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Urologic Principles and Practice

Second Edition

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Urologic Principles and Practice

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Editors

Christopher R. Chapple
Sheffield Teaching Hospitals NHS Foundation, Sheffield, UK

William D. Steers
Department of Urology, University of Virginia, Charlottesville, VA, USA

Christopher P. Evans
Department of Urologic Surgery, University of California, Davis, Sacramento, CA, USA

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This edition of Urologic Principles and Practice is dedicated to William D. Steers, co-author of the first edition. Dr. Steers, a man of many diverse interests and talents, had a dominant presence in International urology until his untimely passing on April 10, 2015. He was the Paul Mellon professor and Chair of the Department of Urology at the University of Virginia School of Medicine. He was a past President of the American Board of Urology from 2010 to 2011 and Editor of the Journal of Urology from 2007 until his passing. With a strong interest in female and pelvic medicine and sexual medicine, Dr. Steers served as chair of the joint ABU/ABOG fellowship in female pelvic medicine and Director on the American Board of Obstetrics and Gynecology. Steers was a member of the U.S. Food and Drug Administration 's Reproductive Medicine Advisory Panel and chaired the National Institutes of Health 's urinary incontinence and interstitial cystitis clinical trial groups. In 2011, Steers was appointed to the advisory council at National Institutes of Health by Kathleen Sebelius and Francis Collins . Steers was President of the University of Virginia physician's practice plan from 2002 to 2009 and was a member of the Health System Strategic Planning and Executive Committees. In 1998, he described the efficacy of Viagra in a highly cited New England Journal of Medicine publication.

In 2003, the University of Virginia awarded Dr. Steers the Hovey Dabney Professorship. Dr. Steers was named by Men's Health magazine as one of the top 15 doctors for men in the USA. He was awarded the American Urological Association 's Hugh Hampton Young Award , Gold Cystoscope Award, Dornier's Innovation prize, Gineste Award for research in erectile dysfunction, and the Zimskind Award in Neurourology.

Dr. Steers had many interests. He was a viticulturist aficionado and with his wife Amy co-owned Well Hung Vineyard in Charlottesville , VA. He also authored YOURometer an iPhone App. used to record urological-related symptoms. Steers' entrepreneurial activities include the development of a cell phone application to record patient symptoms and using the internet Crowdcasting to fund medical research. He was an active runner and outdoorsman.

Bill is survived by his wife, Amy; sons, Colin and Ryan; daughter-in-law, Ali; and grandchildren, Rex and Reese. His vibrant personality, incredible knowledge, and medical skills and thoughtful and generous nature is sorely missed by many. We honor him with this second edition.

Christopher R. Chapple and Christopher P. Evans

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Part I
Basic Sciences in Urology

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1. Gross and Laparoscopic Anatomy of the Upper Tract and Retroperitoneum

Paras H. Shah[1] and Bradley C. Leibovich[1]

(1) Division of Urology, Albany Medical Center, Albany, NY, USA

Paras H. Shah
Email: Shah.Paras@mayo.edu

Bradley C. Leibovich (Corresponding author)
Email: Leibovich.Bradley@mayo.edu

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Introduction

It is of paramount importance that the Urologic surgeon possess a comprehensive anatomic understanding of the retroperitoneal compartment given that in this space, and the contiguous extravesical domain below the peritoneal reflection, reside all the major urologic organs. Moreover, traversing the retroperitoneum are the body's primary blood vessels—the aorta and inferior vena cava (IVC)—from which emerge the vascular supply to the urologic organs. As control of arterial and venous structures is often a critical component to surgery, particularly when performed for an oncologic indication, familiarity with both the conventional and variant anatomic course of these vessels as they approach their target organ is essential. Within the retroperitoneal space is also a rich lymphatic network intimately associated with the aorta and IVC. Secondary infiltration of these lymphatics by kidney, upper tract urothelial, and primary testicular germ cell tumors may necessitate surgical resection of the peri-caval and peri-aortic lymph nodes, emphasizing the importance of understanding principles by which the retroperitoneal compartment is accessed.

Herein, we review the structural organization of the retroperitoneal space, highlighting how the anatomy of this compartment is maneuvered during major urologic procedures, performed via either an open or laparoscopic approach.

Anatomy

The retroperitoneum is bounded anteriorly by the parietal peritoneal layer and posterolaterally by the transversalis fascia. The compartment itself rests upon the belly of the psoas and paraspinal (specifically the quadratus lumborum) muscles, over which lies the lumbodorsal fascia—a connective tissue layer that is itself continuous more laterally with the transversalis fascia (Fig. 1.1).

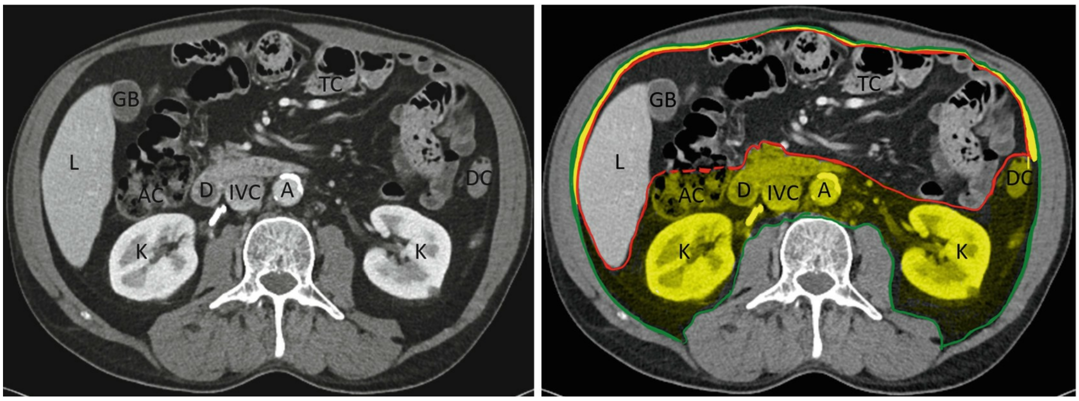

Fig. 1.1 Retroperitoneum vs. peritoneal cavity: the boundaries of the retroperitoneal space, which is highlighted in yellow, are formed by the parietal peritoneum (red) and the transversalis fascia (green). The retroperitoneal compartment is continuous anteriorly with the pre-peritoneal space (dense yellow shade). Within the retroperitoneum are bilateral Kidneys (*K*), the 2nd and transverse segments of the Duodenum (*D*), Ascending Colon at the level of the hepatic flexure (*AC*), Descending Colon below the splenic flexure (*DC*), Aorta (*A*) and Inferior Vena Cava (*IVC*). Additionally, the Liver (*L*), Gallbladder (*GB*), Transverse Colon (*TC*) and Jejunal loops of small intestine are appreciated within the intraperitoneal space

The retroperitoneum can be divided further into four compartments, which from a surgeon's perspective aids in the understanding of access to the urologic organs and major blood vessels situated within this space. These compartments include the Perirenal Space, the Anterior Pararenal Space, the Posterior Pararenal Space, and the Central Vascular Compartment (Figs. 1.2a, b).

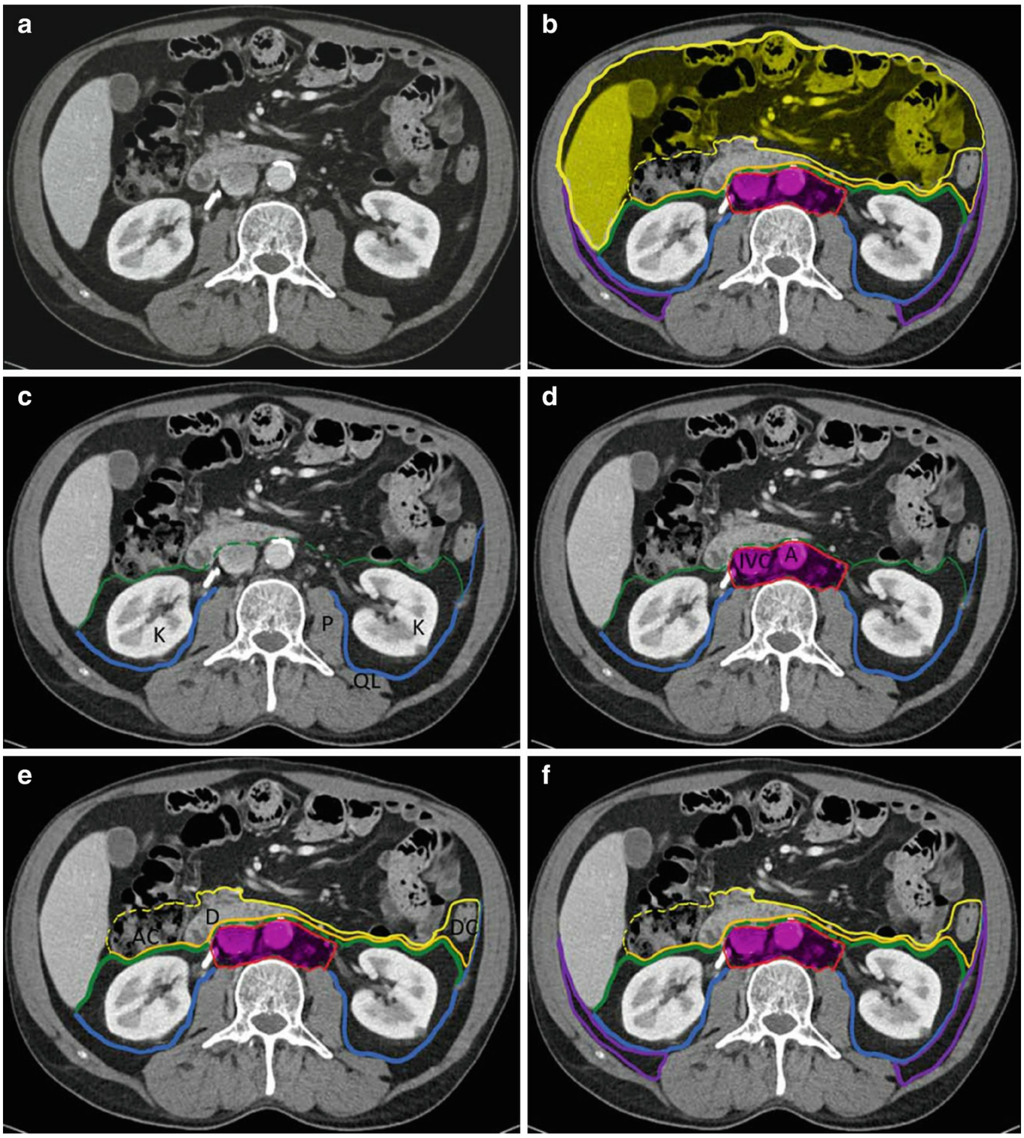

Fig. 1.2 Cross-sectional image of CT abdomen. (**a**) Cross-section image of CT abdomen. (**b**) Divisions of the Retroperitoneum: The peritoneal cavity is lined by a layer of mesothelial tissue referred to as the parietal peritoneum (yellow). The retroperitoneum can be subdivided into four compartments: the perirenal space (blue/green), the central vascular compartment (red), the anterior pararenal space (yellow/orange lines), and the posterior pararenal space (purple). (**c**) Perirenal Space: The Kidneys (*K*) are situated within the perirenal space, which is bordered by the Gerota's fascia anteriorly (green) and the Zuckerkandl's fascia posteriorly (blue). Additionally, the Gerota's fascia crosses over the midline (dashed green) as it drapes over the central vascular compartment to connect to the contralateral perirenal space; within this are the Kneeland's channels, which may allow for communication between the spaces. The Zuckerkandl's fascia continues anteriorly (blue) off the lateral contour of the kidney, forming the lateral border of the anterior pararenal space and connecting to the parietal peritoneum. The perirenal space rests on top of the psoas (*P*) and Quadratus Lumborum (*QL*) muscles. (**d**) Central Vascular Compartment: The Aorta (*A*) and Inferior Vena Cava (*IVC*) are located within the central vascular compartment, outlined in red and shaded in purple. Peri-aortic and peri-caval lymph nodes are within the surrounding fibroadipose tissue. The Gerota's fascia can be seen crossing the midline and draping over the central vascular compartment (dashed green lines). (**e**) Anterior Pararenal Space: Seen here within the Anterior Pararenal Space, which is outlined in yellow anteriorly and orange posteriorly, is the Ascending Colon (*AC*), the Duodenum (*D*), and the Descending Colon (*DC*). The anterior connective tissue border of this space is formed anteriorly by the parietal peritoneum (yellow), which serves as the posterior abdominal wall of the peritoneal compartment, and posteriorly by the Toldt's fascia (orange). (**f**) Posterior Pararenal Space: This compartment, outlined in purple, contains only adipose tissue

Perirenal Space

The perirenal space contains within it the adrenal gland, kidney, and ureter—organs that are all supported by a body of perinephric fat. The volume of fat within this compartment varies widely and is based partly on age, gender, and body mass (Fig. 1.3). The perirenal space is delineated anteriorly by Gerota's fascia (anterior perirenal fascia) and posteriorly by Zuckerkandl's fascia (posterior perirenal fascia), which fuse laterally to essentially envelop these organs and overlying fat layer (Fig. 1.2c). The point of fusion along the lateral contour of the kidney is of clinical relevance as it offers a nice cleavage plane through the perinephric fat by which the capsular kidney surface can be accessed, as is necessary during partial nephrectomy.

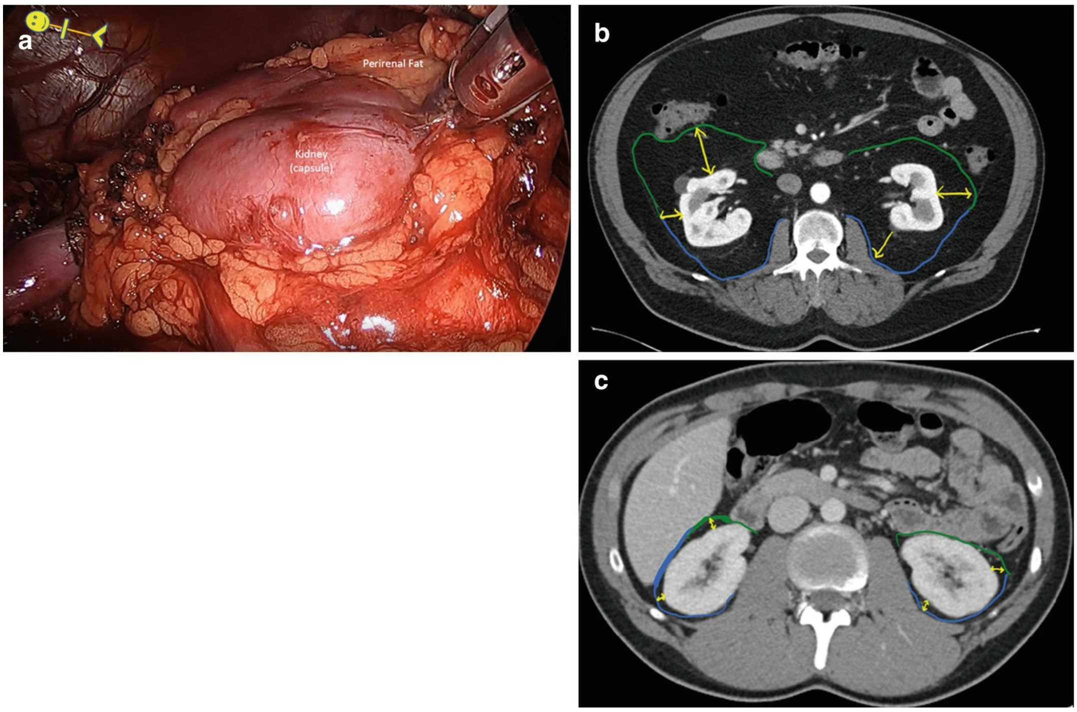

Fig. 1.3 Perinephric fat. (**a**) Intraoperative view of the Kidney with the surrounding Perinephric fat removed off its capsular surface. (**b**) A large volume of perinephric fat, as delineated by yellow arrows, is appreciated around both kidneys. The anterior and posterior perirenal fascia are delineated in green and blue, respectively. (**c**) Minimal perinephric fat volume, as delineated by yellow arrows, is appreciated around both kidneys. The anterior and posterior perirenal fascia are delineated in green and blue, respectively

The posterior perirenal fascia is in fact comprised of two layers, the deep and superficial lamina, which explains its prominence on cross-sectional imaging. Whereas the deep layer is continuous with the anterior renal fascia, the superficial layer of the perirenal fascia deviates anteriorly off the lateral contour of the perirenal space, and is referred to here as the lateral conal fascia. The lateral conal fascia runs along the lateral edge of the anterior pararenal space as it fuses here with the parietal peritoneum (Fig. 1.2c).

The perirenal space is shaped as an inverted pyramid, with the diaphragm serving as the base of this space and the apex of the space directed towards the pelvis. Although the superior border of the perirenal space is solely the diaphragm on the left (Fig. 1.4), the superior border of the perirenal compartment on the right is formed anteriorly by the bare segment of the liver, which is devoid of a peritoneal lining, and posteriorly by the diaphragm (Fig. 1.5). The perirenal space rests on top of the psoas and quadratus lumborum muscles; this interface is formed by close apposition of the Zuckerkandl fascia with the psoas fascia and thoracodorsal fascia, which overlie the psoas and quadratus lumborum muscles, respectively (Figs. 1.2c and 1.6).

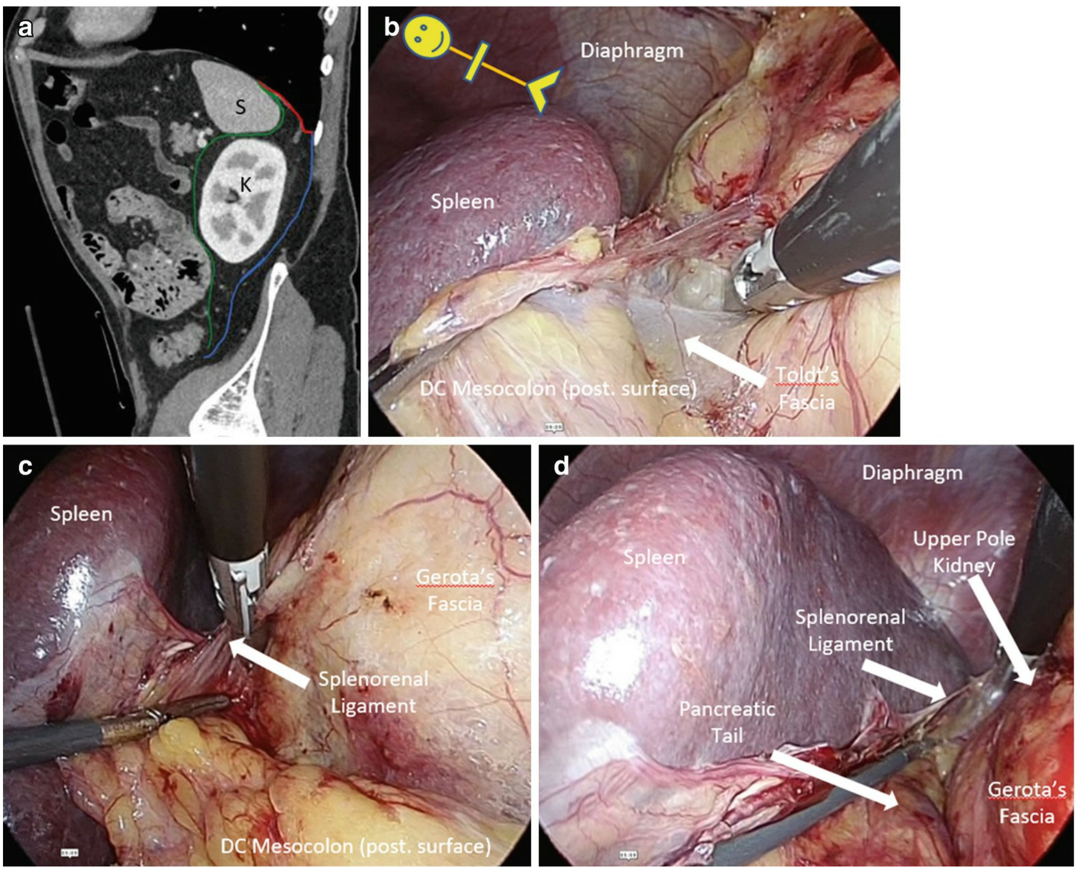

Fig. 1.4 Left perirenal space. (**a**) The superior border of the left perirenal space is the diaphragm (red). The anterior and posterior perirenal fascia are delineated in green and blue, respectively. (**b**) Medial reflection of the left mesocolon permits access to the left perirenal space. (**c, d**) Division of the splenorenal ligament permits medial reflection of the spleen (intraperitoneal location) off the superior aspect of the left perirenal space. *DC* descending *c*olon, *K* kidney, *S* spleen

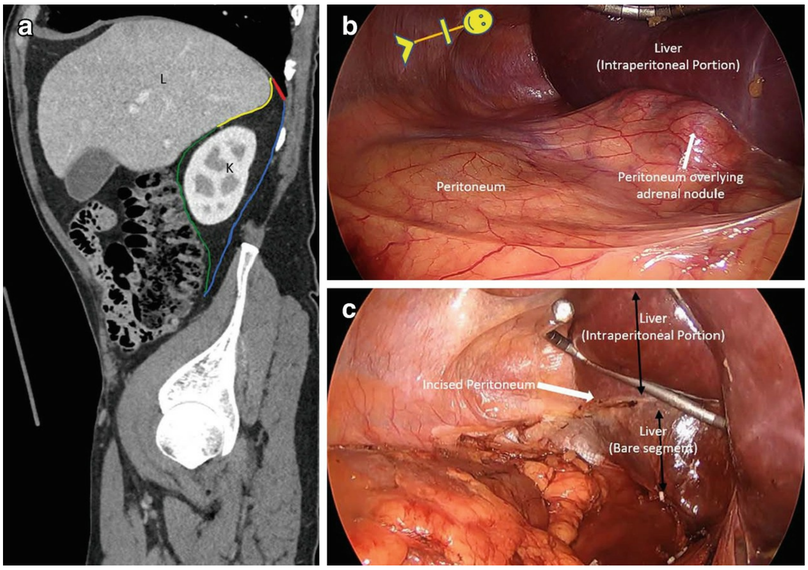

Fig. 1.5 Right perirenal space. (**a**) The superior border of the right perirenal space is formed by both the bare segment of liver (anteriorly; yellow) and the diaphragm (posteriorly; red). The anterior and posterior perirenal fascia are delineated in green and blue, respectively. (**b**) Intraoperative view of the intraperitoneal portion of liver. (**c**) The bare segment of the liver, serving as the superior border of the right perirenal space, can be visualized upon accessing the upper region of the right perirenal space. Of note, the adrenal gland and surrounding perirenal fat have been removed. *K* Kidney, *L* liver

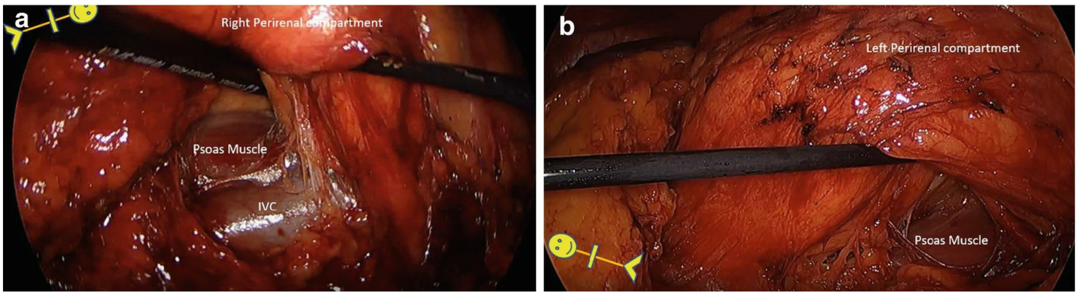

Fig. 1.6 The posterior perirenal fascia of the right (**a**) and left (**b**) perirenal spaces is lifted anteriorly off the Psoas muscle/fascia

Piercing the perirenal fascia medially are renal hilar vessels, which are derived from the great vessels situated within the central vascular compartment (Fig. 1.7). Although the right and left perirenal spaces are separated by this central vascular compartment, cross-talk is thought to exist between them, particularly given the anatomic configuration of Gerota's fascia whereby it crosses the midline to drape over the great vessels at the level of the L3 to L5 vertebrae to fuse with the Gerota's fascia of the contralateral side (Fig. 1.2c). Indeed, it is proposed that trabeculae within the anterior perirenal fascia connective tissue crossing the midline forms the Kneeland channels, allowing for communication between both perirenal spaces [1].

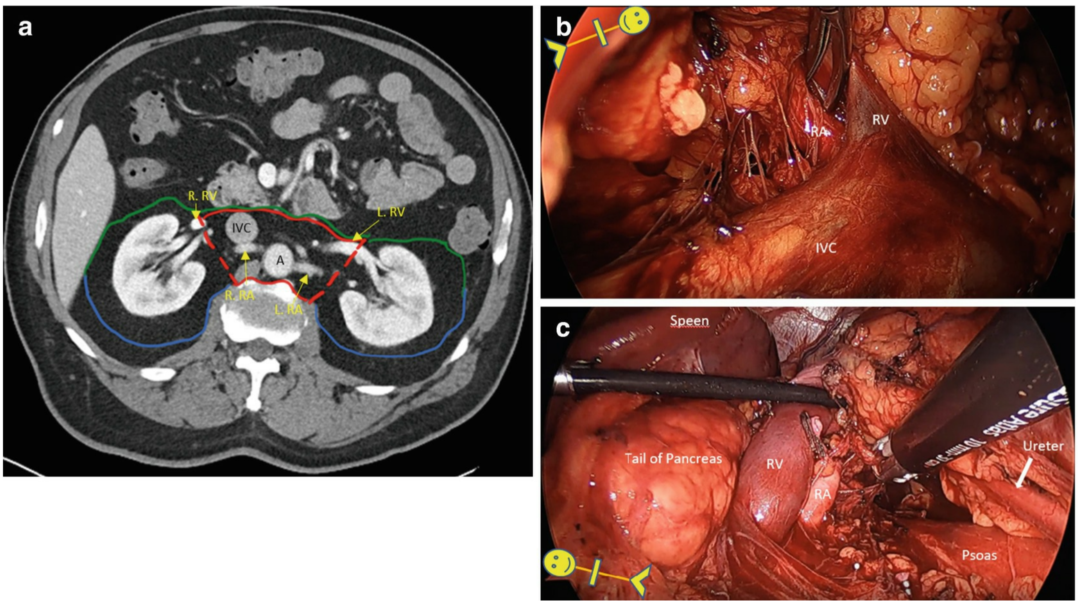

Fig. 1.7 Renal hilum. (**a**) The major renal vessels (RA and RV) pierce the perirenal fascia medially, exiting the central vascular compartment (encircled in red) to enter the hilum of the perirenal space (green and blue). The RA is generally situated posterior to the RV, with the right RA

assuming a retrocaval location. (**b**, **c**) The renal vessels can be visualized within the hilum of the right (**b**) and left (**c**) kidney. *A* aorta, *IVC* inferior vena cava, *RA* renal artery, *RV* renal vein

The ureter is the most posterior structure within the renal hilum, resting behind the renal vessels. It descends within the perirenal space on the anterior surface of the psoas muscle and associated fascia (Fig. 1.8). It courses lateral to the gonadal vein—an important anatomic consideration during urologic procedures in the retroperitoneum. When performing laparoscopic nephrectomy or nephroureterectomy, the gonadal vein should be kept medial (particularly for right-sided procedures) and the ureter displaced anterolateral off the psoas muscle to facilitate dissection towards to renal hilum; this maneuver helps separate the perirenal space (via Zuckerkandl's fascia) off the psoas muscle and is critical in preventing violation of the perirenal fat (Fig. 1.8). Similarly, during retroperitoneal lymph node dissection, the ureter is identified and swept laterally and the gonadal vein kept medially so as to create a space between the perirenal space and central vascular compartment (Fig. 1.9) as well as facilitate ligation of the gonadal vein.

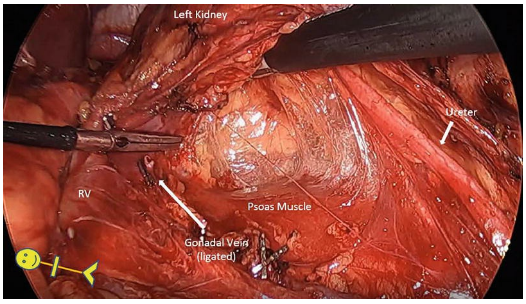

Fig. 1.8 The ureter is situated within the posterior-medial aspect of the perirenal compartment. As the perirenal compartment is lifted anteriorly off the psoas muscle, the ureter can be seen on the posterior-medial aspect of the plane that is created. *RV* renal vein

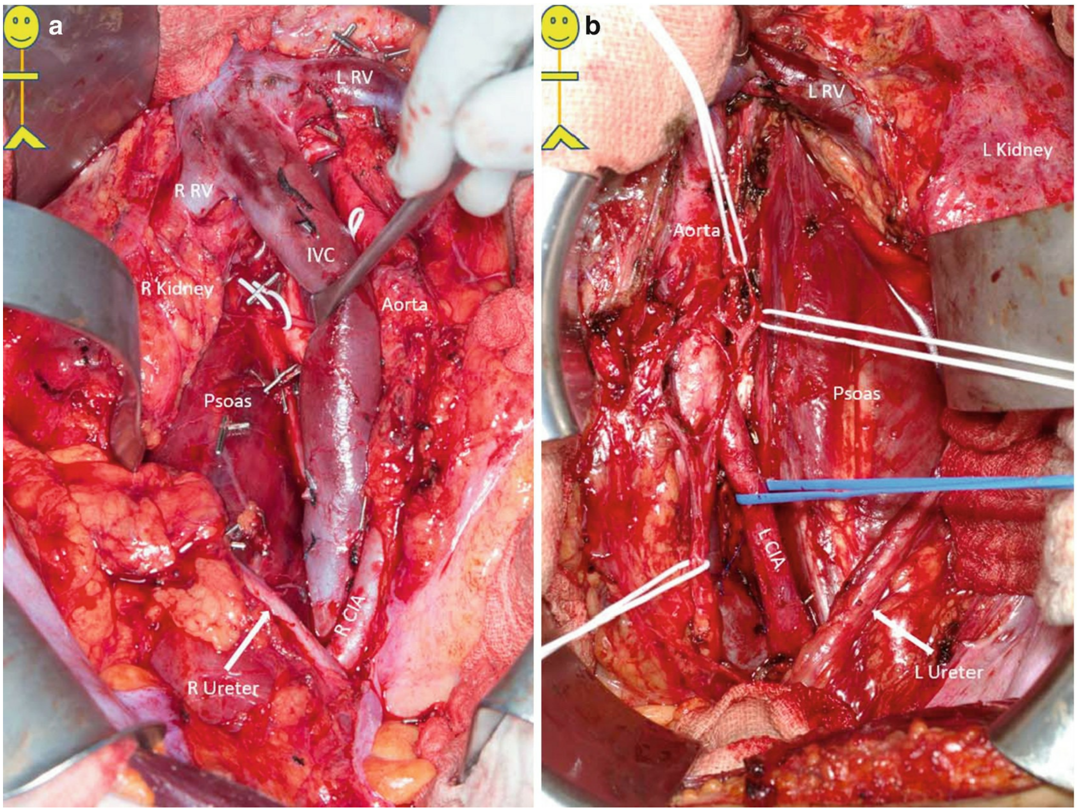

Fig. 1.9 Separation of the perirenal space and the central vascular compartment is facilitated by identification and lateralization of the ureter so as to separate it off from the lateral border of the IVC on the right (**a**) and the from the lateral border of the Aorta on the left (**b**). White vessel loops are used to isolate postganglionic sympathetic fibers. *CIA* common iliac artery, *IVC* inferior vena cava, *RV* renal vein

The ureter in its descent will subsequently course medially and travel underneath the gonadal vein and artery—an anatomic relationship that is often referred to by the aphorism "water under the bridge." It will eventually cross over the common iliac artery just proximal to its bifurcation and dive medially to enter the bladder under the shade of the superior vesical artery.

Anterior Pararenal Space

The anterior pararenal space is situated directly in front of the perirenal spaces laterally and the central vascular compartment medially. It is bounded anteriorly by the parietal peritoneum and posteriorly by the Toldt's fascia, which directly overlies and is opposed to the anterior leaf of the perirenal fascia (Gerota's fascia) (Fig. 1.2e). The anterior pararenal space contains the ascending colon, its mesocolon, and the duodenum on the right and the descending colon along with its mesocolon on the left. The pancreas also resides here with the head oriented towards the right, the tail towards the left, and the pancreatic body in the midline anterior to the central vascular compartment.

Transperitoneal access to the kidney and ureter (perirenal space) as well as the major vessels (central vascular compartment) requires sufficient reflection of structures not only within the peritoneal cavity (intraperitoneal location), but also within the anterior pararenal space. In this regard, it is helpful to understand the relationship of the anterior pararenal space to the intraperitoneal contents.

As aforementioned, the anterior pararenal space is limited anteriorly by the posterior wall of the peritoneal cavity, which is formed by a sheet of mesothelial tissue referred to as the parietal peritoneum (Figs. 1.2 and 1.10) [2]. The perpendicular projection of this mesothelial layer into the peritoneal space is referred to as the visceral peritoneum as it lines the mesentery of the small intestine, which is in an intraperitoneal location. At the level of this small bowel peritoneal reflection, the small bowel mesentery has a broad base that obliquely runs from the duodeno-jejunal flexure (left upper quadrant) towards the cecum (right lower quadrant), essentially mounting the small bowel to the posterior abdominal wall via its mesentery (Fig. 1.10). Invested within the thin fibroadipose layer of the small bowel mesentery are blood vessels derived from the superior mesenteric artery and vein accompanied by lymphatics. In fact, although the small bowel mesentery is attached to the posterior abdominal wall by a broad base, the root of this mesentery is situated primarily around the takeoff of the superior mesenteric artery such that if the small bowel mesentery were detached from its broad-based attachment, it would remain suspended by the SMA, which would essentially serve as a point of pivot (Fig. 1.10).

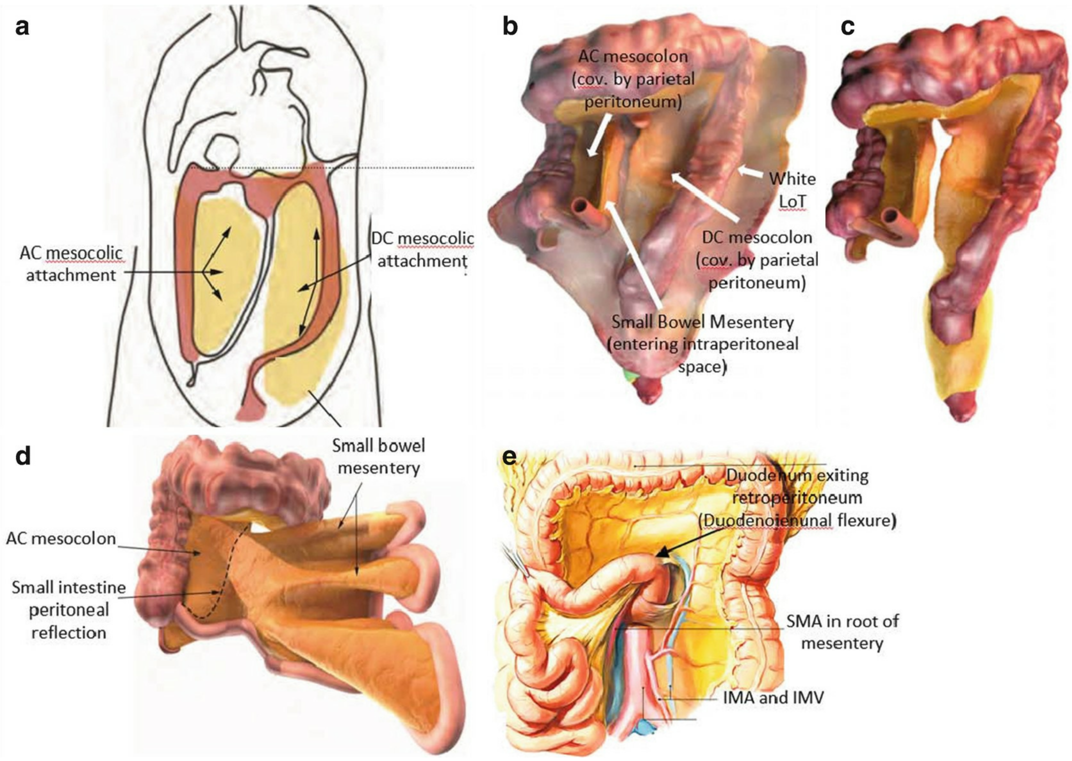

Fig. 1.10 AC mesocolon, DC mesocolon, and small bowel mesentery. (**a**) The AC mesocolon and DC mesocolon lie flat within the anterior pararenal space parallel to the posterior abdominal wall. (**b**) The posterior wall of the peritoneal cavity is formed by a sheet of mesothelial tissue referred to as the parietal peritoneum. This layer drapes over the AC, DC and their respective mesocolons, which are situated within the anterior pararenal space of the retroperitoneum. The lateral edge (antimesenteric border) of the AC and DC where the peritoneal layer drapes over the AC and DC is referred to as the white LoT. (**c**) The AC, DC and their respective mesocolons shown here without the overlying parietal peritoneal covering. (**d**) The small bowel mesentery is covered by the peritoneal reflection and projects into the peritoneal cavity perpendicular to the posterior abdominal wall. (**e**) The root of the small bowel mesentery is formed by the SMA. *AC* ascending colon, *DC* descending colon, *IMA* inferior mesenteric artery, *IMV* inferior mesenteric vein, *LoT* line of toldt, *SMA* superior mesenteric artery [3, 7]

The fatty fibrovascular sheet comprising the small bowel mesentery, which is oriented perpendicular to the posterior abdominal wall and enveloped by visceral peritoneum, is continuous with a similar broad-based adipose-rich fibrovascular sheet that lays horizontally within the anterior pararenal compartment of the retroperitoneum. This structure is referred to as the ascending mesocolon given its insertion into the mesenteric border of the ascending colon (Fig. 1.10), and is comprised of a vast arcade of blood vessels also derived from the SMA, specifically the right colic arterial branch (Fig. 1.11).

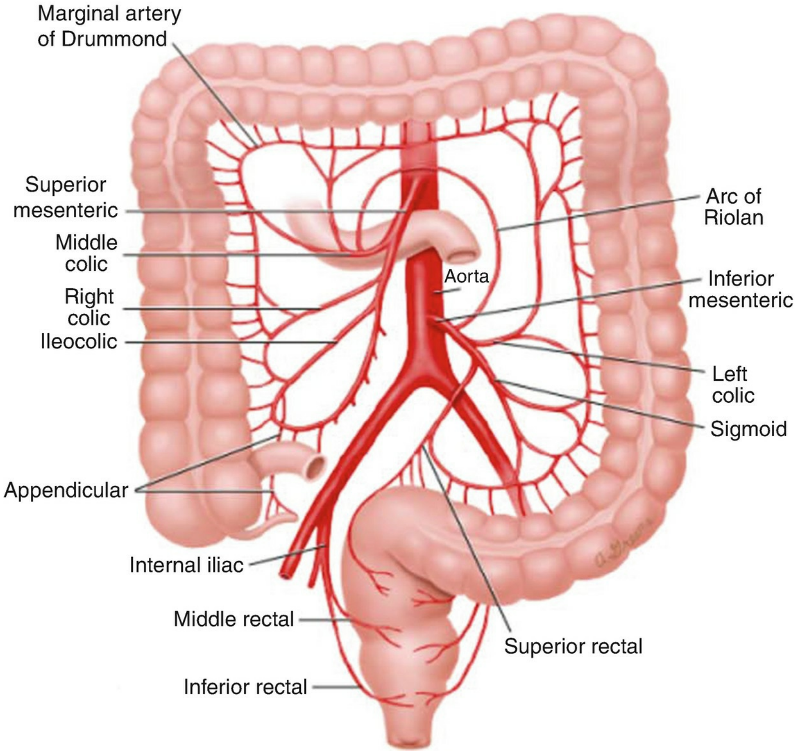

Fig. 1.11 Shown here are the arterial branches of the SMA and IMA. The primary blood supply within the AC mesocolon is derived from the right colic artery whereas the blood supply within the DC mesocolon is primarily from the left colic artery. The Marginal Artery of Drummond and Arc of Riolan permits extensive communication between the SMA, IMA, and hemorrhoidal/rectal arteries, thus allowing for collateral blood supply to the left colon and rectum. *AC* ascending colon, *DC* descending colon, *IMA* inferior mesenteric artery, *SMA* superior mesenteric artery [8]

Embryologically, however, the ascending colon is initially in an intraperitoneal location and attached to the true parietal peritoneal layer of the posterior abdominal wall by its broad-based mesentery that projects into the peritoneal space; as such, the mesentery of the ascending colon is initially lined by a visceral peritoneal layer of mesothelium [2]. It is in later stages of development that the ascending colon, along with its mesentery, assumes a more horizontal position flush up against the original parietal peritoneal layer (which originally had been directly overlying the Gerota's fascia of the perirenal compartment). In doing so, the visceral peritoneal layer lining the mesentery of the ascending colon fuses with the parietal peritoneum of the original posterior abdominal wall, eliminating the potential space in between. This fusion of these visceral and parietal mesothelial layers gives rise to the Toldt's fascia, which now rests on top of the Gerota's fascia and lines the posterior surface of the ascending mesocolon (Fig. 1.12) [2]. Moreover, it is based on this positional shift that the ascending colon and its mesocolon transition from the intraperitoneal to retroperitoneal compartment and become situated immediately anterior to the right perirenal space.

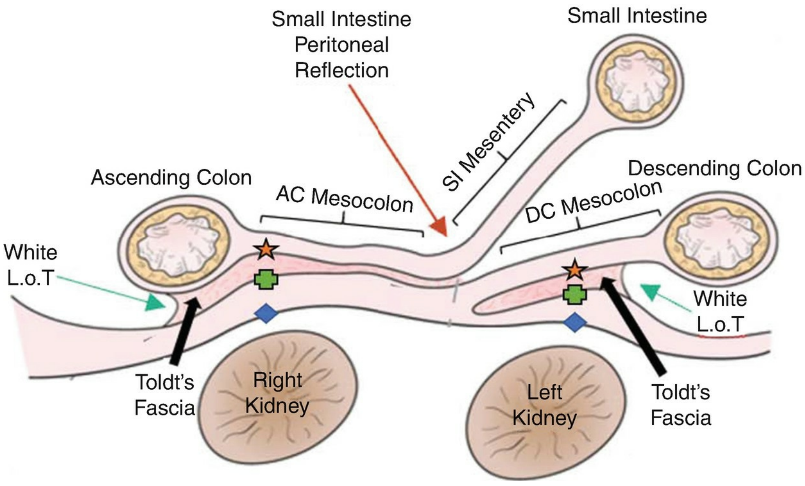

Fig. 1.12 The Toldt's fascia is formed by fusion of the visceral peritoneum layer, which had previously lined the under-surface of the AC mesocolon and DC mesocolon (orange star), and the parietal peritoneum layer (green cross), which had previously formed the posterior wall of the peritoneal cavity as it draped over Gerota's fascia (blue diamond). *AC* ascending colon, *DC* descending colon, *IMA* inferior mesenteric artery, *LoT* line of toldt, *SI* small intestine, *SMA* superior mesenteric artery [9]

The descending colon develops in a manner similar to the ascending colon. Although initially suspended within the peritoneal compartment by a broad fibrovascular mesenteric sheet, it subsequently assumes a more parallel orientation and opposes the posterior abdominal wall so as to overlie the left perirenal space. In doing so, the visceral peritoneal tissue originally lining the back surface of the descending colon mesentery fuses with the parietal peritoneal layer of the posterior abdominal wall, forming Toldt's fascia (Fig. 1.12) [2]. Moreover, the descending colon effectively assumes a retroperitoneal position whereby the mesentery of the descending colon is referred to as the mesocolon and the visceral peritoneal layer that had been lining it forms the new parietal peritoneal surface of the posterior abdominal wall.

Transperitoneal access to the right kidney and hilar vessels is gained primarily through medial reflection of both the ascending colon and mesocolon. This involves first incising the white line of Toldt, which occurs where peritoneal mesothelium reflects over the lateral contour (antimesenteric border) of the ascending colon. The surgeon is now able to access the delicate fibroconnective tissue of Toldt's fascia such that dissection here will allow the right colon and it's mesocolon to detach from the underlying Gerota's fascia overlying the right perirenal space (Fig. 1.13). Of note, the second portion of the duodenum, which also lies within the anterior pararenal space, will subsequently be encountered as the ascending colon mesocolon is lifted off the right perirenal space. Division of duodenal connective tissue attachments to the Gerota's fascia (preferably with non-thermal dissection) enables medial reflection (Kocher maneuver) [4] so as to expose the right renal vein and inferior vena cava (Fig. 1.14).

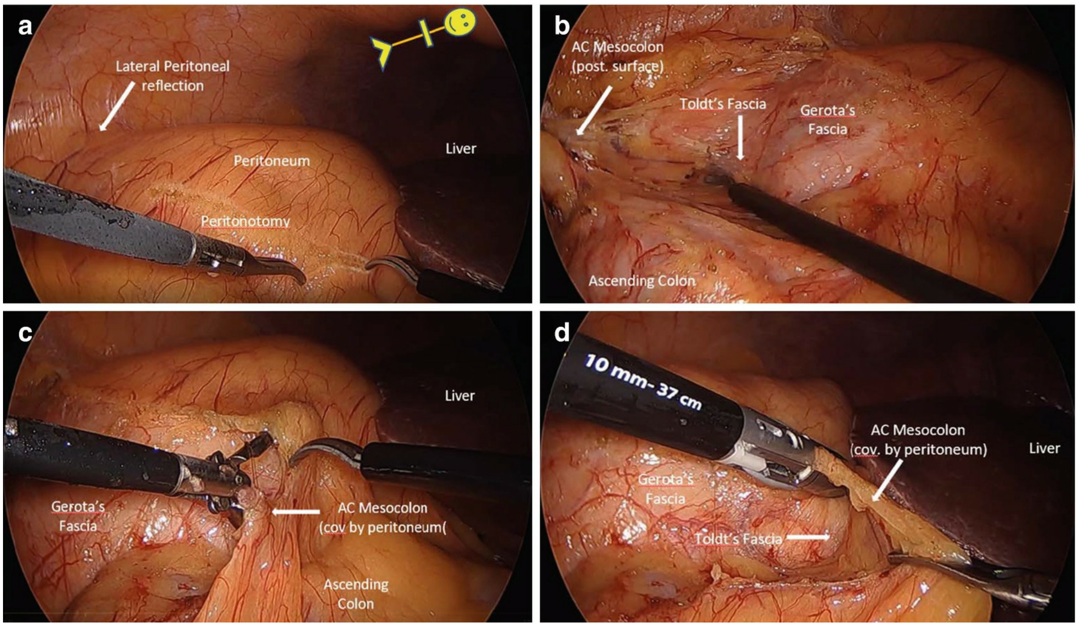

Fig. 1.13 Transperitoneal access to the right perirenal space. (**a**) An incision is made in the peritoneum at the proximity of the white line of Toldt (which occurs at the lateral/antimesenteric border of the AC). (**b**–**d**) The AC along with its mesocolon are medially reflected to permit continued dissection and division of Toldt's fascia. This permits further medial reflection of the AC mesocolon and exposes the underlying Gerota's fascia overlying the right perirenal space. *AC* ascending colon

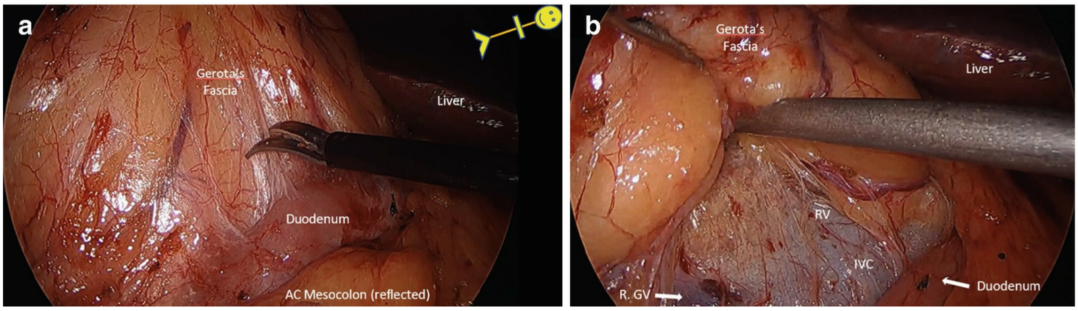

Fig. 1.14 Kocherization of the duodenum. (**a**) Connective tissue attachments of the duodenum to the Gerota's fascia are divided sharple with athermal dissection. (**b**) Medial reflection of the duodenum (Kocherization) exposes the underlying IVC and right RV. The right GV is also sees as it drains directly into the IVC. *AC* ascending colon, *GV* gonadal vein, *IVC* inferior vena cava, *RV* renal vein

Similar to the right perirenal space, transperitoneal access to the left perirenal space involves medial reflection of the descending colon and its mesocolon along with the tail of the pancreas (more superiorly) (Fig. 1.15). This has historically been referred to as the Mattox maneuver. In addition, the splenorenal ligament is often divided to allow medial reflection of the spleen and improve exposure of the upper pole of the kidney (Fig. 1.4).

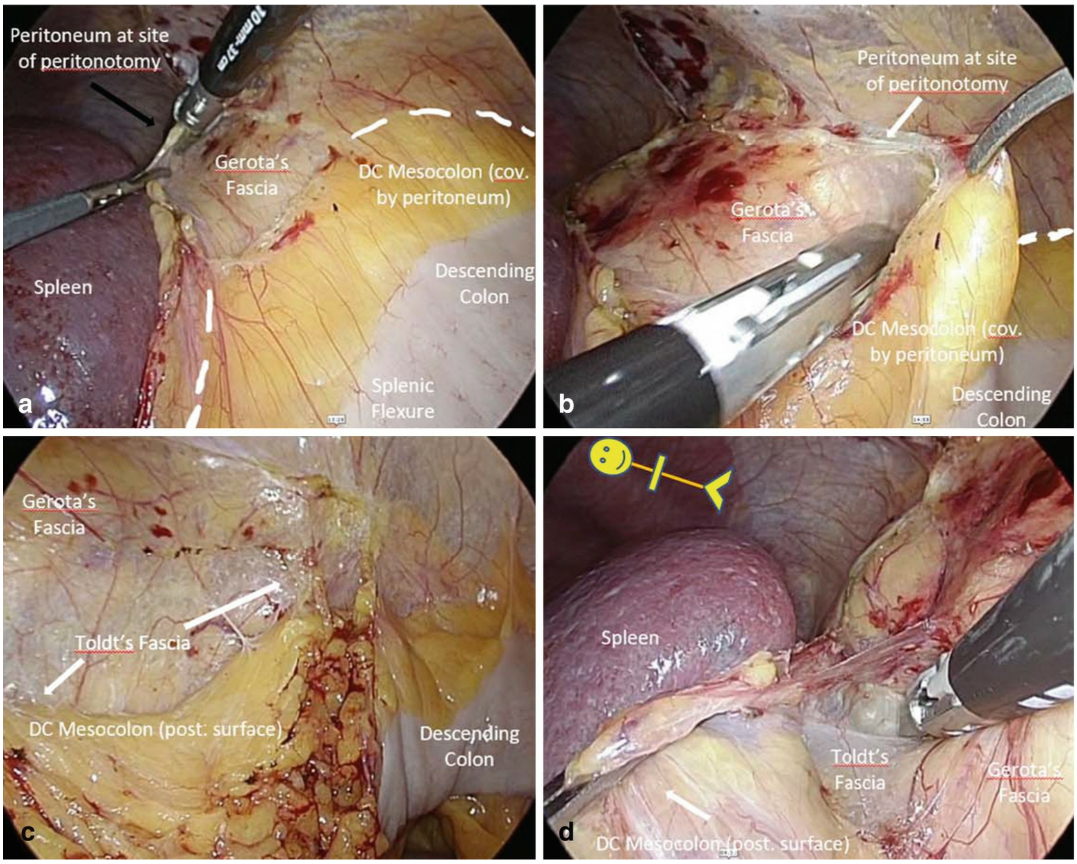

Fig. 1.15 Transperitoneal access to the left perirenal space. (**a**) An incision is made in the peritoneum at the proximity of the white LoT (which occurs at the lateral/antimesenteric border of the descending colon). (**b**–**d**) The DC along with its mesocolon are medially reflected to permit continued dissection and division of Toldt's fascia. This permits further medial reflection of the DC mesocolon and exposes the underlying Gerota's fascia overlying the left perirenal space. *DC* descending colon, *LoT* line of toldt

The Cattel-Braasch maneuver [5] (right medial visceral rotation) is commonly employed during open surgery to gain access to the central vascular compartment. The parietal peritoneum is incised lateral to the ascending colon, around the cecum, and then superiorly along the parietal peritoneum of the posterior abdominal wall at where the peritoneum reflect to line the small bowel mesentery towards the ligament of Treitz/root of the small bowel mesentery, allowing for medial and cephalad displacement of the ascending colon and its mesocolon, the second through fourth portions of the duodenum, and the jejunum and ileum (Fig. 1.16). Landmarks used during this maneuver include the left renal vein, which can be adequately should be exposed as the transverse segments of the duodenum are lifted anteriorly, and/or the inferior mesenteric vein.

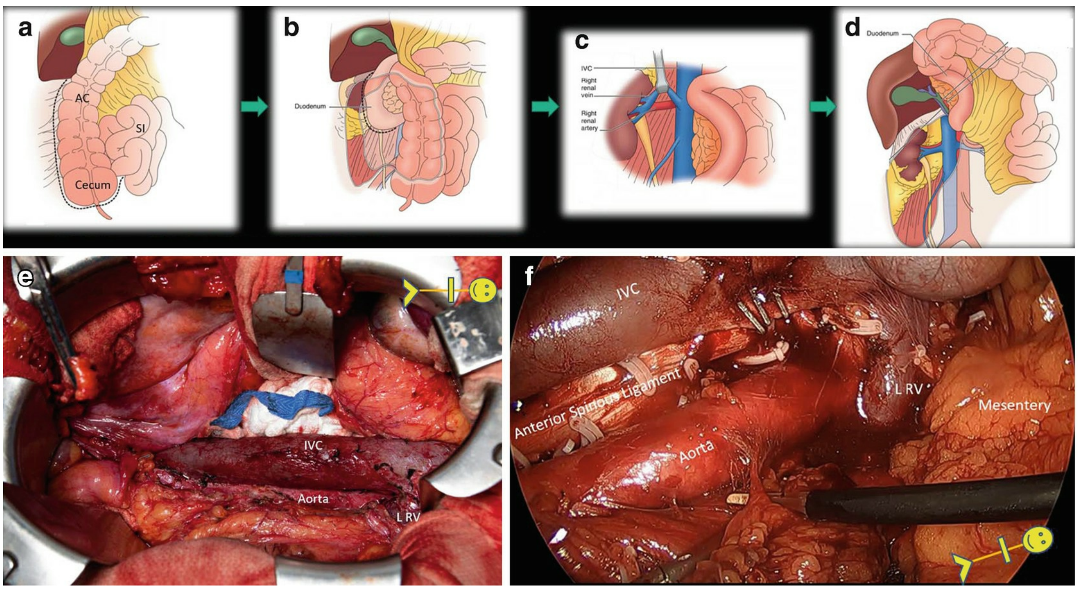

Fig. 1.16 Cattel-Braasch maneuver. (**a**) The parietal peritoneum is incised lateral to the AC (at the white LoT) and around the cecum. (**b**) The AC and its mesocolon are then reflected medially exposing the duodenum. (**c**) The connective tissue attachments of the duodenum to the underlying Gerota's fascia and central vascular compartment are divided, permitting medial reflection of the duodenum—a maneuver referred to as Kocherization. (**d**) The parietal peritoneum of the posterior abdominal wall at the peritoneal reflection of the small bowel mesentery is then incised from the right lower quadrant to the left upper quadrant towards the root of the small bowel mesentery. This incision is continued until visualization of the L RV. This maneuver allows for medial and cephalad displacement of the AC and its mesocolon, the 2nd through 4th portions of the duodenum, and the jejunum and ileum. (**e**) Exposure of the central vascular compartment after Cattel Braasch maneuver during open surgery. Note visualization of the L RV. (**f**) Exposure of the central vascular compartment after Cattel Braasch maneuver during laparoscopic surgery. Note visualization of the L RV. *AC* ascending colon, *IVC* inferior vena cava, *LoT* line of toldt, *SI* small Intestine, *RV* renal vein [5]

Posterior Pararenal Space

The posterior pararenal space consists entirely of adipose tissue (Fig. 1.2f). It is situated immediately behind the posterior perirenal fascia and its anterior fascial extension, the lateral conal fascia. The posterior pararenal space is bounded posteriorly by the transversalis fascia. Given that the lateral conal fascia fuses with the parietal peritoneum, the posterior pararenal space is contiguous with the preperitoneal fatty layer (Fig. 1.1).

Central Vascular Compartment

The central vascular compartment of the retroperitoneum extends from the T12 vertebrae, where the aorta passes through the aortic hiatus of the diaphragm and emerges from the thoracic space, down to the level of the L4 vertebrae, where the aorta bifurcates into the common iliac arteries. Within this space reside the abdominal aorta and its efferent branches, the vena cava and its afferent tributaries, an elaborate network of lymphatics that invest the aorta and vena cava, and the abdominal sympathetic chain (Fig. 1.2d).

The central vascular compartment is bounded posteriorly by the anterior spinous ligament (also referred to as the anterior longitudinal ligament), which overlies the vertebral spine, laterally by the perirenal space and its associated fascia, and anteriorly by both the midline connective tissue extension of Gerota's fascia and Toldt's fascia, which serves as the posterior connective tissue border of anterior pararenal compartment (Figs. 1.2 and 1.17). Of note, the crus of the diaphragm are also visualized posteriorly within the central vascular compartment as they insert onto the anterior-lateral aspects of the L1 and L2 vertebral body; the abdominal sympathetic chains can be seen emerging from underneath the crus bilaterally as they descend alongside the lateral aspect of the vertebral bodies (Fig. 1.17); thus, the crus serve as a valuable landmark when performing a nerve-sparing retroperitoneal lymph node dissection.

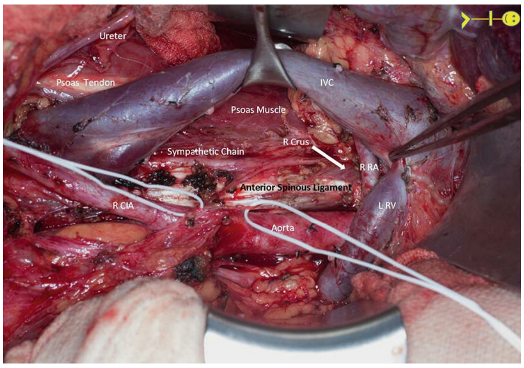

Fig. 1.17 Central vascular compartment. The anterior spinous ligament forms the posterior border of the central vascular compartment. The sympathetic chain can be seen emerging from underneath the cover the crus of the diaphragm and traveling caudally along the lateral edge of the anterior spinous ligament and medial border of the psoas muscle. Emanating from the sympathetic chain are the post-ganglionic splanchnic serves (encircled by white vessel loops), which on the right, travel beneath the IVC to arrive onto the anterior surface of the Aorta. *CIA* common iliac artery, *IVC* inferior vena cava, *RA* renal artery, *RV* renal vein

Aorta

The major branches encountered off the anterolateral aspect of the abdominal aorta when proceeding cephalad to caudad are the celiac trunk, the superior mesenteric artery, the left and right renal arteries, the left and right gonadal arteries, and the inferior mesenteric artery. The middle sacral artery is also encountered at the bifurcation of the aorta (Fig. 1.18).

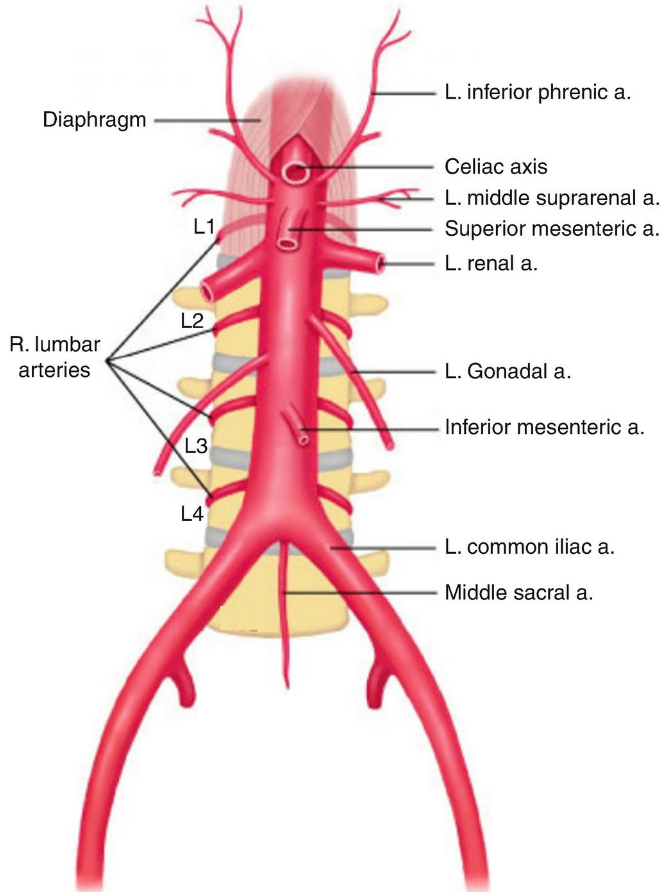

Fig. 1.18 Major vascular branches of the aorta

Superior Mesenteric Artery

The working space of urologic surgeons is most often limited superiorly by the renal hilar vessels; as such, the superior mesenteric artery (and the vessels above) is generally not exposed during open and laparoscopic urologic procedures. Nevertheless, the surgeon should be mindful of the superior mesenteric artery location given its close proximity to the renal hilar vessels. Indeed, the left renal vein crosses the midline anterior to the aorta, but posterior and inferior to the take-off of the superior mesenteric artery (Figs. 1.17 and 1.19). Similarly, the third and fourth portions of the duodenum, which reside within the anterior pararenal space, course posterior and inferior to the superior mesentery artery, and in doing so, lie directly anterior to both right and left renal veins (Fig. 1.19). In this regard, Kocherization [4] of the duodenum provides access to the right renal vein as well as the distal aspect of left renal vein as it enters the inferior vena cava (Fig. 1.20) while medial and cephalad displacement of the anterior pararenal compartment, specifically during the Cattel-Braasch maneuver, lifts the duodenum along with the SMA off the left renal vein, exposing its more proximal extent (Fig. 1.17) [5].

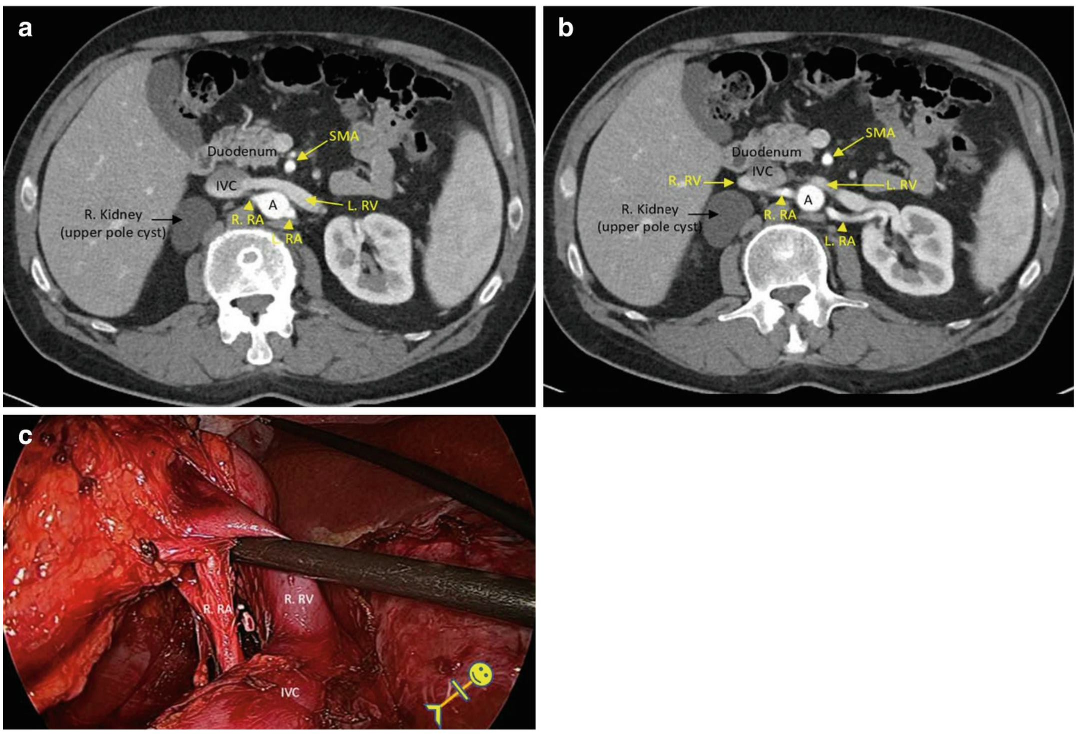

Fig. 1.19 Central vascular compartment. (**a**) The L RV courses anterior to the Aorta, and inferior and posterior to the SMA. The duodenum is immediately anterior to the IVC and L RV within the anterior pararenal space. (**b**) The R RA and L RA enter the hilum of the kidney posterior to the corresponding R LV and L RV. In doing so, the R RA travels posterior to the IVC. (**c**) Seen here within the right renal hilum is the R RV, which is the anterior most structure, and the R RA, emerging from behind the IVC. *A* aorta, *IVC* inferior vena cava, *RA* renal artery, *RV* renal vein, *SMA* superior mesenteric artery

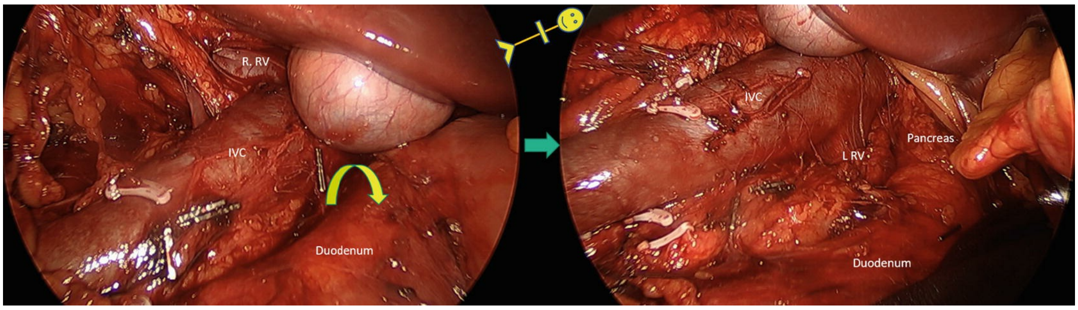

Fig. 1.20 More extensive medial reflection (e.g. Kocherization) of the duodenum off the medial edge of the IVC permits access to the interaortocaval space and the L RV. *IVC* inferior vena cava, *RV* renal vein

Intraoperative injury to the superior mesenteric artery can be especially catastrophic as such circumstances would render the entirety of the small bowel and proximal colon vulnerable to ischemia. One possible scenario arises during the Cattel-Braasch maneuver, whereby incision of the parietal peritoneum lateral to the ascending colon, around the cecum, and diagonally along the posterior peritoneal peritoneum towards the ligament of Treitz (duodenojejunal flexure) detaches the ascending colon and its mesocolon from the underlying Gerota's fascia and the broad-based small bowel mesentery from the posterior abdominal wall [5]. As aforementioned, this enables medial visceral rotation and exposes both the right perirenal space and central vascular compartment up to the level of the left renal vein (Figs. 1.16 and 1.17). Given that the superior mesenteric artery is the primary blood supply to the small intestine and right colon, this maneuver leaves the mobilized intestinal segments on a stalk formed by the SMA, which is referred to here as the root of the mesentery. Accordingly, the pulse of the SMA should be periodically assessed to ensure the vessel is not twisted or subject to excessive traction caused by retraction instruments being used to maintain exposure of these retroperitoneal spaces. An alternative scenario arises when performing a left nephrectomy, as care should be taken not to confuse the superior mesenteric artery for the left renal artery when obtaining hilar control.

Renal Artery

Branching off the lateral aspect of the aorta below the superior mesenteric artery are the left and right renal arteries (Fig. 1.19). Given that the IVC is situated slightly anterior to the Aorta, the renal arteries course posterior to their corresponding renal veins as they enter the renal hilum (Figs. 1.7 and 1.19). Moreover, the right renal artery arrives at the renal hilum by crossing the interaortocaval space behind the IVC (Figs. 1.17, 1.19, and 1.21). When performing nephrectomy for large renal masses that may encroach medially and obscure access to the renal hilum, the renal artery can be controlled in the interaortocaval space as it branches off of the aorta; this approach also helps ensure that control of the main renal artery is obtained as opposed to arterial branches, which commonly form more distally within the renal hilar location.

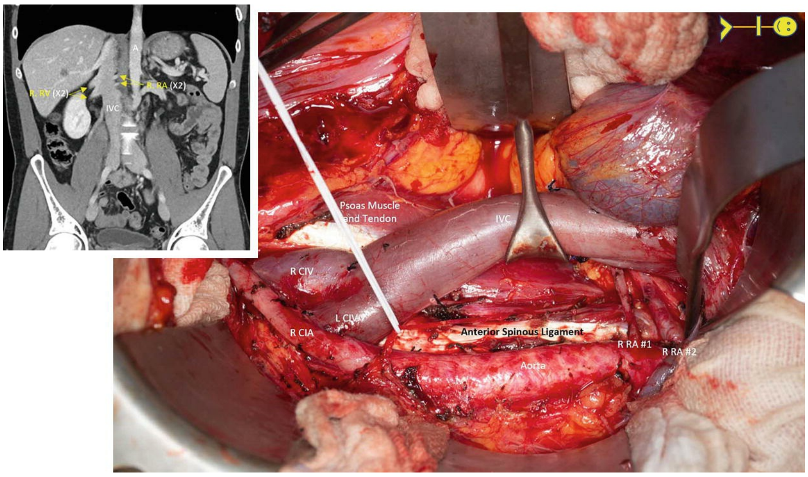

Fig. 1.21 Seen here within the interaortocaval space are two renal arteries (R RA #1 and RRA#2). R RA #1, given that it enters the renal hilum with the main R RA (RRA #2), is referred to as a supernumerary artery. Take note of the course of the R RA, traveling posterior to the IVC en route to the right renal hilum. *CIA* common iliac artery, *CIV* common iliac vein, *IVC* inferior vena cava, *RA* renal artery, *RV* renal vein

The urologic surgeon should be aware of the possibility for both accessory and supernumerary renal arteries. Accessory renal arteries, often referred to as polar vessels, most often emerge off the left side of the aorta and direct supply a polar region of the kidney where supernumerary arteries emerge off the aorta and enter the hilum alongside the main renal artery (Fig. 1.21). Accessory arteries most commonly supply the lower pole of the kidney whereas supernumerary vessels are usually found in a location superior to the renal vein. Radiographic assessment of the aorta and its branches in the preoperative setting is extremely valuable in this regard and aid in surgical planning (Fig. 1.21).

Gonadal Artery

The gonadal artery emerges off the anterolateral aspect of the aorta and joins its corresponding gonadal vein as they descend in the retroperitoneum within the perirenal space (Fig. 1.22a). It is important to be cognizant of the right gonadal artery as it crosses over the anterior surface of inferior vena cava, as inadvertent division during the "split-and-roll" maneuver during retroperitoneal lymph node dissections can result in bleeding. This is especially the case given that the gonadal artery is much narrower in caliber than its corresponding gonadal vein.

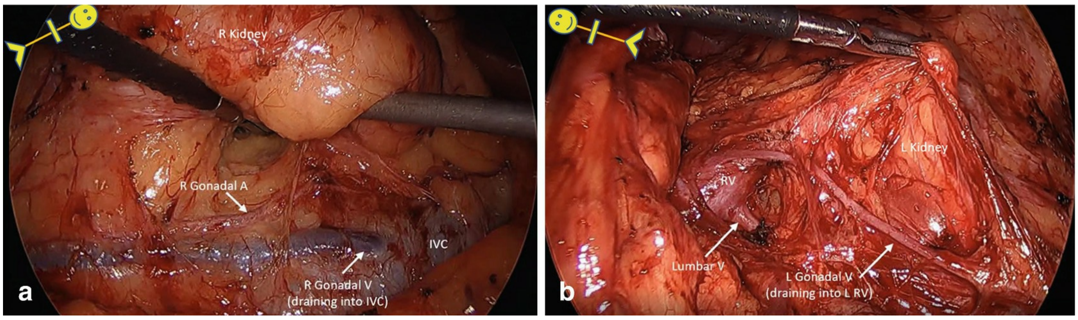

Fig. 1.22 Gonadal vessels. (**a**) The R Gonadal V drains directly into the IVC. Seen adjacent to it is the R Gonadal A, which is much narrower in caliber and courses over the IVC to the join the R Gonadal V. (**b**) The L Gonadal V drains directly into the L RV. *A* artery, *IVC* inferior vena cava, *RV* renal vein, *V* vein

Inferior Mesenteric Artery

The final major branch of the abdominal aorta is the inferior mesenteric artery (IMA) (Fig. 1.23), which supplies the descending colon, sigmoid colon, and rectum. The IMA participates in two watershed regions of the large intestine, specifically at the level of the splenic flexure and the lower rectum. At the splenic flexure, the left colic artery of the IMA communicates with the middle colic artery of the SMA via two vascular arcades within the colonic mesentery—the marginal artery of Drummond, which runs closest to the mesenteric border of the colon, and the meandering artery of the mesentery, which is closer to the root of the vessel (Fig. 1.11). Similarly, anastomoses between the superior rectal artery of the IMA with the middle and inferior rectal arteries coming off the internal iliac artery form the watershed region of the rectum.

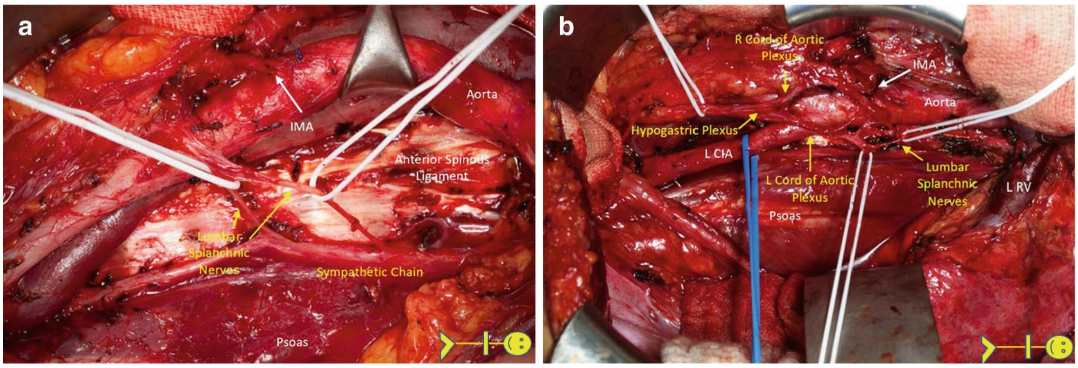

Fig. 1.23 Sympathetic nervous system structures within the central vascular compartment. (**a**) With the Aorta retracted medially, the left sympathetic trunk is seen traveling on the lateral edge of the anterior spinous ligament and medial border of the psoas muscle. Branching off the sympathetic trunk are the post-ganglionic lumbar splanchnic nerves (encircled by white vessel loops); they can be seen entering the cord of the aortic plexus below the level of the IMA. (**b**) The confluence of the L and R sympathetic cords of the Aortic plexus is seen below the level of the IMA, giving rise to the hypogastric plexus at the bifurcation of the Aorta. *CIA* common iliac artery, *IMA* inferior mesenteric artery, *RV* renal vein

The overlapping nature of the blood supply to the colon is an important anatomic consideration, particularly during a retroperitoneal lymph node dissection as ligation of the IMA may be necessary to ensure completeness of resection; although an effort should be made to preserve the IMA, ischemic damage to the colon is unlikely to occur in the event the IMA is compromised due to this robust vascular network that exists between its branches and those of the SMA and internal iliac artery.

Moreover, the IMA is a critical landmark during retroperitoneal lymph node dissection given that below the IMA, the right and left cords of the aortic plexus begin to convalesce so as to eventually give rise to the hypogastric plexus at the level of the aortic bifurcation (Fig. 1.23). Indeed, modified templates for retroperitoneal lymph node dissection for metastatic testicular cancer minimize dissection below the IMA to minimize disruption of the hypogastric plexus and aid in the preservation of antegrade ejaculation [6].

Lumbar Arteries

Situated posterolaterally along the abdominal aorta are the lumbar arteries. In general, there are four pairs of lumbar arteries in total, of which only three are encountered in the infrarenal location (Fig. 1.24). The lumbar arteries initially assume a lateral course upon branching off the aorta and then subsequently dive posteriorly to travel lateral to the anterior spinous ligament and alongside the lateral edges of the lumbar vertebral bodies. Given the aorta is lateralized slightly to the left of the vertebral spine, lumbar arteries emerging from the right edge of the aorta traverse the interaortocaval space underneath the inferior vena cava.

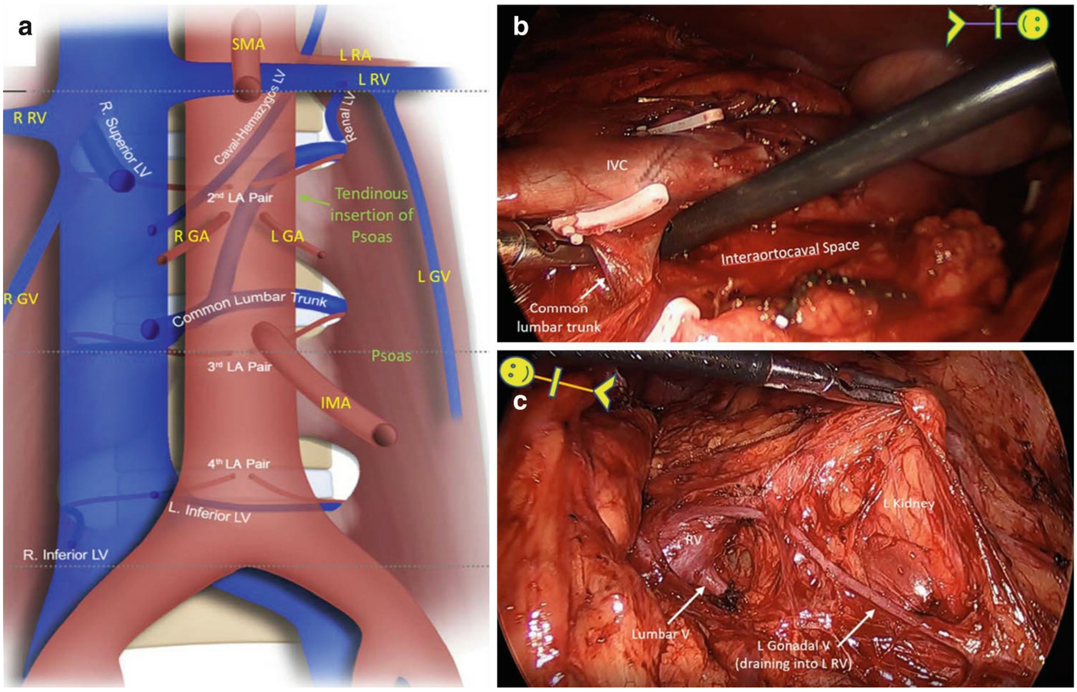

Fig. 1.24 Architecture of the lumbar vessels (arteries and veins). (**a**) Seen here is the relationship of the lumbar veins that drain into the IVC relative to the main venous branches of the IVC. Additionally, the anatomic distribution of the lumbar arteries is seen here relative to the major arterial branches of the Aorta. (**b**) Laparoscopic view of the common lumbar trunk within the interaortocaval space as it drains into the IVC. (**c**) Laparoscopic view of the renal lumbar vein draining into the posterior aspect of the L RV. *GA* gonadal artery, *GV* gonadal vein, *IMA* inferior mesenteric artery, *LA* lumbar artery, *LV* lumbar vein, *RA* renal artery, *RV* renal vein, *V* vein [6]

The two superior pairs of lumbar arteries dive behind the crus of the diaphragm as they course posteriorly whereas the two inferior pairs exit the central vascular compartment behind the sympathetic trunk and medial to the tendinous insertions of the psoas muscle along the lateral aspect of the L3-L5 vertebrae. Given that the infrarenal lumbar arteries (and corresponding veins) closely abut the medial edge of the psoas muscle belly upon exiting the retroperitoneum, medial traction placed directly onto the psoas muscle (i.e. with a sponge stick) can help tamponade bleeding that occurs during division of the lumbar vessels.

Inferior Vena Cava

Renal Vein and Gonadal Veins

The renal vein is the anterior most structure of the renal hilum, overlying the renal artery as it exits the perirenal space and enters the central vascular compartment (Fig. 1.7). The left renal vein, which is longer than the right, courses anterior to the aorta en route to the IVC and is situated below the takeoff of the SMA (Figs. 1.17 and 1.19). Anatomic variations of the left renal vein include a retroaortic left renal vein, which travels posterior to the aorta, and a circumaortic left renal vein, which is comprised of two veins traveling both anterior and posterior to the aorta.

Unique to the left renal vein is the drainage it receives from both the left gonadal vein and left adrenal vein, as well as in many cases the second right lumbar vein (Fig. 1.22b). This is unlike the case on the right, where the gonadal vein, renal vein, and adrenal vein independently drain into the inferior vena cava (Fig. 1.22a). The drainage pattern of the left renal vein is of clinical relevance when performing retroperitoneal surgery, especially left nephrectomy, as the left gonadal vein may be traced superiorly to aid in identification of the left renal vein. Another consideration related to the anatomy of the gonadal venous drainage involves the risk for avulsion of the right gonadal vein off the IVC when performing a right nephrectomy, particularly via a minimally-invasive approach. Given that the gonadal veins descend in the perirenal compartment parallel to the ureter, anterior traction placed on the ureter and surrounding perirenal fat to separate these structures from the lateral edge of the IVC and lift off the psoas fascia can cause traction on the right gonadal vein, resulting in avulsion; as such, this maneuver should be performed in a manner where the Gerota's fascia is entered lateral to the vein, leaving it in a medial position adjacent to the inferior vena cava.

Transperitoneal access to the right renal vein is gained primarily through medial mobilization and Kocherization [4] of the second portion of the duodenum (Fig. 1.14), whereas the left renal vein can be accessed a multitude of ways. The most conventional approach, employed when performing a left nephrectomy, involves medial reflection of the descending colon and its mesocolon along with the tail of the pancreas (Fig. 1.25). Alternatively, exposure can be obtained from the right through more extensive Kocherization [4], whereby the duodenum and pancreatic head are both medially and anteriorly reflected off the connective tissue overlying the central vascular compartment (Fig. 1.20), or the Cattel-Braasch maneuver (Fig. 1.16) [5]. In general, maneuvers to expose the renal veins offer good accessibility to the renal arteries; the exception is when performing nephrectomy for a large right renal mass, where medial encroachment by the tumor may necessitate control of the right renal artery in the interaortocaval space.

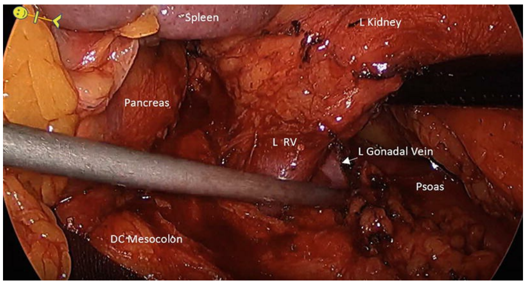

Fig. 1.25 Access to the left perirenal space and exposure of the left renal hilum involves medial reflection of the DC and its mesocolon as well as medial reflection of the pancreatic tail. *DC* descending colon

Lumbar Veins

The lumbar veins drain into the posterolateral inferior vena cava, but unlike the lumbar arteries, they do not necessarily occur in pairs and are variable in location and number. Along the infrarenal IVC, generally three lumbar veins are encountered on the right whereas two lumbar veins occur on the left (Fig. 1.24).

The right superior lumbar vein, which is large in caliber, is seen just below the confluence of the right renal vein and IVC and above the entry of the right gonadal vein. The right middle lumbar vein, which is variably present, is mid-way between the renal vein and IVC bifurcation, and may form a common trunk with the corresponding left lumbar vein. The right inferior lumbar vein is encountered just above the confluence of the right common iliac vein and IVC.

The primary lumbar vein on the left IVC occurs mid-way between the left renal vein and iliocaval junction, approximately at the level of the IMA, which can serve as a landmark. This vein, often referred to as the common lumbar trunk, forms from the convalescence of several tributaries (up to 3) that course behind the aorta and across the interaortocaval space; as such, proximal control of this vein may involve only a single suture tie while distal control may require multiple branches to be clipped in the interaortocaval location and then again the paraaortic location as they emerge lateral to the edge of the anterior spinous ligament from behind the left sympathetic trunk. The second left lumbar vein is situated more inferiorly at the iliocaval junction, just superior to where the right common iliac artery drapes over the left common iliac vein.

The lumbar veins emerge from behind the sympathetic trunk and tendinous insertions of the psoas muscle (or the right crus in the case of the right superior lumbar vein), lateral to the anterior spinous ligament. The left lumbar veins run posterior to the aorta as they cross the interaortocaval space to drain into the IVC.

Sympathetic Plexus

From a urologic perspective, the sympathetic nerve plexuses within the retroperitoneum are important for maintenance of antegrade ejaculation. Understanding the anatomy of this neural network is particularly relevant when performing nerve-sparing retroperitoneal lymph node dissection given the intimate association between these nerves and the major vessels within the central vascular compartment. The sympathetic system can be divided into four major structures for the ease of understanding what needs to be preserved when nerve-sparing is attempted: the abdominal sympathetic chain, the infrarenal lumbar splanchnic nerves, the right and left cords of the aortic plexus, and the hypogastric plexus (Fig. 1.23) [6].

The abdominal sympathetic chain emerges from under the crus of the diaphragm and descends the posterior central vascular space in the paravertebral location, along the lateral edge of the anterior spinous ligament and anteromedial to the tendinous insertions of the psoas muscles to the L3-L5 vertebrae. The IVC and Aorta overly the right and left sympathetic chains, respectively. Two main lumbar splanchnic nerves emerge from each sympathetic trunk from between the level of the L1-L4 vertebrae and join their respective cord of the aortic plexus, which run longitudinally along anterior surface of the aorta; in many cases, accessory splanchnic nerves can be seen branching off the sympathetic trunk and entering the aortic plexus below the IMA [6]. Both lumbar splanchnic nerves on the right course posterior to the IVC and travel across the interaortocaval space to join the right cord of the aortic plexus. Thus, a paracaval lymph node tissue can be dissected off the adventitia of the IVC with relative impunity given the nerves do not traverse this space.

The superior right lumbar splanchnic nerve comes off the sympathetic trunk at the level of the right renal vein above where the right superior lumbar vein drains and can be seen coursing obliquely across the interaortocaval space so as to enter the right cord of the aortic plexus below the right gonadal artery. The inferior right lumbar splanchnic nerve emerges from the sympathetic trunk just below the level of the right gonadal vein and can also be seen in the interaortocaval space superior to the left common lumbar trunk [6]; it enters the right cord of the aortic plexus at or below the level of the IMA. As such, during the interaortocaval lymph node dissection, the nerves should be prospectively identified and isolated to avoid inadvertent injury as the lumbar vessels are ligated and/or fibroadipose tissue is dissected off the adventitia of the medial edges of the IVC and aorta.

On the left, the superior lumbar splanchnic nerve emerges from below the level of the left renal vein and courses anteriorly and inferiorly through the paraaortic fibroadipose tissue to join the left cord of the aortic plexus at the origin of the left gonadal artery. The inferior lumbar splanchnic nerve branches off the sympathetic trunk more caudally, and often just superior to where the third left lumbar artery dives posteriorly behind the sympathetic trunk into the psoas muscle; it intersects the left cord of the aortic plexus at or below the level of the IMA [6].

Neural crosstalk between the right and left cords of the aortic plexus increases below the level of the IMA, but their true convalescence is appreciated at the level of the aortic bifurcation, where the hypogastric plexus is formed.

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2. Gross and Laparoscopic Anatomy of the Lower Tract and Pelvis

Bastian Amend[1] and Arnulf Stenzl[1]

(1) Department of Urology, Eberhard Karls University, Tuebingen, Germany

Bastian Amend
Email: bastian.amend@med.uni-tuebingen.de

Arnulf Stenzl (Corresponding author)
Email: urologie@med.uni-tuebingen.de

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Introduction

An overview of the gross and laparoscopic anatomy of the lower urinary tract should summarize both long-standing anatomic knowledge and current scientific findings. In few fields has the anatomic understanding grown as much as urology, especially concerning anatomy of the lower urinary tract. Whereas the gross anatomy is already well known, now research is increasingly contributing to our understanding of the microscopic level. This concerns especially the detailed anatomy and topography of the sphincter mechanism of the urinary bladder, the routing and function of the neural structures in the pelvis and, for example, the anatomic structure of the pelvic floor. The transmission of these new findings in combination with traditional anatomic knowledge into urological practice, including the growing field of laparoscopic surgery, is essential to maintain and improve the success of treatments for our patients. The following chapter gives a clear, detailed and informative summary of the anatomy of the lower urinary tract, especially considering of laparoscopic and endoscopic surgery.

The History of the Study of the Urological Anatomy

The historiography of urology goes back to 1000 BC in Egypt. The first description of a bladder catheter made of bronze dates to this time, and bladder stone surgery also seems to have been practiced. The prostate was first described by Herophilus of Chalcedon in 300 BC. Human cadaver sections enabled this first glimpse.

After the widespread rejection of anatomical studies up to the Middle Ages, detailed descriptions of human anatomy began to emerge again with the work of Leonardo da Vinci (1452–1519), Andreas Vesalius (1514–1564) from Brussels and their successor Eustachi (1500–1574). The anatomy of the urogenital tract was mainly revealed by Étienne de la Rivière of Paris with the description of the seminal vesicles, Marcellus Malpighi (1628–1694) with the exploration of renal functioning and Lorenzo Bellini (1643–1704) with the identification of the renal tubuli. The progress of microscopic examinations further advanced the basic anatomical knowledge. In 1684, Mery described the existence of the bulbourethral glands, which was later attributed to Cowper.

The founder of the study of the pathology of the urogenital tract was Giovanni Battista Morgagni (1682–1771) with his work “De sedibus et causis morborum.” Giovanni Battista Morgagni is considered the first to describe prostatic hyperplasia.

One of the milestones in urology—urological endoscopy—goes back to Phillip Bozzini of Frankfurt who invented the first endoscope using candlelight in 1806. This made possible the exploration of the internal anatomical details of a living individual [1].

Topographic Anatomy of the Anterior Abdominal Wall

The increasing significance of laparoscopic procedures, especially for intrapelvic and prostatic surgery, necessitates a detailed understanding of the topographic anatomy of the anterior abdominal wall. Figure 2.2 illustrates the different structures in addition to a laparoscopic view of the male pelvis (Fig. 2.1) at the beginning of robotic-assisted radical prostatectomy. Beside topographic knowledge of specific anatomic landmark physiologic movement of intraabdominal structures, e.g. pulsation of arteries or undulated contraction of the ureters, and manipulation with introduced catheters (bladder neck visualisation during robot-assisted prostatectomy by catheter pull) help to identify relevant structures to proceed with surgery.

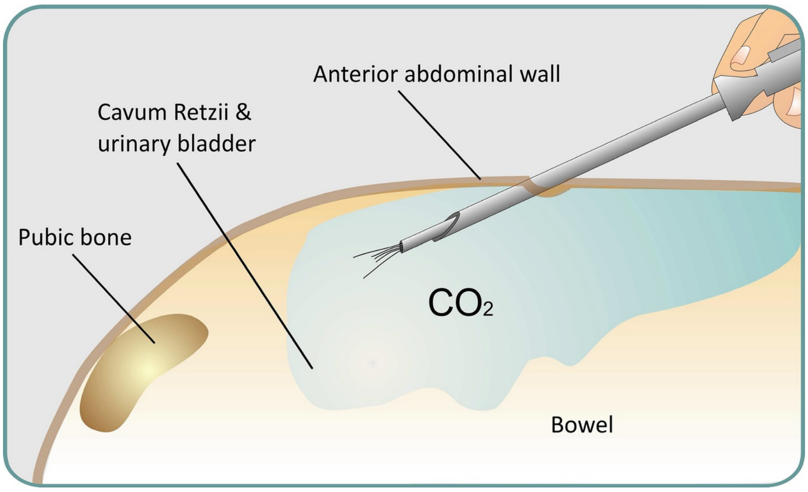

Fig. 2.1 The drawing illustrates the laparoscopic line of sight during pelvic or prostate surgery (illustrated by P.M. Weber, University Hospital of Tuebingen)

Five tissue folds subdivide the anterior abdominal wall. The former embryonic urachus forms the median umbilical ligament between the urinary bladder and the umbilicus. On both sides lateral to the median umbilical ligament, the remnants of the fetal umbilical arteries shape the medial umbilical ligaments/folds—the space in between is called the supravesical fossa. During cystectomy, the medial umbilical ligaments are the main structures to identify and control the superior vesical pedicle including the superior vesical artery. The inferior epigastric vessels underlie the lateral umbilical ligaments/folds. These structures have important significance regarding hernia classification. Medial to the lateral umbilical fold, the medial inguinal fossa represents the passage of direct inguinal hernias. The lateral inguinal fossa corresponds to the deep inguinal ring—the entry to the inguinal canal. An indirect inguinal hernia accompanies the components of the spermatic cord through the inguinal canal into the scrotum. In paediatric urology the Prentiss maneuver requires comprehensive knowledge of the inguinal canal and the course of inferior epigastric vessels to fascilitate adequate orchidopexy in boys with short spermatic cord.

The external iliac vessels and the iliopsoas muscle leave the pelvis below the inguinal ligament, which connects the anterior superior iliac spine to the pubic tubercle. The lacunar ligament is located directly medial to the external iliac vein connecting the inguinal ligament to the superior pubic ramus and represents the caudal extent during lymphadenectomy for prostate or bladder cancer. Lateral to the external iliac vessels the genitofemoral nerve dividing into two branches, the femoral nerve (laterally adjacent to the psoas major muscle) and the lateral femoral cutaneous nerve are at risk to be damaged during lymphadenectomy depanding on the extend of surgery (Fig. 2.2) [2, 3].

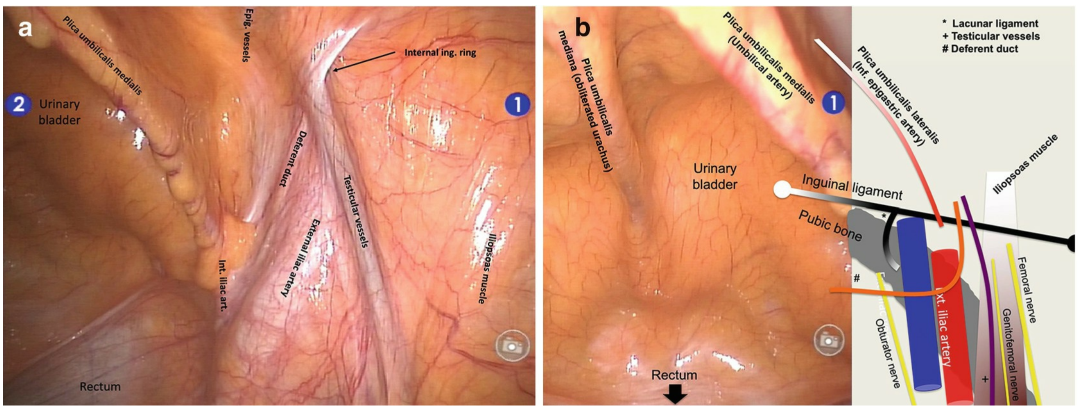

Fig. 2.2 (**a**) Laparoscopic view into the male pelvis with annotated anatomic landmarks. (**b**) Topographic anatomy of the male pelvis. Left: laparoscopic view at the beginning of robotic-assisted laparoscopic prostatectomy. Right: draft of the anatomical structures of the inguinal region in addition to the left intraoperative view (Reprinted from Amend et al. [55] with permission from Springer Nature)

Female Pelvis

A plain promontorium and wide-open iliac wings characterize the female pelvic bone. The peritoneal pelvic cavity harbours the urinary bladder, the ureters, the uterus, the vagina, the ovaries, the Fallopian tubes and the rectum. The uterus, in between the urinary bladder and the rectum, leads to varying peritoneal conditions, starting from the anterior abdominal wall. The parietal peritoneum covers approximately the upper half of the urinary bladder, the uterus, the adnexa and the anterior wall of the rectum. Thereby the parietal peritoneum forms two parts of the abdominal cavity: the rectouterine excavation (Douglas' fold) and the vesicouterine excavation. A vaginal manipulator helps to expose these pelvic spaces during laparoscopic surgery. The peritoneal fold between the uterus/cervix and the pelvic wall is called the ligamentum latum or broad ligament, although these structures lack some of the typical features of a ligament in the anatomical sense. The uterine artery, the uterine venous plexus and parts of the distal third of the ureters are included in the broad ligament. Ovaries and the Fallopian tubes are also joined to the broad ligament by a peritoneal duplication. The ovaries receive their blood supply through the suspensory ligament (often also called infundibulopelvic ligament), and they are connected to the uterus by the (proper) ovarian ligament, which is part of the broad ligament and includes a secondary blood supply called ovarian branches of the uterine artery. At least, the round ligaments represent connections between the deep inguinal rings and the uterine horns. Embryogenetic, the round ligament corresponds to the gubernaculum testis in males.

The rectouterine folds mark the borders of the rectouterine pouch—they consist of fibrous tissue and smooth muscle fibers, and also include the inferior hypogastric plexus (Fig. 2.3).

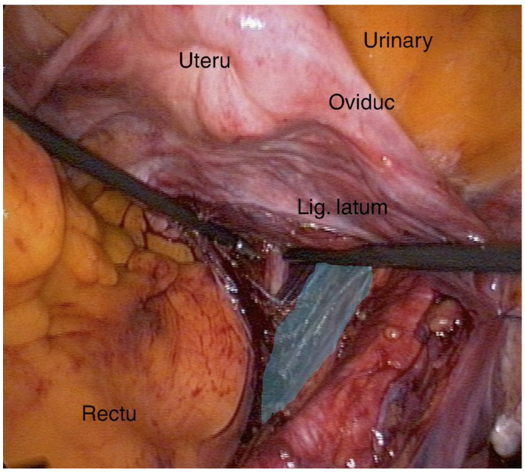

Fig. 2.3 Laparoscopic view into the female pelvis . The right rectovaginal fold is marked lucent blue

The pelvic fascia with its parietal and visceral layer covers the borders of the subperitoneal space; the clinical synonym is "endopelvic fascia". The endopelvic fascia also forms the superior layer of the fascia of the pelvic and urogenital diaphragm. The urinary bladder is attached to the pubic bone/symphysis pubis via the pubovesical ligaments (analogous to the puboprostatic ligaments in male humans, see also below) with lateral connections to the superior layer of the fascia of the pelvic diaphragm. Between the different subperitoneal organs, connective and fatty tissue fills the resulting spaces (presacral, prevesical, paracervical, parametrial). The stability of the uterus and the cervix is guaranteed by the rectouterine (synonym, sacrouterine) ligament and the topography of the other pelvic organs. The cardinal ligaments (synonym, transverse cervical ligaments) on the base of the broad ligament, joining the cervix and the lateral pelvic wall, are not there at birth but are shaped throughout a lifetime by the increasingly compact and strong connective tissue. They increasingly support the topographical position of the cervix [2, 4–6].

Male Pelvis

In contrast to the female pelvis, in male humans the pelvic bone is narrower and marked by a more protruding promontorium, resulting in a heart-shaped pelvic entry. The pelvis accommodates the urinary bladder, the ureters, the prostate, the seminal vesicles, the deferent ducts and the rectum. The parietal peritoneum also covers the pelvic organs starting from the anterior abdominal wall to the anterior rectal wall. Between the urinary bladder and the rectum, the deepest point of the abdominal cavity forms the rectovesical excavation. On both sides the rectovesical fold confines the excavation and includes the inferior hypogastric plexus. The deferent ducts shape the paravesical fossa by raising a peritoneal fold.

The subperitoneal space in front of and lateral to the urinary bladder is clinically called the cavum retzii. A look at the existing literature concerning the anatomical conditions of the subperitoneal fascias, especially the prostate-surrounding tissue and the formation of the so-called Denonvilliers' fascia, demonstrates an inconsistent presentation and nomenclature. The following explanations will outline the most usually published anatomical findings and interpretations. The pelvic fascia in males also consists of two parts: a parietal layer, which covers the lateral wall of the pelvis, and a visceral layer covering the pelvic organs. The tendinous arch represents the transition between the parietal and visceral part. Often the visceral layer is clinically indicated as the endopelvic fascia, especially with regard to radical prostatectomy and nerve-sparing procedures. Whether the prostate is actually separated by its own prostatic fascia is under discussion. The absence of the fascia in the apical region of the prostate and the formation of the so-called puboprostatic ligaments by the endopelvic fascia suggest that the visceral layer of the pelvic fascia (=endopelvic fascia) and the fascia of the prostate (periprostatic fascia) correlate. Generally, the periprostatic fascia is described as a multilayered structure, which incorporates neurovascular structures, fatty and fibrous tissue. Interindividual and prostate aspect depended variations (fusion of fascias and prostate capsule) are common, especially with regard to the prostate gland size. The puboprostatic ligaments between the anterior aspect of the prostate and the pubic bone/symphysis pubis do not represent ligamentous structures in the proper sense. In fact, the puboprostatic ligaments are characterized by an aggregation of the pelvic fascia. Possibly muscle fibers (smooth or striated) also contribute to the configuration of the so-called puboprostatic ligaments. Especially in large prostates the correct identification of the dissection plane between the anterior prostate aspect and the puboprostatic ligaments may be difficult.

Similarly, there is a lack of clarity regarding Denonvilliers' fascia. The anatomical nomenclature utilizes the description rectoprostatic fascia or septum. It represents a membranous separation between the rectum and the prostate/urinary bladder. The fascia emerges from two layers of a peritoneal cul-de-sac, ranging from the deepest point of the rectovesical excavation to the pelvic floor. Recent examinations report the termination of the Denonvilliers' fascia located at the junction of the prostate and the dorsal (fibrous) part of the rhabdosphincter. In addition, the presence of smooth muscle fibers inside the fascial layers has been reported. There has been extensive discussion about the possibility of surgical separation of both layers during radical prostatectomy. Currently it is evident that microscopically the rectoprostatic fascia consists of two formerly peritoneal layers, which often cannot be divided bluntly. It is assumed that authors illustrating techniques of fascia separation are referencing to the space between Denonvilliers' fascia and the rectal fascia propria (a part of the visceral layer of the pelvic fascia = endopelvic fascia). Furthermore, adhesions between Denonvilliers' fascia and the prostatic capsule, primarily at the base of the seminal vesicles, have been identified. These individual findings have to be taken into account for precise retro-prostatic preparation with regard to positive surgical margins during prostatectomy independent of the surgical approach. Periprostatic neural and vascular structures are focused on below [2, 4, 6–16].

Pelvic Floor

Two fibromuscular layers are responsible for the closure of the inferior pelvic aperture: the pelvic diaphragm and the urogenital diaphragm. It has to be emphasized at this point that the term urogenital diaphragm is not part of the anatomic nomenclature. Particularly the presence of a deep transverse perineal muscle was under extensive discussion, whereas recent studies confirm that a deep transverse perineal muscle is present.

The pelvic diaphragm consists of the levator ani muscle and the coccygeus muscle (M. ischiococcygeus). The levator ani muscle in turn consists of the following structures, which are named according to their origins and insertions: the pubococcygeus muscle, iliococcygeus muscle and puborectalis muscle. A superior and inferior fascia covers the levator ani muscle, the superior layer being part of the parietal layer of the pelvic fascia as described above. The levator ani muscle forms an archway-shaped opening for the anus and urethra in males, and the anus, vagina and urethra in females. Interestingly, the levator ani muscle thickness has been reported smaller and the steepness inside the pelvis greater comparing males to females. This might be dedicated to the general form of the bony pelvis and the physical necessities during pregnancy. The innervations for the striated muscles derive principally from the sacral plexus (S3 and S4); some nerve fibers reach the puborectal muscle via the pudendal nerve located in the pudendal canal. Even though the contributions of the shape topography and the contraction of the pelvic diaphragm to anal continence seem to be proven, it is still unclear to what extent these anatomical structures also affect urinary continence. Recent publications have reported the muscular independence between the pelvic diaphragm and the striated external urethral sphincter, whereas an association by connective tissue forming a tendinous connection starting from the inferior part of the external urethral sphincter in females could be demonstrated. Especially because of these interactions, authors suggest the necessity of an intact pelvic diaphragm for urinary continence.

The relevance of the rectourethralis muscle in males is regularly discussed with respect to post-prostatectomy urinary continence. Special incontinence tapes aim to repair the assumable posterior loss of the external urinary sphincter complex after prostatectomy, which is naturally guaranteed by muscular and fascial dorsal structures (Denonvilliers' fascia, rectourethralis muscle). Recent studies characterized the rectourethral muscle as the anterior branch of longitudinal fibers of the anterior smooth muscle component of the rectum, which directs through the deep transverse perineal muscle to the perineal body. The posterior branch of rectal longitudinal smooth muscles passes between the internal and external anal sphincter to the perineum (Fig. 2.4).

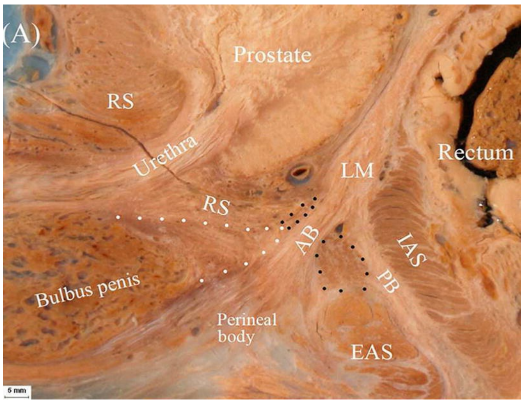

Fig. 2.4 Sagittal cross-section of celloidin fixed male human pelvic floor: deep transvers perineal muscle marked with black dots. Connective tissue of the penile bulb marked with white dots (*RS* rhabdosphincter, *LM* longitudinal muscle of the rectum, *AB* anterior bundle of LM, *PB* posterior bundle of LM, *EAU* external anal sphincter). (Reprinted from Zhai et al. [13] with permission from Elsevier)

Considering the urogenital diaphragm, the exact anatomical and histomorphological composition is still undefined. Almost all anatomical atlases report that the urogential diaphragm consists of the deep transverse perineal muscle (less developed in females) with a superior and inferior urogenital fascia. Additionally, the superficial transverse perineal muscle inserting at the perineal body (=central tendon of perineum), the striated external urethral sphincter and the surrounding connective tissue complete the traditional view of the urogenital diaphragm. In addition, as described above, smooth muscle fibers originating from the anterior rectal wall integrate into or perforate the urogenital diaphragm (rectourethralis muscle). With reference to the discussions of the existence of a deep transverse perineal muscle, prevailing descriptions in literature and also recent studies of human cadavers report the presence of the deep transvers perineal muscle (Fig. 2.4). The urogenital diaphragm is described as layers of connective tissue embedding the external urethral sphincter in conjunction with the perineal body, the deep transvers perineal muscle, the structures of the inferior pubic bone and the superficial transverse perineal muscle. Whether these findings about the muscular structures of the urogenital diaphragm are possibly due to age-related fatty degeneration of muscular tissue is under discussion and remains unexplained. The main vascular and neural structures—the internal pudendal artery and the pudendal nerve—are located directly below the urogenital diaphragm. The internal pudendal artery is a branch of the internal iliac artery and the pudendal nerve originates from the sacral plexus (S2-4). Both structures surround the sacrospinous ligament and follow the inferior pubic bone inside the pudendal canal as described below. The bulbourethral glands (Cowper's glands) are located laterally to the membranous urethra at the level of the urogenital diaphragm. They could be visible during deep urethral repair, perineal prostatectomy or gender reassignment surgery. The urethral sphincter mechanism is described out below [2, 6, 13, 17–26].

Urinary Bladder

The urinary bladder is a muscular, distensible organ for urine collection and controlled micturition. Macroscopically the urinary bladder is divided into the apex, corpus, fundus and collum. The average filling volume ranges between 300 and 500 cm^3. The mucosa is only loosely adherent to the subjacent muscular layers, except for the trigone where a direct adhesion to the submucosal layers can be found. A fold raised between the obliquely passing ureters on both sides forming the ureteral orifices characterizes the trigone.

The urinary bladder wall is structured as follows: mucosa (transitional cells), submucosa, detrusor muscle (three layers), and surrounding adipose and connective tissue. The detrusor muscle is subdivided into an external and internal longitudinal muscle layer, as well as an interjacent circular layer. The bladder neck, including the trigone, consists of two muscular layers. A specialized circular smooth muscle could not be found. The longitudinal muscle fibers in conjunction with the extending longitudinal fibers of both ureters extend below the bladder neck and reach the muscular layers of the urethra. In male humans these structures reach to the point of the seminal colliculus. Therefore, a closure of the bladder neck to maintain continence, even in case of damage of the rhabdosphincter (e.g. traumatic urethral injury), or to ensure antegrade ejaculation is possible.

The blood supply of the urinary bladder generally derives from two main branches of each of the internal iliac arteries: the superior vesical artery and the inferior vesical artery—often named the superior and inferior vesical pedicle during surgery. The superior vesical artery descends from a common branch with the former umbilical artery, which is part of the medial umbilical ligament (landmark for the superior vesical pedicle during cystectomy). The inferior vesical artery arises from a common branch of the middle rectal artery. Prostatic branches generally derive from the inferior vesical artery. Varying distinct venous plexuses on both sides of the vesical base secure the blood drainage of the urinary bladder. These venous vessels communicate extensively with the prostatic venous plexus in male and the vaginal venous plexus in female humans. Both, the thin venous vessel wall (especially in case of neoplastic vascularization) and the numerous venous interconnections might result in demanding vascular control during radical surgery.

Organs of the pelvis, in contrast to other regions, present a widespread field of lymph node drainage. The urinary bladder drains its lymph fluid through external iliac lymph nodes, internal iliac lymph nodes, lymph nodes in the obturator fossa and common iliac lymph nodes (Fig. 2.5).

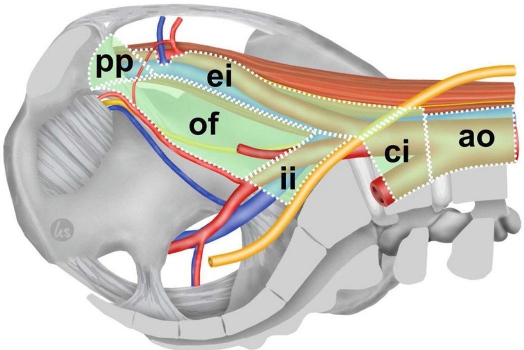

Fig. 2.5 Areas of lymphadenectomy for pelvic surgery: post pubic (pp), external iliac (ei), obtorator fossa (of), internal iliac (ii), common ilica (ci), aortal (ao). (Reprinted from Schilling et al. [28] with permission from Wiley-Blackwell)

A complex neural system facilitates the correct functioning of the urinary bladder as a storage and drainage system. Interactions between independent reflex pathways and arbitrary actions are necessary for a precise process. Both the autonomous and the somatic nervous system contribute to carrying out the tasks of bladder filling and emptying.

Anatomic nerve fibers reach the urinary bladder (and adjacent organs) through the inferior hypogastric plexus (=pelvic plexus). The inferior hypogastric plexus thus comprises the parasympathetic and sympathetic nerve tracts. Anatomically the inferior hypogastric plexus derives from the singular superior hypogastric plexus, which reaches the pelvis proximally and medial to the crossing of the distal ureter and the common iliac artery on both sides (Fig. 2.6). The inferior hypogastric plexus is part of the bilateral rectouterine or rectovesical fold beside the pouch of Douglas (Fig. 2.3). The plexus extends laterally to the rectum, the vagina (in females), the bladder neck and the seminal vesicles (in males) in a sagittal direction. The continuing course of nerve fibers along the prostate is described in the next chapter. An allocation of nerve fibers within the plexus to innervated targets seems to be possible. Roughly, the anterior part is responsible for urogenital innervations, and the posterior part serves the rectum.

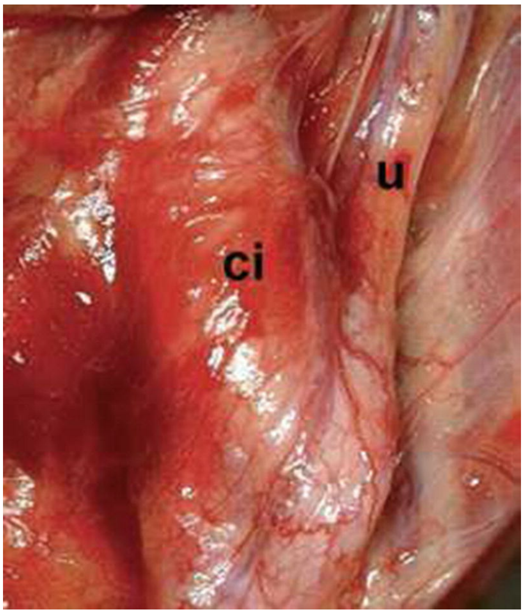

Fig. 2.6 Nerve course of the sympathetic fibers deriving from the superior hypogastric plexus (*ci* common ilica artery, *u* ureter). (Reprinted from Schilling et al. [28] with permission from Wiley-Blackwell)

The sympathetic fibers of the inferior hypograstric plexus originate from the superior hypogastric plexus, which is fed by nerve fibers from the lumbar sympathetic trunk condensed in 2–3 lumbar splanchnic nerves, as well as from sacral splanchnic nerves, which derive straight from the sacral part of the sympathetic trunk.

Sympathetic excitation generally results in inhibition of the detrusor muscle and stimulation of the smooth muscle sphincter cells, which leads to a filling of the urinary bladder. The parasympathetic fibers derive from the sacral spinal cord (S2-S5) and reach the inferior hypogastric plexus via pelvic splanchnic nerves exiting from the foramina of the sacral bone. Sensory afferent nerve fibers of the urinary bladder (and most probably of the proximal urethra as well) run along the parasympathetic nerves. Contraction of the detrusor muscle is mediated through the parasympathetic nervous system. The pudendal nerve is part of the somatic nervous system and innervates the striated parts of the external urethral sphincter. The pudendal nerve courses in the pudendal canal (Alcock's canal) at the bottom of the inferior pubic bone after the distribution of the lumbosacral plexus (S2–4). The variation of an intrapelvic nerve branching off the pudendal nerve prior to entering the pudendal canal and running on the inside of the levator muscle has been described. Stimulation results in increased contraction of the external urethral sphincter and adjacent segments of the levator ani muscle. Complex interconnections on different sections of the central nervous system, including Onuf's nucleus (located in the sacral part of the spinal cord), the periaqueductal grey, the pontine micturition center and the frontal lobe of the cerebrum, are involved in the process of filling and emptying. For example, it could be demonstrated that pelvic floor training for stress urinary incontinence not only influences the competence of the sphincteric mechanisms, but the training also results in restructuring of supraspinal central nervous system components [2, 4, 27–32].

Prostate, Seminal Vesicles and Deferent Ducts

The prostate is often compared to a chestnut of about 20 g. With the base aligned to the urinary bladder and the apex proximate to the external urinary sphincter, the prostate incorporates the prostatic urethra with a length of about 3 cm.

As a result of benign prostatic hyperplasia sizes up to 300 g are possible, which influences topography to the adjacent organs and structures (periprostatic nerves, striated and smooth muscle of the sphincter complex) as well as the distribution of the subsequently described prostatic zones.

McNeal defined the different zones of the prostate based on histopathological analysis: the peripheral zone, the central zone, the transitional zone and the anterior fibromuscular zone. This definition has to be separated from the macroscopic classification into lobes.

The ejaculatory ducts are paired tubes formed on each side by fusion of the deferent duct and the duct of the seminal vesicle. The orifices of the ejaculatory ducts are located on the seminal colliculus (also called the verumontanum). 15–30 orifices of ducts of the prostate glands are located beside the seminal colliculus.

The seminal vesicles are located lateral to the deferent ducts. Dorsally and laterally fibers from the inferior hypogastric plexus engulf the vesicles. The space between Denonvillier's fascia dorsally and the fascia covering the posterior wall of the bladder is called the spatium urovesicale (urovesical space). Recent studies describe smooth muscle fibers merged longitudinally into the Denonvillier's fascia, which connect the urinary bladder to the prostate at the entry of the ejaculatory ducts. This so-called vesicoprostatic muscle has to be identified and dissected during radical prostatectomybladder (neck preparation) (Fig. 2.7). Branches of the inferior vesical artery, the middle rectal artery and the artery of the vas deferens usually reach the seminal vesicle at its tip.

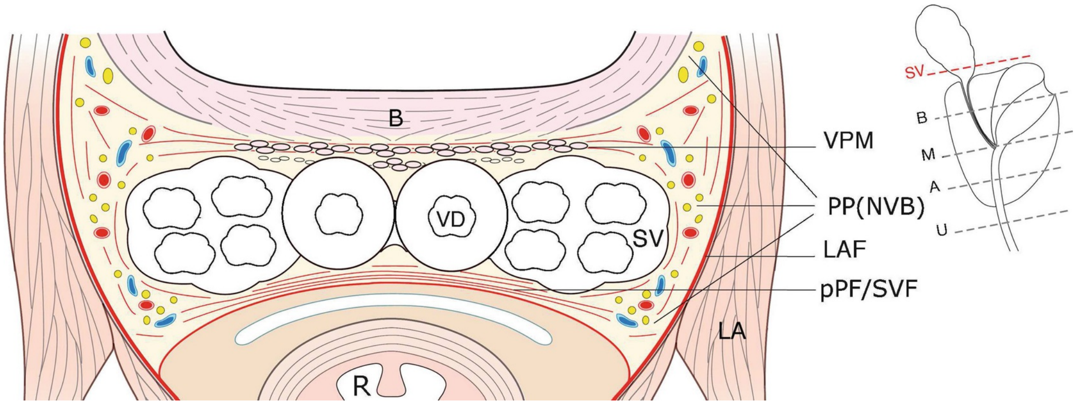

Fig. 2.7 Axial cross-section of the pelvis at the level of seminal vesicles (SV) illustrates the relation of deferent duct (VD), seminal vesicle, bladder (B), neurovascular bundle (NVB) and rectum (R) to the posterior pelvic fascia (synonymic seminal vesical fascia (SVF) or Denonvilliers' fascia), the vesicoprostatic muscle (VPM) and the levator ani fascia (LAF). (Reprint of Walz et al. [16] with permission of Elsevier)

The deferent duct is characterized by a dilatation prior to the confluence with the duct of the seminal vesicle called the ampulla. The deferent duct is accompanied by one or two separate arteries (arteries of the vas deferens), which derive from the inferior vesical artery. These arteries play an important role (beside additional cremasteric arteries) to ensure testicular blood supply during two-staged Fowler-Stephens procedure to treat cryptorchism with intraabdominal testis and the need to divide the main testicular vessels.

The inferior vesical and the middle rectal artery contribute to the blood supply of the prostate. The main vessels enter the prostate on both sides at the dorsolateral aspect close to the base of the prostate. Smaller vessels perforate the prostate capsule directly. Venous drainage moves from the surrounding prostatic venous plexus.

Accessory pudendal arteries can be found in about 25% of the patient population undergoing radical prostatectomy. An accessory pudendal artery is defined as a vessel starting above the level of the levator ani muscle, running down to the penile structures below the symphysis pubis and the pubic bone, respectively. Some authors subdivide the accessory arteries into lateral (alongside the anterolateral aspect of the prostate) and apical (inferior and lateral to the puboprostatic ligaments) accessory pudendal arteries. The extent of their contribution to the erectile function of the penis is still under investigation and discussion.

The puboprostatic complex includes the puboprostatic ligaments, the prostatic venous plexus and their correlation to the prostate and the external urethral sphincter. The puboprostatic ligaments formed by the endopelvic fascia, first described by Young, are described above. The prostatic venous plexus communicates extensively with the distinct venous plexus of the urinary bladder cranially and the superficial/deep dorsal veins of the penis. The proper name (Santorini's plexus) refers to their initial discovery by Giovanni Domenico Santorini in 1724. The venous plexus is imbedded in the fibrous structure of the so-called puboprostatic ligaments. The puboprostatic plexus directly covers the anterior elevated part of the external urethral sphincter (see also following chapter). The proximate neighborhood of sphincter structures, periprostatic nerves continuing beside the urethra and big venous vessels explains the risk of functional damage by an uncontrolled dissection of the Santorini's plexus.

The description of the anatomic affiliations of pelvic lymph nodes to the drainage field was originally based on lymphographic studies. Recent findings are the results of sentinel lymph node studies. The injection of ^{99m}Tc-labeled nanocolloid into the prostate facilitates the identification of sentinel lymph nodes either by surgery or by radiological imaging (Fig. 2.8). The lymph nodes of the obturator fossa, the external iliac lymph nodes, the internal and finally the common iliac lymph nodes are responsible for the drainage of the prostate gland (Figs. 2.8 and 2.9).

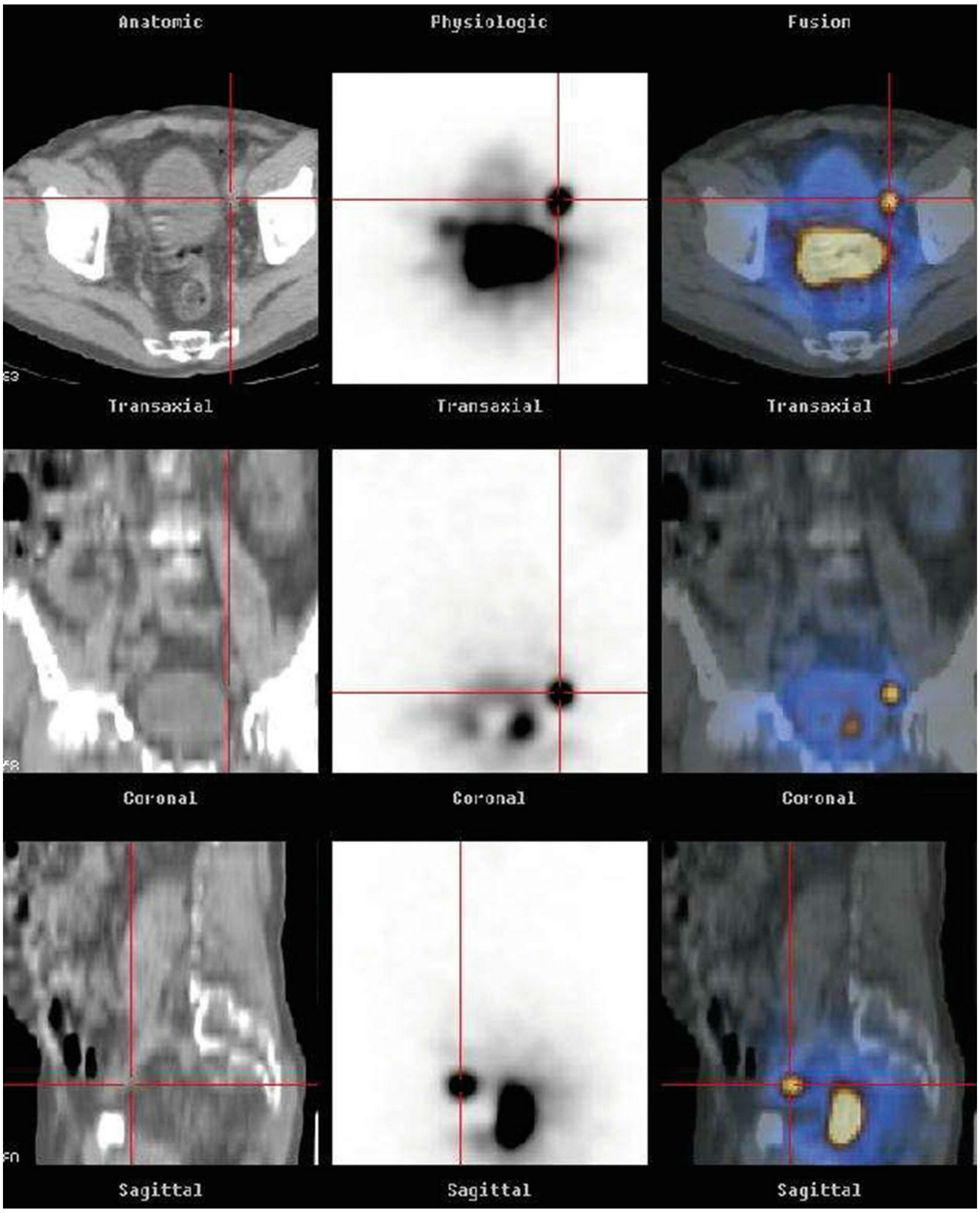

Fig. 2.8 Radiological image of sentinel lymph nodes after injection of ^{99m}Tc-labeled nanocolloid into the prostate. Left column: CT scan images, middle column: SPECT images, right column: CT/SPECT fused images. Sentinel lymph node located inside the red indicator

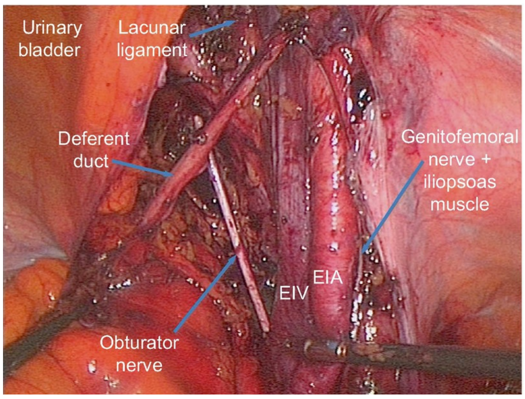

Fig. 2.9 Situs after laparoscopic lymphadenectomy for prostate cancer; EIV: external ilic vein, EIA: external iliac artery. The lacunar ligament as the distal extent of lymphadenectomy

Although oncological aspects are still the main concern of every radical prostatectomy treating prostate cancer, quality of life aspects including erectile function as well as continence have become important. The existence of the endopelvic fascia equipollent to the visceral layer of the pelvic fascia has been outlined above. Most authors would agree that the neurovascular structures are located between the prostate surface with its fibromuscular capsule and the visceral layer of the pelvic fascia, which extends to Denonvilliers' fascia at the dorsolateral aspect of the prostate (Fig. 2.10). Some studies describe a merger between the different parts of the multilayered fascia as described above. Whether nervous tissue can also be found in the fold between the visceral and the parietal layer of the pelvis remains unclear. In 1985, Donker, Walsh et al. were the first to extensively describe the neurovascular bundle. The technique of nerve-sparing radical prostatectomy and cystectomy was adapted regarding these anatomical findings. Especially the course of these periprostatic nerves has resurfaced as a focus of academic interest the last decade. The entry of the inferior hypogastric plexus into the pelvis and its location lateral to the seminal vesicles, including the convergent fibers of the sacral splanchnic nerves (sympathetic) and pelvic splanchnic nerves (parasympathetic), has been referred to above. Furthermore, the presence of somatic nerves with a percentage of about 5% has been detected. This might explain in conjunction with the confirmation of sensory fibers, responsible for innervation of the membranous/proximal penile urethra, that uni- or bilateral nerve-sparing also influences post-prostatectomy continence (Fig. 2.10).

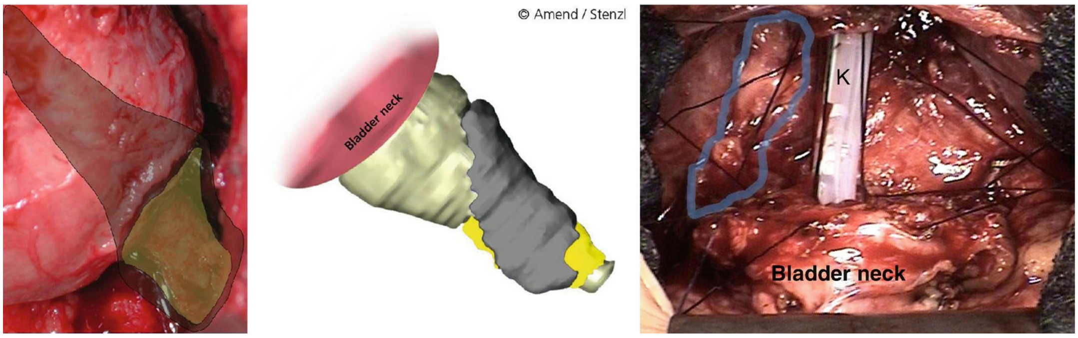

Fig. 2.10 Retropubic radical prostatectomy . Left: prostate after apical preparation with isolated membranous urethra (yellow shade). The grey shade outlines the area of the rhabdosphincter. Right: nerve-sparing procedure on left side (marked in blue) and partial nerve-sparing procedure on right side before anastomosis (K: transurethral catheter)

In contrast to a separate dorsolateral nerve bundle, several authors reinvestigated the anatomy and described different nerve dispersions. The periprostatic nerves proceed divergently especially in the mid-part of the prostate; therefore, a varying amount of nerve tissue can be found also in the anterior and anterolateral aspect of the prostate in addition to the known accumulation in the dorsolateral course (Figs. 2.11 and 2.12). Characteristically the nerve fibers converge towards the apex located at the posterior and posterolateral side of the apex and the urethra, respectively. In addition, parts of the periprostatic nerves leave the craniocaudal course and enter into the prostate for innervations. Initial investigations demonstrated the correlation of neural impulses routed through the nerve fibers on the anterior aspect of the prostate and erectile function. Beside the description of somatic periprostatic nerves additional emerging studies clarified the different nerve quantities surrounding the prostate gland. Relevant portions of parasympathetic and sympathetic fibers have been found anterolaterally at the level of the prostate base with subsequent condensation to a posterolateral course at the prostatic apex. The data supports a higher release of the periprostatic tissue for nerve-sparing with emphasis to the prostatic base-if the oncologic situation justifies this approach (Fig. 2.13) [2, 4, 7–12, 16, 19, 30, 33–50].

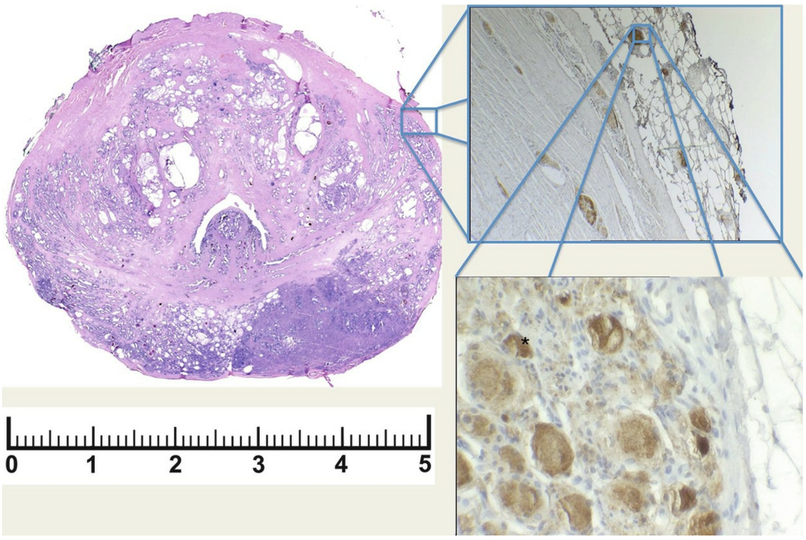

Fig. 2.11 Whole mounted horizontal section (left side, HE staining) of the prostate (∗prostate carcinoma). Staining with protein-gene-product (PGP) 9.5 antibodies illustrates the existence of nerve fibers anterior-lateral [42]

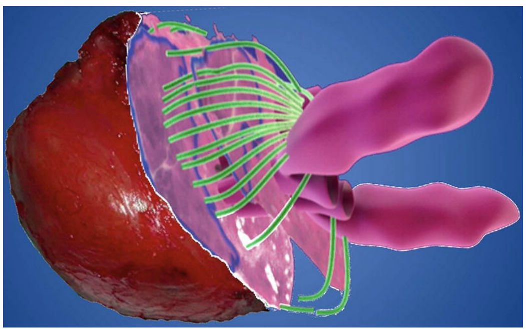

Fig. 2.12 3D reconstructions of nerve courses (right side: green lines) based on prostate specimens (left side) and whole mounted sections (middle part)

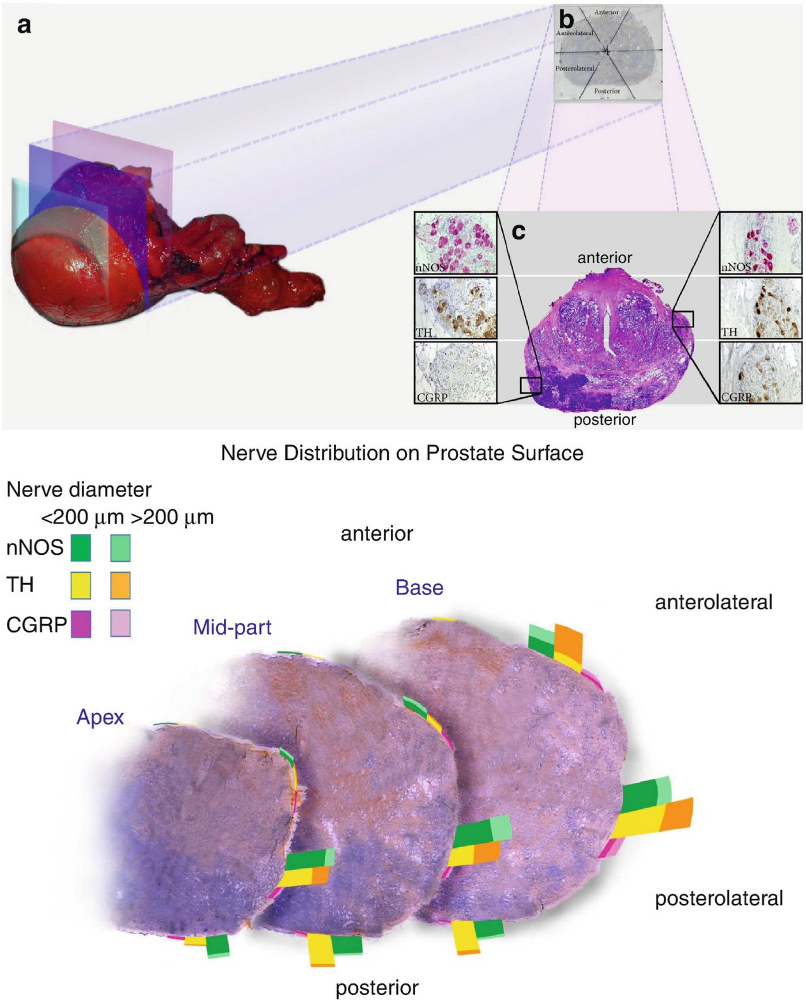

Fig. 2.13 Upper image illustrates prostate cross-sections with sectored quantification of nNOS+, TH+ and CGRP+ periprostatic nerves. Lower image illustrates the nerve distribution of the different qualities ranging from base to apex. (Reprint of Sievert et al. [49] with permission of John Wiley and Sons)

Urethra

Male Urethra

The urethra is subdivided into four different parts: the intramural part (=pre-prostatic urethra) at the bladder neck, the prostatic urethra, the membranous urethra and the spongy urethra surrounded by the corpus spongiosum. Transitional cells in large sections characterize the mucosa. The distal part near the navicular fossa is marked by a stepwise transition over stratified columnar cells to stratified squamous cells. The muscle layer is divided into an inner longitudinal, a middle circular and an inconsistently described outer longitudinal stratum. The bulbourethral artery, a branch of the internal pudendal artery entering at the level of the penile bulb, supplies the spongy urethra.

Female Urethra

The female urethra is about 3–5 cm long. The histology is equivalent to the male urethra.

Aspects of the urethral closure mechanisms are focused on in the following paragraph.

Sphincter Mechanisms

Traditional anatomy reports two muscular structures to achieve continence of the lower urinary tract: the voluntary, striated, external urethral sphincter (rhabdosphincter) located in the urogential diaphragm and the autonomous, smooth internal sphincter (lissosphincter) located in the bladder neck. However, the anatomical and functional understanding of the sphincter complex has changed over time (Fig. 2.14). In comparison to the periprostatic anatomy, various descriptions have been published. The contribution of three different components to the sphincter complex is commonly accepted: the detrusor muscle fibers of the bladder neck including the trigone, the intrinsic smooth muscle fibers of the urethral wall and the external urethral sphincter. The description of the systematic anatomical circumstances and the interaction of the mentioned components vary with different authors.

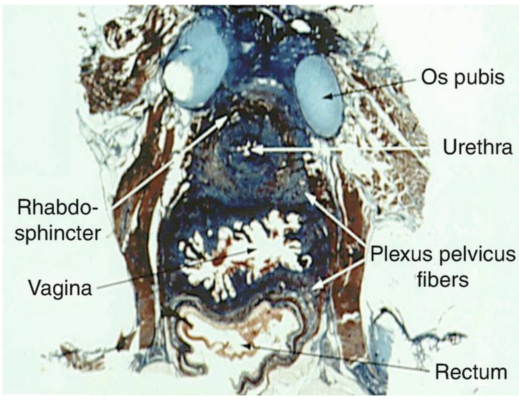

Fig. 2.14 Fetal female pelvis illustrating the omega-shaped rhabdosphincter surrounding the urethra and the topographical location of plexus pelvicus fibers. (Reprinted from Colleselli et al. [51] copyright 1998, with permission from Elsevier)

The Bladder Neck Component

The presence of the circumscribable, circularly oriented smooth muscle sphincter at the outlet of the urinary bladder was denied by different authors 200 years ago. It has been demonstrated both that the detrusor muscle fibers condense especially in the direction of the trigone and that the smooth intrinsic fibers of the urethral wall arrange a complex interacting network of muscle strands at the bladder outlet. In male humans, as reported before, the detrusor fibers reach the point of the seminal colliculus. The bladder neck component is thought to be innervated by the autonomic nervous system.

The Urethral Wall Component

The smooth muscle fibers of the urethral wall do not act as a detached actor. In fact, they can be interpreted as a continuance of the muscular complex of the bladder neck. The urethral muscular layer consists of longitudinally (inner and (inconsistently described) outer layer) and circularly (middle layer) oriented muscle fibers. Reports of the exact anatomical condition vary. Also, these smooth muscle fibers receive autonomic innervations.

The External Urethral Sphincter

Many authors have shaped the anatomical understanding of the external urethral sphincter , but an overall accepted anatomical and functional definition is still lacking. Consensus of opinion exists regarding the three-dimensional profile of the external sphincter. The terms omega-shaped and horseshoe-shaped are most often used to illustrate the external sphincter in male as well as female humans (Figs. 2.15 and 2.16). Muscle fibers are located in the anterior and lateral part of the urethra—only fibrous tissue forms the dorsal interconnection between the dorsolateral “ends” of the external sphincter. In the same way, authors concur that the external sphincter is not part of an urogential diaphragm (deep transverse perineal muscle) and that the external sphincter only has a fibrous connection to the surrounding tissue (including the pelvic diaphragm).

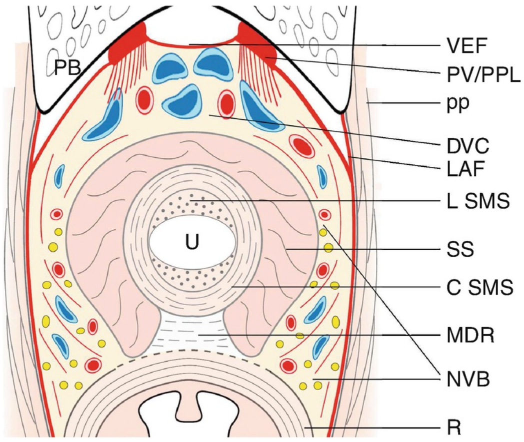

Fig. 2.15 Schematic illustration of the u-shaped rhabdosphinter (SS) (pubic bone (PB), visceral endopelvic fascia (VEF), puboprostatic ligament (PPL), puboperinealis muscle (PP), dorsal vein complex (DVC), levator ani fascia (LAF), longitudinal lissosphincter (L SMS), circular lissosphincter (C SMS), median dorsal raphe (MDR), neurovascular bundle (NVB) and rectum (R)). (Reprint of of Walz et al. [16] with permission of Elsevier)