery to form two longitudinal vessels. These vaginal azygos arteries run along the anterior and posterior vaginal wall.

Vaginal Artery

In addition to vaginal branches of the uterine artery one or more arteries originating from the internal iliac artery directly run to the vagina. These vaginal arteries (Figs. 3.5, 3.7, and 3.10) correspond to the inferior vesical artery in males and supply the vagina, vaginal vestibule as well as the vesical trigone and urethra.

Middle Rectal Artery

The last visceral branch of the internal iliac artery is the middle rectal artery (Figs. 3.5 and 3.7) running above the levator ani muscle within the lateral rectal pedicles together with autonomic nerve fibers of the rectal plexus to reach the rectal wall. However, in contrast to both the superior vesical and uterine arteries the middle rectal arteries are much smaller in size and inconstantly present, as the rectal blood supply is mainly provided by the more promiment superior rectal artery running within the mesorectum (Figs. 3.17 and 3.18).

Obturator Artery

The obturator artery (Figs. 3.5, 3.7, 3.9, 3.10, and 3.13) is one of the first branches of the internal iliac artery. However, it does not primarily supply the pelvic viscera, but leaves the pelvic cavity via the obturator canal to approach the adductor muscles of the medial thigh. In the pelvis the artery passes medially to the internal obturator muscle and caudally to the obturator nerve which converges with the obturator vascular pedicle at the entrance foramen of the obturator canal. At its proximal segment the obturator artery is located in close proximity both to the ureter and the ovary and it gives off iliac branches supplying the iliopsoas muscle. From the distal segment vesical branches may ramify and pass medially to the urinary bladder.

Frequently, an anastomotic connection between the obturator and inferior epigastric artery is provided by a pubic branch running across the pubic bone over the pectineal ligament (Figs. 3.13, 3.14, and 3.20). A prominent pubic branch is also termed corona mortis ("crown of death"), because in earlier times an inadvertent injury of this vessel during inguinal or femoral hernia repair has led to serious bleedings. In up to one third of cases the obturator artery does not originate from the internal iliac artery but from the inferior epigastric artery or even the external iliac artery sending an enlarged pubic branch directly towards the obturator canal. In any case, special attention should be payed to these vascular variations, when operating in the obturator fossa and paravesical space, e.g. for extended pelvic lymphadenectomy.

Internal Pudendal Artery

The internal pudendal artery (Figs. 3.7, 3.10, and 3.11) is one of the terminal branches of the anterior division of the internal iliac artery and supplies the perineal region, anal canal, external genital organs, and pelvic floor muscles. The artery descends laterally in front of the piriformis muscle and sacral nerve plexus roots, leaves the pelvis through the infrapiriform hiatus of the greater sciatic foramen and bends around the ischial spine to enter into the ischioanal fossa via the lesser sciatic foramen. The artery is accompanied medially by the internal pudendal vein and pudendal nerve. Branches of the internal pudendal artery include muscular branches for the pelvic and gluteal region, inferior rectal artery, perineal arteries, posterior labial branches, branches to the vestibular bulb and vaginal introitus, deep and dorsal artery of the clitoris.

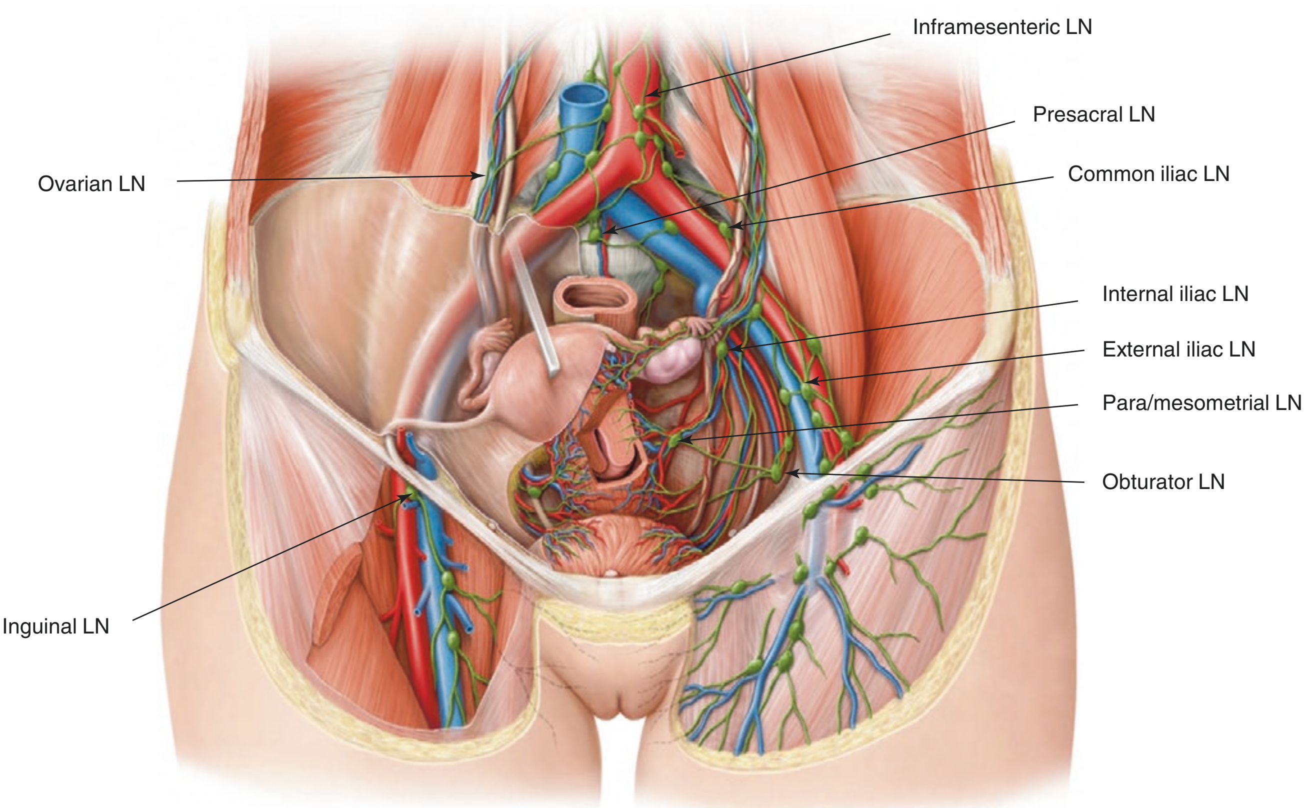

Fig. 3.12 Lymph nodes (LN) and lymphatic drainage of female genital organs. Ventral view. The uterus is shifted to the right side, the peritoneum is removed on the left side and above the aortic bifurcation (Reproduced from Schünke et al. [24])

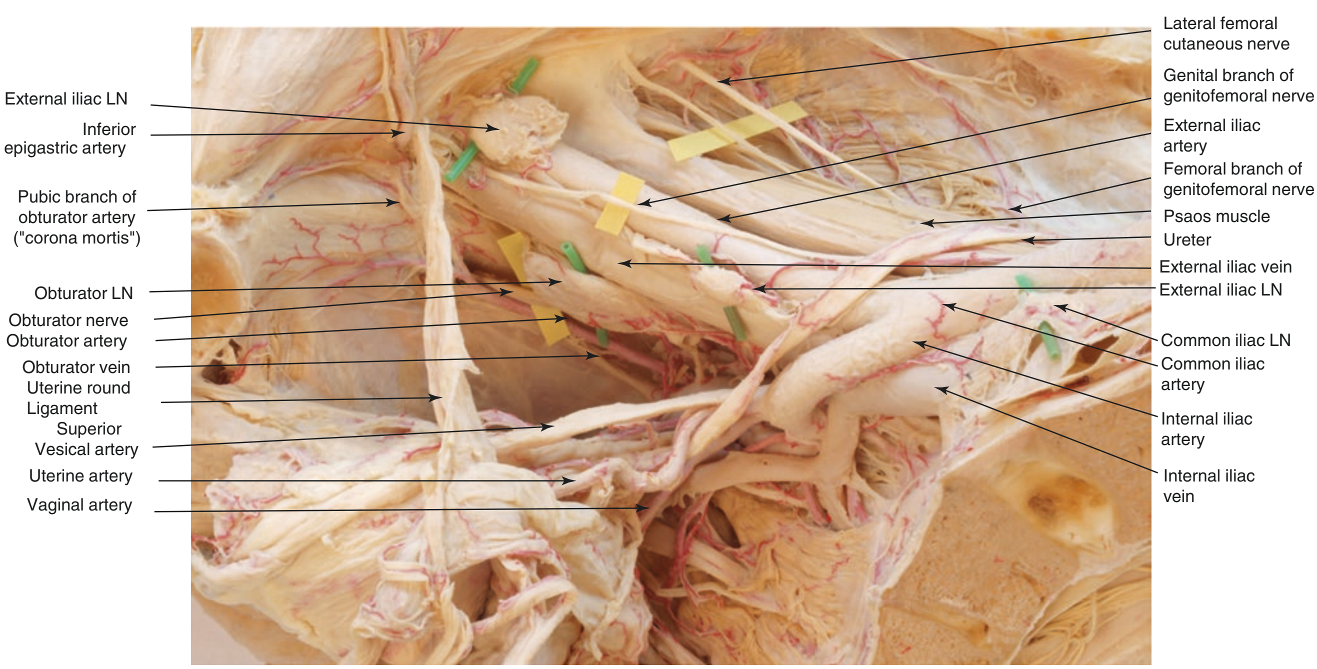

Fig. 3.13 Female right-sided hemipelvis, view from left side. The peritoneum is completely removed and the pelvic viscera are shifted to the left side to expose the blood vessels, nerves and ureter at the right pelvic sidewall. Lymph nodes (LN) are marked by green plastic tubes, nerves by yellow plastic strips. Formaldehyde-fixed specimen

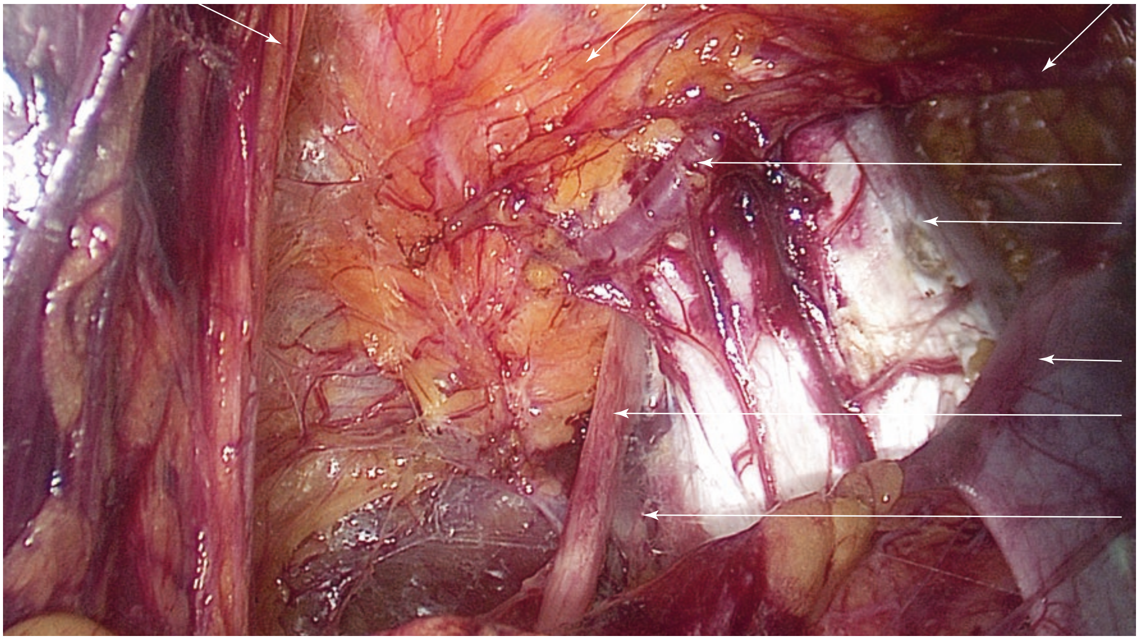

Fig. 3.14 Exposure of right-sided prevesical space and obturator fossa. Laparoscopic cranial view. A prominent pubic branch is visible crossing the pectineal ligament and the superior pubic ramus

Inferior Gluteal Artery

The inferior gluteal artery (Fig. 3.7) is the other terminal branch of the anterior division of the internal iliac artery, however often originating from a common stem together with the internal pudendal artery. It also decends anterior to the piriformis muscle and sacral nerve plexus, but then passes posteriorly between the ventral rami of the sacral spinal nerves and traverse the infrapiriform hiatus of the greater sciatic foramen to reach the gluteal and posterior femoral region.

The posterior trunk or division of the internal iliac artery comprises the following branches:

Iliolumbar Artery

The iliolumbar artery is the only ascending branch of the internal iliac artery passing posterior to the external iliac vessels and obturator nerve in front of the sacroiliac joint to reach the psoas muscle. The iliac and lumbar branches supply the muscles of the corresponding regions and establish anastomoses with the gluteal and deep circumflex iliac arteries.

Lateral Sacral Arteries

Usually a superior and inferior branch originate from the internal iliac artery, descend and approach the anterior sacral foramina to supply the sacral canal and dorsal sacral region. The lateral sacral arteries anastomose from both sides with the median sacral artery.

Superior Gluteal Artery

The superior gluteal artery (Fig. 3.7) corresponds to the terminal branch of the posterior division of the internal iliac artery. Immediately after its origin the large vessel traverses between the first ventral rami of the sacral spinal nerves to leave the pelvis via the suprapiriform hiatus of the greater sciatic foramen. Deep and superficial branches of the superior gluteal artery supply the gluteal and sacral region and anastomose with the inferior gluteal, deep circumflex iliac and circumflex femoral arteries.

Pelvic Veins

As a general rule, larger veins such as the common, external and internal iliac veins follow the course of their arterial counterparts. In most cases, the veins run medially or dorsomedially to the arteries. The same observation holds true for most of the parietal branches (e.g. obturator, pudendal, gluteal veins) of the internal iliac artery, whereas the visceral branches display different features: the urinary bladder, uterus and vagina are drained by venous plexus which are interconnected with each other and release the blood into multiple vesical, vaginal and uterine veins. These veins do

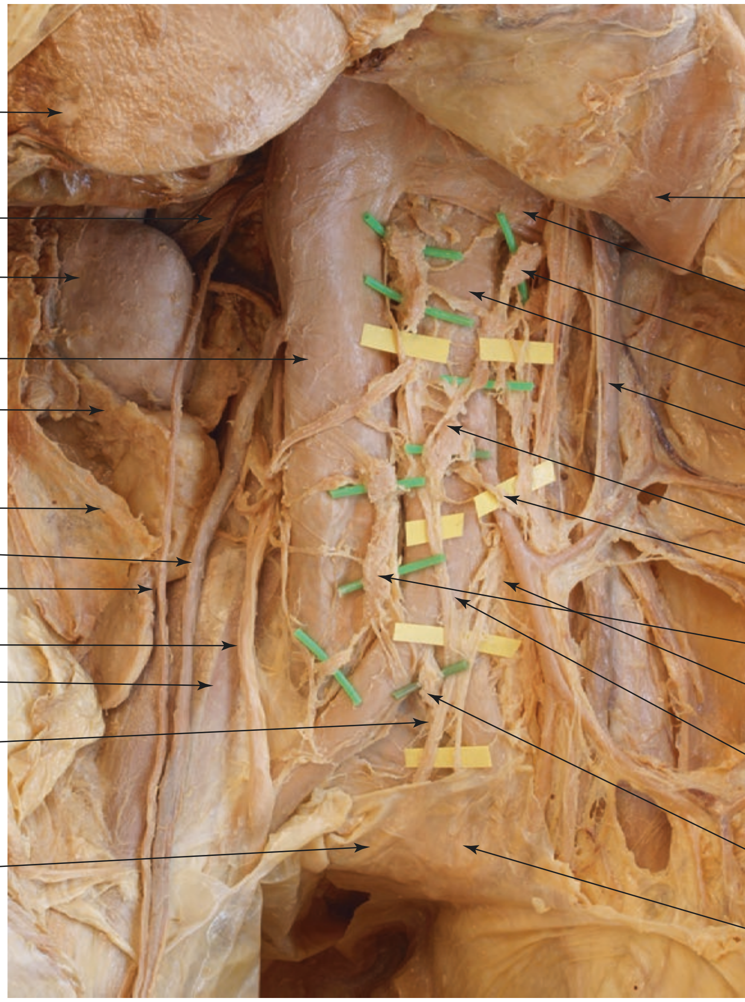

Fig. 3.15 Prevertebral and retroperitoneal region. Ventral view. The parietal peritoneum is removed down to the entrance into the pelvic cavity on both sides, the anterior renal fascia is removed on the left side. Lymph nodes (LN) are marked by green plastic tubes, nerves by yellow plastic strips. Formaldehyde-fixed specimen

not strictly accompany and parallel the arteries until they have entered into the internal iliac vein.

It has to be emphasized that during laparoscopic or roboter assisted surgery, pelvic veins often collapse due to the intraperitoneal pressure exerted by gas insufflation onto the thin venous walls. Thus, special care must be taken to clearly identify and respect the pelvic veins, because injury may occur inadvertently and lead to troublesome bleeding sometimes only evident after diminishing the intraperitoneal pressure.

Lymph Nodes and Lymphatic Drainage of the Uterus and Uterine Adnexa

In general, lymphatic drainage follows the blood supply of the corresponding organs and is realized by a network of rather thin-walled lymphatic vessels and lymph nodes grouped along the nutrient vascular branches and enveloped by fatty and loosely arranged connective tissue. As the arterial supply of the uterus and uterine adnexa originates from two sources (uterine and ovarian arteries), the main lymphatic drainage involves both pelvic and paraaortic routes and is therefore complex and multidirectional due to the peculiar ontogenetic anatomy of the female genital tract [3]. However, direct lymphatic drainage pathways into the anterior pelvic compartment via the vesicouterine ligaments or into the posterior compartment via the uterosacral ligaments could not be demonstrated [15, 16].

Lymphadenectomy is considered to be an integral component of the surgical treatment for uterine carcinoma. Due to the topographic complexity of lymphatic drainage and close proximity between lymph nodes and both blood vessels and nerves, pelvic and paraaortic lymph node dissection are challenging and often time consuming procedures. Therefore, profound anatomical knowledge of the different lymph node