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This chapter is dedicated to my friend Harald Hötzingler who was an excellent radiologist and a good co-worker.

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1.1

Introduction

The pelvic floor constitutes the caudal border of the human's visceral cavity. It is characterized by a complex morphology because different functional systems join here. A clear understanding of the pelvic anatomy is crucial for the diagnosis of female pelvic diseases, for female pelvic surgery as well as for fundamental mechanisms of urogenital dysfunction and treatment.

Modern imaging techniques are used for the diagnosis of pelvic floor or sphincter disorders. Furthermore, they are employed to determine the extent of pelvic diseases and the staging of pelvic tumors. In order to be able to recognize the structures seen on CT and MRI as well as on dynamic MRI, a detailed knowledge of the relationship of the anatomical entities within the pelvic anatomy is required.

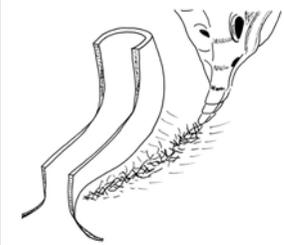
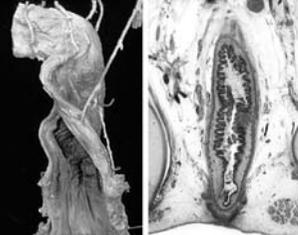
The *Terminologia Anatomica* [15] contains a mixture of old and new terms describing the different structures of the pelvis. Throughout this chapter the actual anatomical terms are used and compared with clinical terms. Furthermore, they are defined and illustrated (see Table 1.1).

1.2

Morphological and Clinical Subdivision of the Female Pelvis

The anatomy of the female pelvis and perineum shows a lack of conceptual clarity. These regions are best understood when they are clearly described and subdivided according to functional and clinical requirements: The actual clinical subdivision discerns an anterior, a middle and a posterior compartment. Whereas an anterior and posterior compartment may be found in the male as well as in the female, a middle compartment can only be found in the latter. The

Table 1.1. Box of terms and definitions

Term	Figure	Terminologia Anatomica (TA)		Clinical term	Definition	Renaming (according to our results)	Existence
		English	Latin				
1. Anococcygeal body		Anococcygeal body; anococcygeal ligament	Corpus anococcygeum; corpus anococcygeum	–	TA: The term corpus, rather than ligamentum, is used in TA because it is a stratified non-ligamentous structure in which fleshy muscle attachments underlie a tendon	Not necessary	+
2. Perineal body		Perineal body	Corpus perineale; centrum perinei	–	TA: The perineal body is fibromuscular rather than tendinous and quite unlike the centrum tendineum of the diaphragm Our option: The perineal body itself is tendinous, nevertheless it cannot be compared with the flat centrum tendineum of the diaphragm	Though tendinous, not necessary	+
3. Perineal membrane		Perineal membrane	Membrana perinea	–	Dense connective tissue between external urethral sphincter (and transverse perineal muscle in male) and pubic bone	Not necessary	+
4. Anorectum		Rectum and anal canal	Rectum et canalis analis	Anorectum	Our option: The clinical term includes both, the rectum and the anal canal, not taking into account that they are of different origin	Necessary to pick up in TA	+
5. Presacral (sub)compartment		–	–	–	Our option: Small space between presacral fascia and sacral and coccygeal vertebrae containing vessels	Necessary to pick up in TA	+
6. Presacral fascia		Presacral fascia	Fascia presacralis	Waldeyer's fascia (?)	Caudal part of the parietal pelvic fascia		+

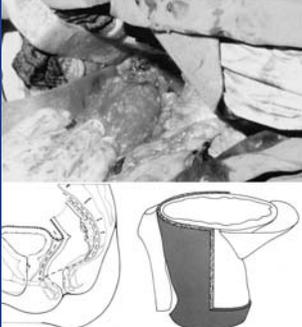
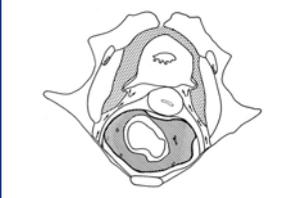
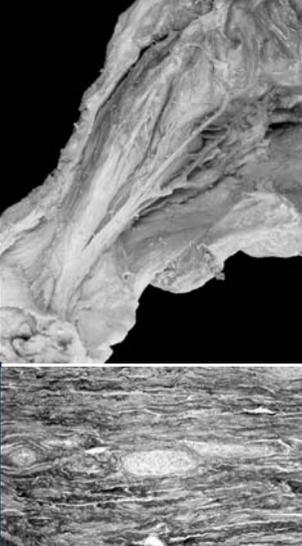
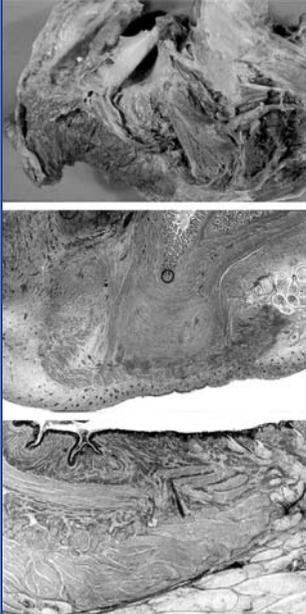
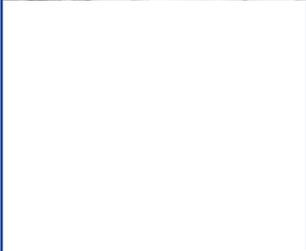
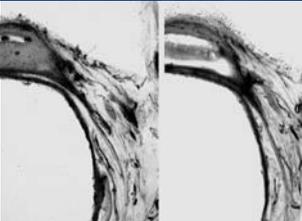
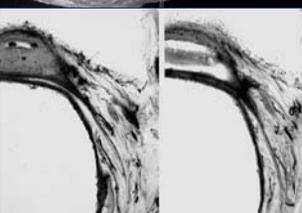
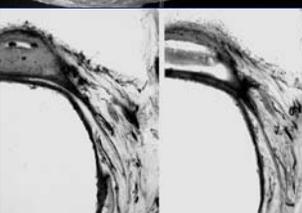
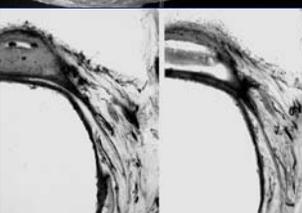
Term	Figure	Terminologia Anatomica (TA)		Clinical term	Definition	Renaming (according to our results)	Existence
		English	Latin				
7. Perirectal compartment		–	–	Mesorectum	Our option: Compartment filled by the rectal adventitia including nerves, vessels, lymph nodes	Necessary to pick up in TA	+
8. Rectal fascia or “Grenzlamelle”		–	–	Waldeyer's fascia (?)	Our option: Outer connective tissue lamella of the rectal adventitia, bordering the perirectal compartment	Necessary to pick up in TA	+
9. Inferior hypogastric plexus		Inferior hypogastric plexus; pelvic plexus	Plexus hypogastricus inferior; plexus pelvicus	Pelvic plexus	Autonomic nerve plexus within the recto-uterine or recto-vesical fold	Exclusively into the old and clinical term: pelvic plexus	+
10. Uterosacral ligament		Uterosacral ligament or recto-uterine ligament	Li. rectouterinum	–	Dense connective tissue running from the edges of the cervix uteri to the region of the sacrospinous ligament, then ascending and joining the pelvic parietal fascia	Exclusively into the uterosacral ligament	+
11. Rectovaginal fascia		Rectovaginal fascia; rectovaginal septum (female)	Fascia rectovaginalis; septum rectovaginale	–	Our option: Plate of dense connective tissue, smooth muscle cells and nerves, locally arranged between rectum and vagina	Exclusively into the term rectovaginal/rectogenital septum	+

Table 1.1. Box of terms and definitions (Continued)

Term	Figure	Terminologia Anatomica (TA)		Clinical term	Definition	Renaming (according to our results)	Existence
		English	Latin				
12. Anal sphincter complex		–	–	–	Includes all muscle layers of the anal canal: internal (smooth) sphincter, longitudinal (smooth) muscle, external (striated) sphincter	Necessary to pick up in TA	+
13. Pubovesical ligament		Medial pubovesical ligament, pubovesicalis, lateral pubovesical ligament	Lig. mediale pubovesicale, m. pubovesicalis, lig. laterale pubovesicalis	–	Most confusing structure! Our option: there is only one structure running from the pubic bone to the vesical neck. It mainly consists of smooth muscle cells intermingled with strands of dense connective tissue	Exclusively into the term pubovesical muscle	+
14. Levator ani muscle		Levator ani	M. levator ani	–	Muscle that constitutes the main part of the pelvic diaphragm and is composed of the Mm. pubococcygei, ilio-coccygei, and puborectales of each side		+
15. Tendinous arch of the pelvic fascia		Tendinous arch of the pelvic fascia	Arcus tendineus fasciae pelvis	–	Our option: This structure originates from the pubic bone laterally, it is connected with the superior fascia of the pelvic diaphragm “white line” laterally and with the pubovesical ligament medially. It may falsely be called Lig. laterale puboprostaticum or Lig. laterale pubovesicale		+

Term	Figure	Terminologia Anatomica (TA)		Clinical term	Definition	Renaming (according to our results)	Existence
		English	Latin				
16. Para-visceral fat pad		–	–	–	Our option: Fat pad at the lateral side of the bladder that develops in situ. Functionally necessary for the movements of bladder	Necessary to pick up in TA	+
17. Broad ligament		Broad ligament of the uterus	Lig. latum uteri	–	Peritoneal fold between the uterus and the lateral wall of the pelvis		+
18. Recto-uterine fold		Recto-uterine fold	Plica recto-uterina	–	Peritoneal fold passing from the cervix uteri on each side of the rectum to the posterior pelvic wall		+
19. Recto-uterine pouch		Recto-uterine pouch	Excavatio recto-uterina	Space of Douglas	Deep peritoneal pouch situated between the recto-uterine folds of each side		+
20. Vesico-uterine fold		Vesico-uterine fold	Plica vesico-uterina	–	Peritoneal fold between bladder and uterus on each side		+
21. Vesico-uterine pouch		Vesico-uterine pouch	Excavatio vesico-uterina	–	Slight peritoneal pouch between the vesico-uterine folds of each side		+
22. Transverse cervical ligament or cardinal ligament		Transverse cervical ligament, cardinal ligament	Lig. transversum cervicis, lig. cardinale	Cardinal ligament	Connective tissue structures that should extend from the side of the cervix to the lateral pelvic wall Our option: The cardinal ligament does not exist	Necessary to omit	0
23. Mesosalpinx		Mesosalpinx	Mesosalpinx	Identical	Double fold of peritoneum at the upper margin of the broad ligament		+
24. Mesovarium		Mesovarium	Mesovarium	Identical	Double fold of peritoneum attached at the dorsal portion of the broad ligament		+
25. Mesometrium		Mesometrium	Mesometrium	–	So-called meso of the uterus, greatest portion of broad ligament	According to Höckel is morphogenetic unit of cervix and proximal vagina. Necessary to redefine	+

term “compartment” is routinely used by radiologists and all surgeons operating on the pelvic floor. This term is not identical with the term “space”. According to former literature a lot of spaces are supposed to be arranged in the region of the pelvis: retrorectal, pararectal, rectoprostatic, rectovaginal, retropubic, paravesical, etc. [35, 43, 56]. From the point of view of the surgeon, “spaces” are empty [45]. They are only filled with loose connective tissue and neither contain large vessels nor nerves. Some years ago, we already proposed dropping the term “space” and speaking of compartments instead, taking into account that a compartment may be filled by different tissue components [19].

Within the following chapter we first present the posterior compartment and then the anterior one. This is in accordance with the viewpoint of the radi-

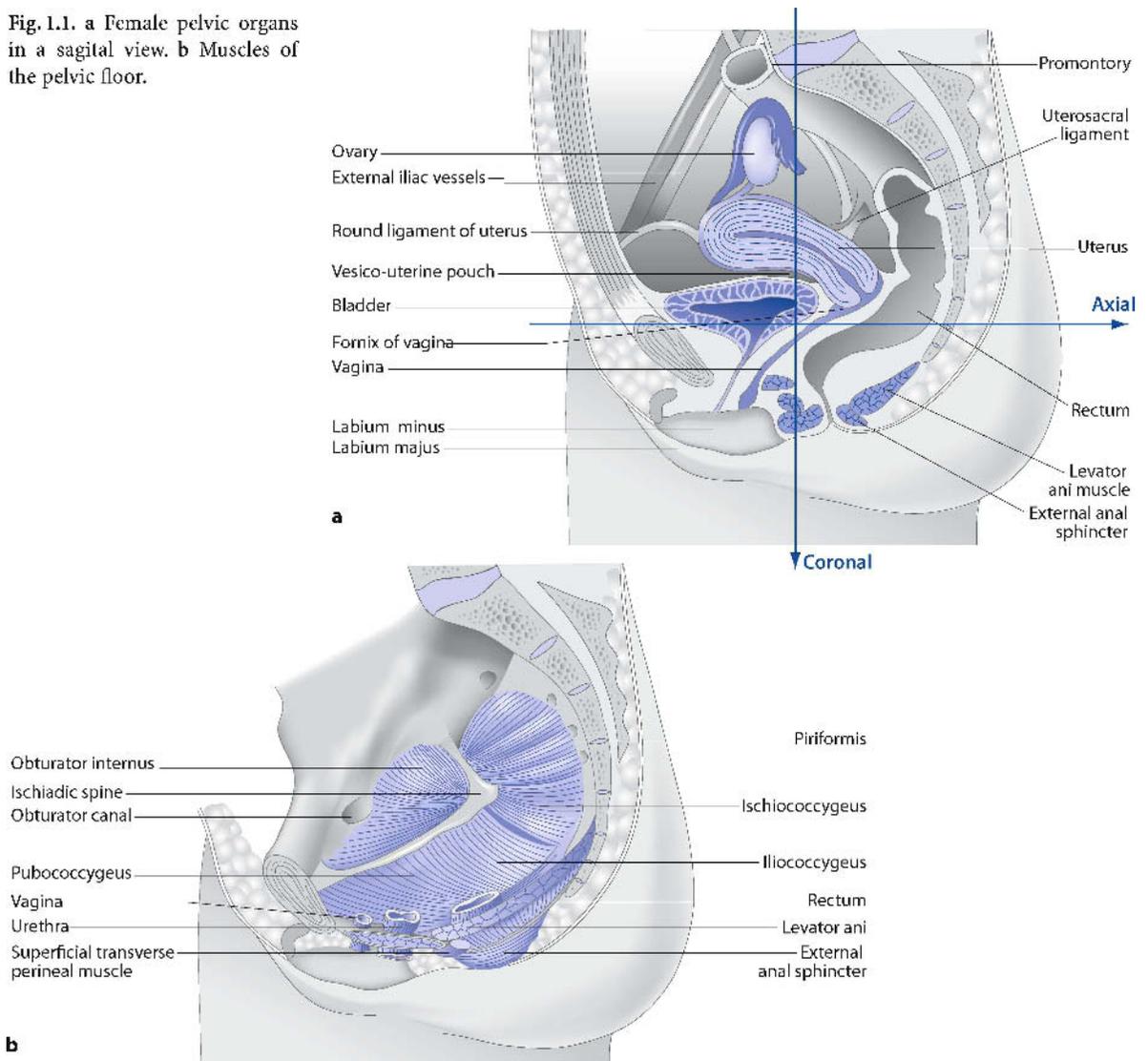
ologists and with the course of the vessels and nerves. An “extra” middle compartment that is characteristic for the female is presented in detail at the end of this chapter.

What is our common knowledge about the borders of the different pelvic compartments and what do we know about their content?

Posterior compartment

The borders of the posterior compartment are the skeletal elements of the sacrum and the coccyx dorsally. They are completed by the anococcygeal body (see Table 1.1) dorsocaudally and by the components of the levator ani muscle laterally and caudally (Fig. 1.1a). The rectovaginal fascia constitutes an incomplete border ventrocranially. The ventro-

Fig. 1.1. a Female pelvic organs in a sagittal view. b Muscles of the pelvic floor.



caudal border is composed of the perineal body (see Table 1.1). The only organ of the posterior compartment is the anorectum (see Table 1.1) (Fig. 1.1a,b).

Anterior compartment

The borders of the anterior compartment are the pubic symphysis ventrally, the components of the levator ani muscle laterally (Fig. 1.1b) and the perineal membrane (see Table 1.1) caudally. There is no distinct border between the anterior and middle compartment in the female. The contents of the anterior compartment are bladder and urethra (Fig. 1.1b).

Middle compartment

The borders are the components of the levator ani muscle laterally and the perineal body caudally (Fig. 1.1b). No distinct borders can be described ventrally, whereas the rectovaginal fascia/septum constitutes the dorsal border. The middle compartment contains the female genital organs that are arranged in a more or less coronal plane. In more detail the ovaries, the uterine tubes, the uterus and the vagina are situated in this compartment (Fig. 1.1a).

Perineal body

The perineal body is part of the perineum. It is situated between the genital organs and the anus and may be considered as a central or meeting point because a number of different structures join here.

1.3 Compartments

1.3.1 Posterior Compartment

1.3.1.1 Connective Tissue Structures

In macroscopic dissection of embalmed cadavers it is nearly impossible to distinguish subcompartments within the connective tissue of the posterior compartment. Our comparative study of adult and fetal pelvis shows that two subcompartments can be distinguished within the posterior compartment:

A small presacral subcompartment (see Table 1.1) is situated in front of the sacrum and coccyx. It is bordered by the caudal segments of the vertebral column dorsally and ventrolaterally, it is clearly demarcated by the pelvic parietal fascia (see Table 1.1) (Fig. 1.2), which is called presacral fascia (see Table 1.1) at this position. In fetuses, the presacral subcompartment contains loose connective tissue, but it is predominated by large presacral veins.

The major part of the posterior pelvic compartment is filled by the anorectum and its accompanying tissues, constituting the perirectal subcompartment (see Table 1.1). This perirectal tissue is identical with the rectal adventitial tissue [17, 24] (see Table 1.1), which develops along the superior rectal vessels. In the adult, it mainly consists of adipose tissue subdivided by several connective tissue septa (Fig. 1.3a, b). Within this perirectal tissue the supplying structures of the rectum are enclosed: the superior rectal vessels, stems and branches, the branches of the variable medial rectal vessels, rectal nerves and rectal lymphatics, vessels and nerves. The localization of these lymphatic nodes is strikingly different from that of the other lymph nodes of the posterior compartment that are situated laterally in the neighborhood of the iliac vessels [40, 50].

The rectal adventitia develops from a layer of condensed mesenchymal tissue, which – later on – forms a dense connective tissue in fetuses (Fig. 1.3c). In the newborn child it is remodeled by small fat lobules occurring between the connective tissue lamellae. The outer lamella covers the perirectal subcompartment and is called “rectal fascia” [17, 23] or “Grenzlamelle” [49, 50] (see Table 1.1). It constitutes the morphological border of the perirectal subcompartment. The craniocaudal extent of the perirectal subcompartment depends on the branching pattern of the superior rectal vessels, thus the perirectal compartment is broad laterally and dorsally and it is often rather thin ventrally where it is only composed of some connective tissue lamellae. As can be seen in sagittal sections the extent of the perirectal subcompartment decreases in size in a craniocaudal direction (Fig. 1.2c).

What is situated outside the rectal fascia and therefore outside the perirectal subcompartment? Dorsally, the presacral subcompartment is loosely attached to the perirectal compartment (see above). Laterally the supplying structures (autonomic nerves and branches of the iliac vessels) of the urogenital organs constitute a nerve-vessel plate (Fig. 1.3c). The latter is accompanied by connective tissue and fills the remaining space between the perirectal compartment

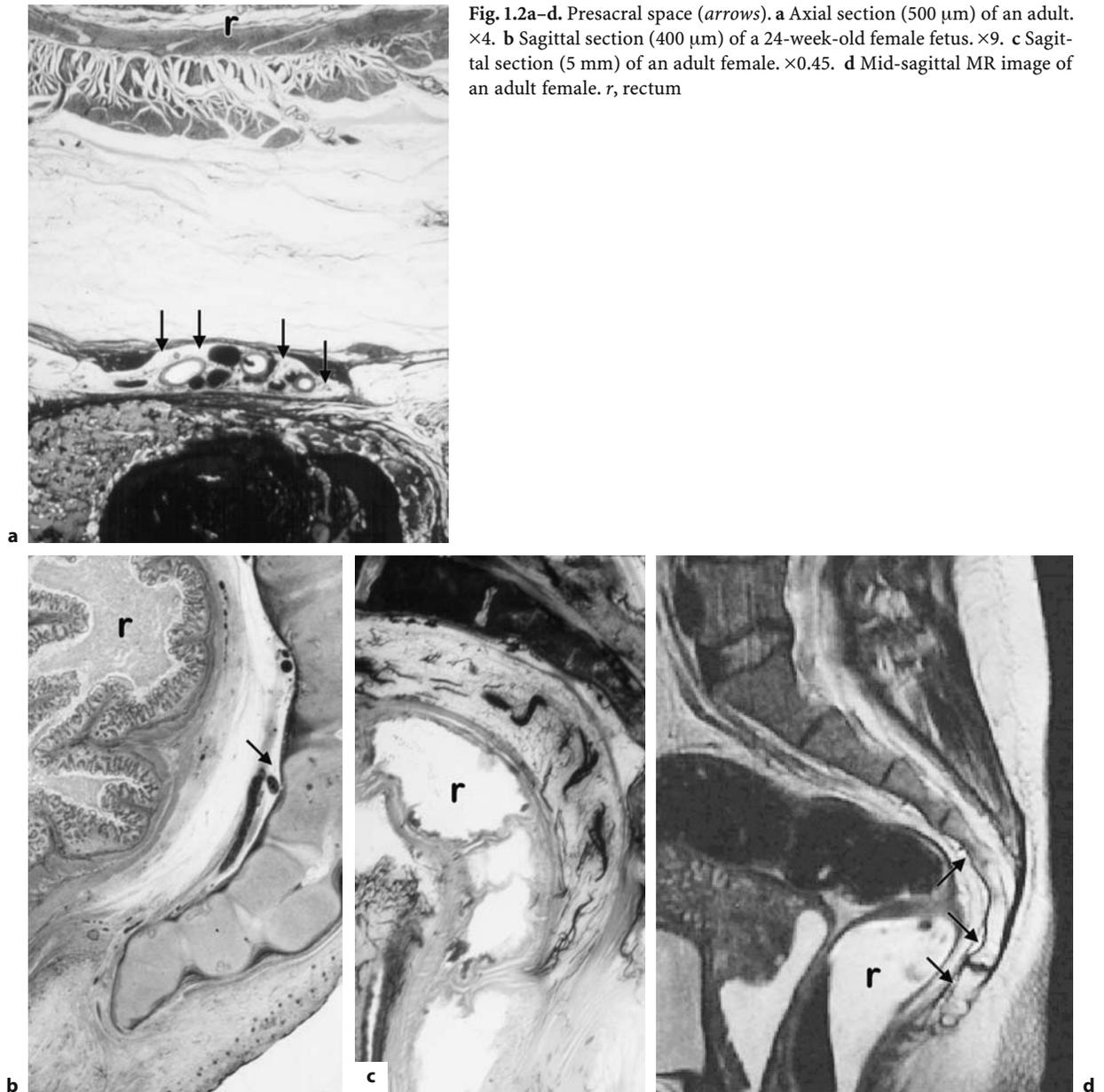


Fig. 1.2a–d. Presacral space (*arrows*). **a** Axial section (500 μm) of an adult. $\times 4$. **b** Sagittal section (400 μm) of a 24-week-old female fetus. $\times 9$. **c** Sagittal section (5 mm) of an adult female. $\times 0.45$. **d** Mid-sagittal MR image of an adult female. *r*, rectum

and the lateral pelvic wall. In the female, the nerves of the inferior hypogastric plexus (see Table 1.1) are attached to the uterosacral ligament (see Table 1.1) that is directly situated between the rectal fascia and the inferior hypogastric plexus (Fig. 1.3a,c) [18].

The ventral border of the perirectal compartment represents the border between posterior and middle compartment. It differs in a craniocaudal direction, i. e. to the peritoneum of the recto-uterine pouch at a level with the cervix uteri and the fornix vaginae and to the posterior wall of the vagina more caudally. As we have recently shown [1, 24, 36] a two layered recto-

vaginal fascia/septum (see Table 1.1) develops in the female and is identical to the male's rectoprostatic fascia/septum or Denonvillier's fascia [53]. At a level with the anorectal flexure, additional bundles of longitudinal smooth muscles are situated at the anterior rectal wall forming the muscular portion of the rectovaginal fascia ventrally (Fig. 1.4). The smooth muscle bundles are accompanied by nerves, some of them crossing the midline and they are connected to the smooth muscle layer of the rectal wall. Caudally these additional smooth muscle bundles are attached to the connective tissue of the perineal body (Fig. 1.4).

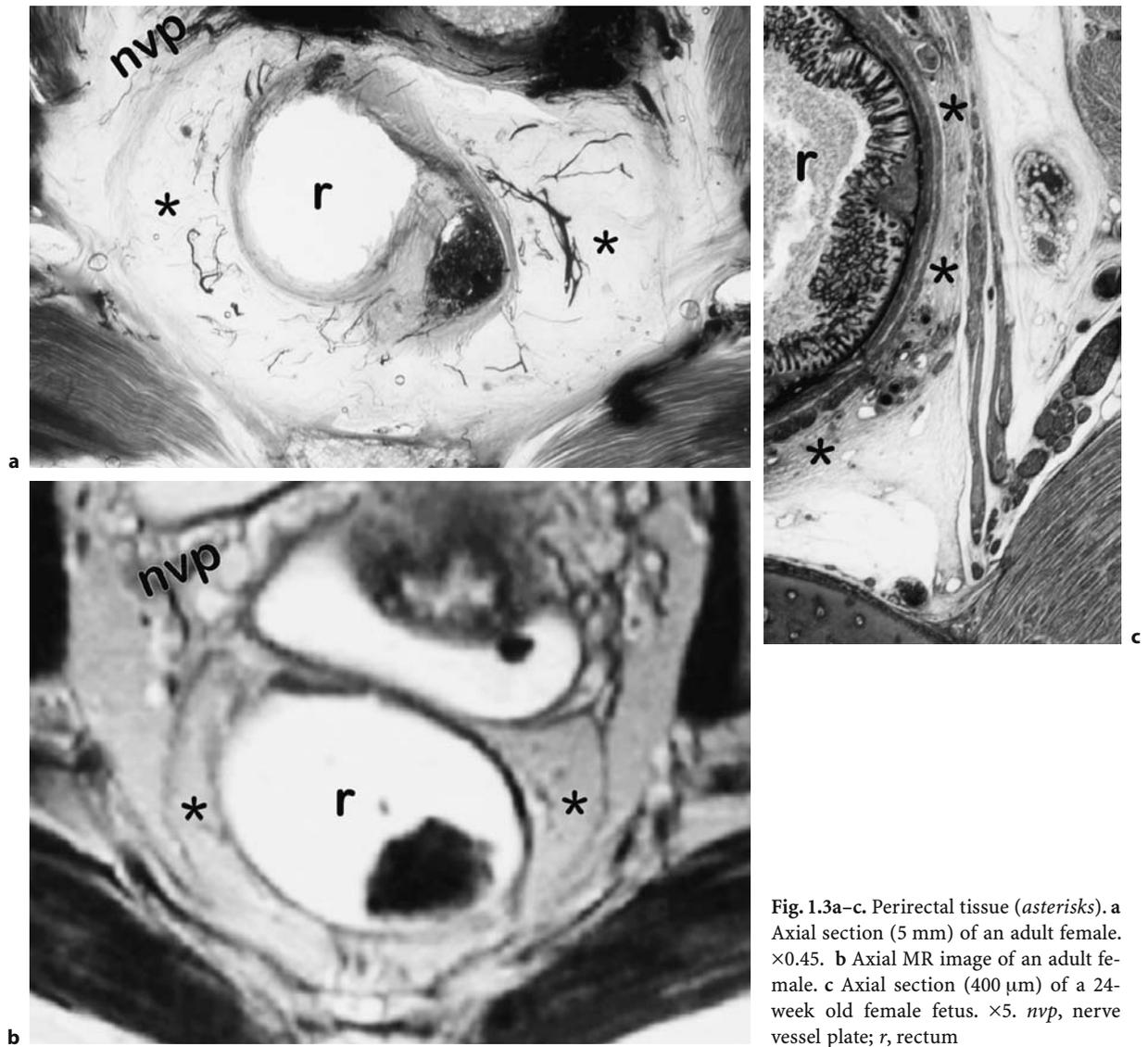
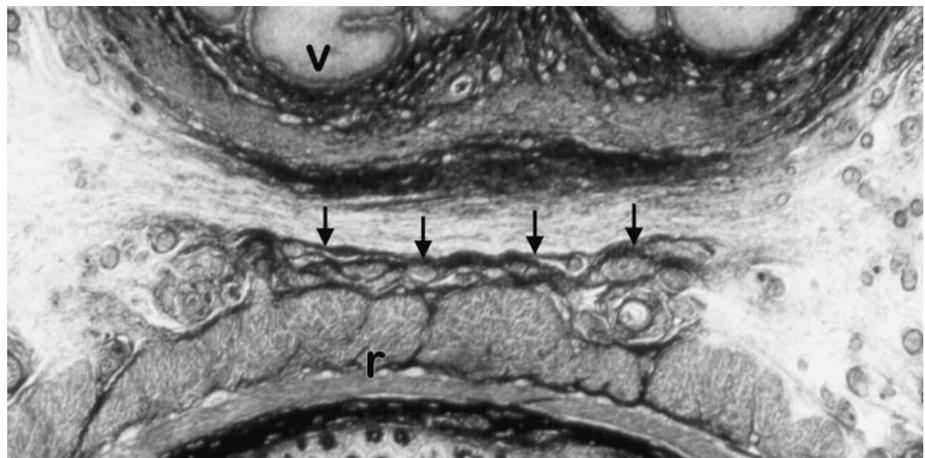


Fig. 1.3a-c. Perirectal tissue (*asterisks*). **a** Axial section (5 mm) of an adult female. $\times 0.45$. **b** Axial MR image of an adult female. **c** Axial section (400 μm) of a 24-week old female fetus. $\times 5$. *nvp*, nerve vessel plate; *r*, rectum

Fig. 1.4. Rectovaginal fascia (*arrows*). Axial section (400 μm) of a 24-week-old female fetus. $\times 28$. *v*, Vagina; *r*, rectum



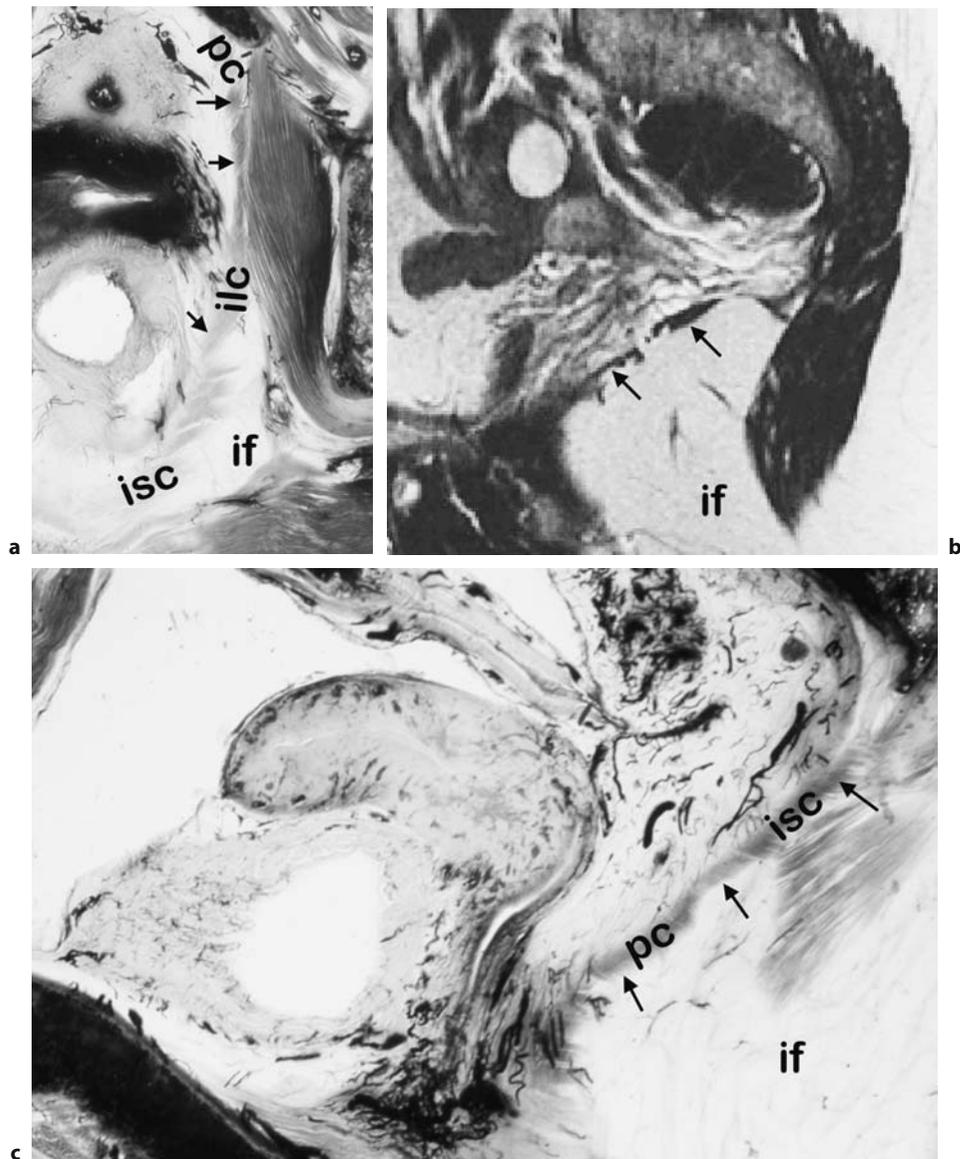


Fig. 1.5a–c. Levator ani muscle (arrows). **a** Axial section (5 mm) of an adult female. $\times 0.6$. **b** Parasagittal MR image of an adult female. **c** Sagittal section (5 mm) of an adult female. $\times 1.0$. *isc*, ischiococcygeal muscle; *if*, ischioanal fossa; *ilc*, iliococcygeal muscle; *pc*, pubococcygeal muscle

1.3.1.2 Muscles

Within the posterior pelvic compartment all components of the levator ani muscle are to be found: the pubococcygeus muscles and the iliococcygeus muscles constitute an irregular plate and insert into the coccyx where they overlap each other in a staggered arrangement (Fig. 1.5). The inferior component, the puborectalis muscles, do not insert into any skeletal

structure. Behind the rectal wall the fiber bundles of each puborectalis muscle criss-cross, thus constituting a muscular sling around the anorectal flexure (Fig. 1.6). In the craniocaudal direction the pubococcygeus muscle and the puborectalis muscle are more or less continuous. In sectional anatomy they can be differentiated by the different directions of their fiber bundles, those of the pubococcygeus taking a slightly descending course, those of the puborectalis exclusively situated in the horizontal plane. The different



Fig. 1.6a–c. Puborectalis muscle (*arrows*). **a** Axial section (5 mm) of an adult female. $\times 0.8$. **b** Axial MR image of an adult female. **c** Axial section (400 μm) of a female newborn specimen. $\times 4$. *u*, urethra; *v*, vagina; *r*, rectum

components of the levator ani muscle can already be distinguished in early fetal life [21]. Sexual differences found in the levator ani muscle of the adult are already marked in late fetal life: the levator ani constitutes a thick and well developed muscle in the male fetus whereas it is thinner and already intermingled with connective tissue in the female fetus (Fig. 1.6b). This is particularly true of its puborectalis portion.

The puborectalis muscle is continuous with the external anal sphincter caudally (Fig. 1.7). The macroscopic distinction between both muscles is provided by the anococcygeal body. The puborectalis has no skeletal attachment dorsally, but the deep portion of the sphincter ani externus is indirectly fastened to the coccyx by the anococcygeal body.

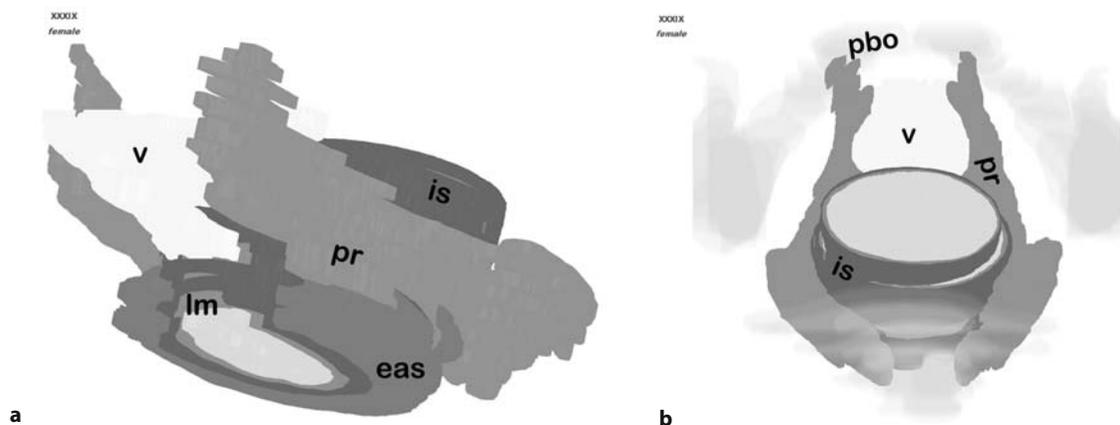


Fig. 1.7a,b. Computer-assisted reconstructions of a female fetus. **a** Oblique ventrolateral view. **b** Descending dorsoventral view. *v*, vagina; *lm*, longitudinal muscular layer; *pr*, puborectalis muscle; *eas*, external anal sphincter; *is*, internal sphincter; *pbo*, pubic bone

The sphincter ani externus is the outer part of the anal sphincter complex (see Table 1.1). The other components are the smooth internal sphincter and the longitudinal muscle layer of the anorectum, the latter is interposed between the sphincters. Whereas macroscopically the external anal sphincter presents itself as a continuous sheet covering the anal canal (Fig. 1.8a), it can be subdivided into a deep, anorectal portion and a superficial, subcutaneous portion in sectional anatomy (see Fig. 1.8b). This deep portion is a clearly demarcated layer of circularly arranged striated muscle fibers; the superficial portion is characterized by an intermingling of the striated muscle fibers with the smooth longitudinal muscle (also called “intersphincteric space”). The form of the external anal sphincter can be best studied in three dimensional reconstructions of histological or anatomical orthogonal sections [20]: At an anorectal level above the perineum where the external anal sphincter is continuous with the puborectalis muscle dorsally (Fig. 1.8c), it is missing in the midline ventrally, but it is thickened ventrolaterally where it becomes part of the anterior compartment in males and the middle compartment in females. At a level of the perineum the external anal sphincter is complete ventrally (see Fig. 1.15a), but it turns inwards and forms a muscular continuum with the smooth internal sphincter and the longitudinal muscle dorsally. As can be seen from the fetal sections, sexual differences in the anal sphincter complex are already present prenatally: the sphincter complex as a whole is thicker in the male than in the female, the anterior portion, however, is thick in the female and thinner and more elongated in the male.

1.3.1.3

Reinterpreted Anatomy and Clinical Relevance

The posterior compartment is predominated by the rectum and its surrounding connective tissue. The morphological demarcation of this compartment is formed by the rectal fascia. In CT the rectal fascia may be discriminated as a slightly hyperdense sheath [27, 47] and in MRI it is visible as a thin, hypointense structure. It is important for the diagnosis and staging of rectal tumor [4, 7, 28]. According to our results the macroscopic borders of the perirectal compartment are clearly demarcated in the adult female where the sacrouterine ligaments constitute the lateral borders and where the posterior border is marked by the pelvic parietal fascia. The perirectal adipose tissue constitutes functional fat that adapts to the different filling volumes of the rectum and constitutes a gliding sheath for the movements of that organ. In contrast to prior literature [43, 46] we did not find any ligament or even ligamentous structures binding the rectum to the lateral pelvic wall. Thus, there is neither a “rectal stalk” nor a dense “paraproctium”.

The most common surgically correctable cause of fecal incontinence in woman is childbirth with injury of the sphincter. External sphincter injuries occur in 6%–30% of woman [51]. It should be differentiated between complete or incomplete sphincter disruptions. Our morphological investigation [20] supports the fact that the external anal sphincter is not a totally circular muscle. We have thoroughly described the parts of the sphincter complex, in order to help the pelvic radiologists and surgeons to identify these structures and, if possible, to reconstruct them in a meticulous way.

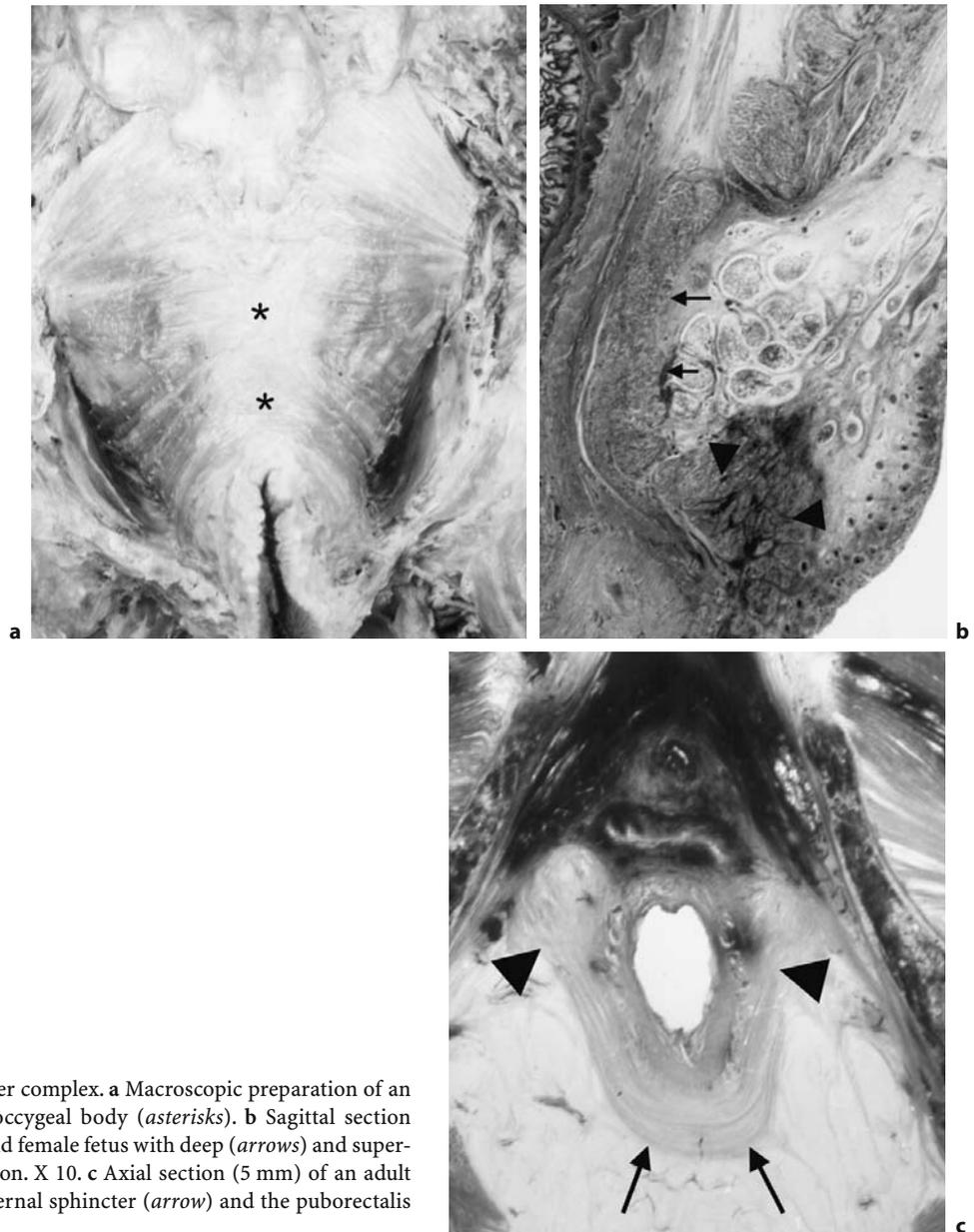


Fig. 1.8a–c. Anal sphincter complex. **a** Macroscopic preparation of an adult female with anococcygeal body (*asterisks*). **b** Sagittal section (500 μm) of a 20-week-old female fetus with deep (*arrows*) and superficial (*arrowheads*) portion. X 10. **c** Axial section (5 mm) of an adult female, fusion of the external sphincter (*arrow*) and the puborectalis (*arrowhead*). $\times 0.6$

Rectoceles are hernial protrusions of the anterior rectal wall and the posterior vaginal wall into the vagina and/or throughout the vaginal introitus. The size of the rectocele does not correlate with symptoms and it is often diagnosed in a population without symptoms. Trauma or obstetrical injuries weaken the rectovaginal fascia/septum. Rectoceles occur with laxity of the connective tissue in advancing years, multiparity, poor bowel habits, perineal relaxation and increased intra-abdominal pressure in constipation [31, 59]. In the successful repair of a rectocele the rectovaginal fascia/septum seems to be the key structure [8, 44].

1.3.1.4

Important Vessels, Nerves and Lymphatics of the Posterior Compartment:

- Superior rectal artery
 - Rectal nerves
 - Rectal lymph nodes
 - Inferior hypogastric plexus
 - Superior hypogastric plexus
 - Common iliac artery
 - Internal iliac artery
- (Veins have a corresponding course.)

1.3.2

Anterior Compartment

1.3.2.1

Connective Tissue Structures

When dissecting along the lateral and ventral wall in embalmed cadavers, it is easy to isolate the bladder including the embedding tissues and all the adjacent structures. During dissection, no lateral stalks are found that might be responsible for the fixation of the bladder or the urethra. Ventrally a cord can be identified. It takes an ascending course from the pubic bone to the neck of the bladder and it is usually called the pubovesical ligament (see Table 1.1) (Fig. 1.9a). It is connected to the tendinous arch of the pelvic fascia (see Table 1.1). Together, both structures incompletely subdivide the retropubic region into a prevesical subcompartment and a preurethral subcompartment. From the comparative sectional study of fetal and adult pelvis we learned the detailed composition of the connective tissue structures within the anterior compartment.

With the exception of its neck and its posterior wall the bladder is covered by adipose tissue (Fig. 1.9b). The latter constitutes a semicircular pad that fills the gap between the lateral pelvic wall and the ventral and lateral wall of the bladder. The fat pad is not sub-

divided by ligaments or any other dense connective tissue septa, but sometimes may be crossed by variable branches from the obturator vessels. It develops in situ (Fig. 1.9c) from a large paravisceral fat pad (see Table 1.1) in human fetuses [22] and neither contains large vessels, nerves nor lymphatics. The latter derive from the internal iliac vessels and join the dorsolateral edge of the bladder. Their branches, which are always accompanied by a sheath of dense connective tissue, embrace the bladder and urethra. Thus nerves, vessels and lymphatics are directly situated at the lateral and dorsal wall of the bladder and medially to the fat pad. Ventrocranially, both fat pads join in the midline. Their dorsal edge nearly abuts at the perirectal compartment and their caudal border abuts the levator ani laterally and the pubovesical or puboprostatic ligament ventrally. Thus they are not part of the preurethral subcompartment that is filled by connective tissue accompanying the deep dorsal vessels of the clitoris.

Within the anterior compartment two structures are found that are composed of dense connective tissue: the tendinous arch of the pelvic fascia that originates from the pubic bone and that is connected to the pelvic parietal fascia covering the levator ani muscle on its visceral side (superior fascia of the pelvic diaphragm; see Table 1.1) and the semicircular fibrous sheath that covers the ventral and lateral

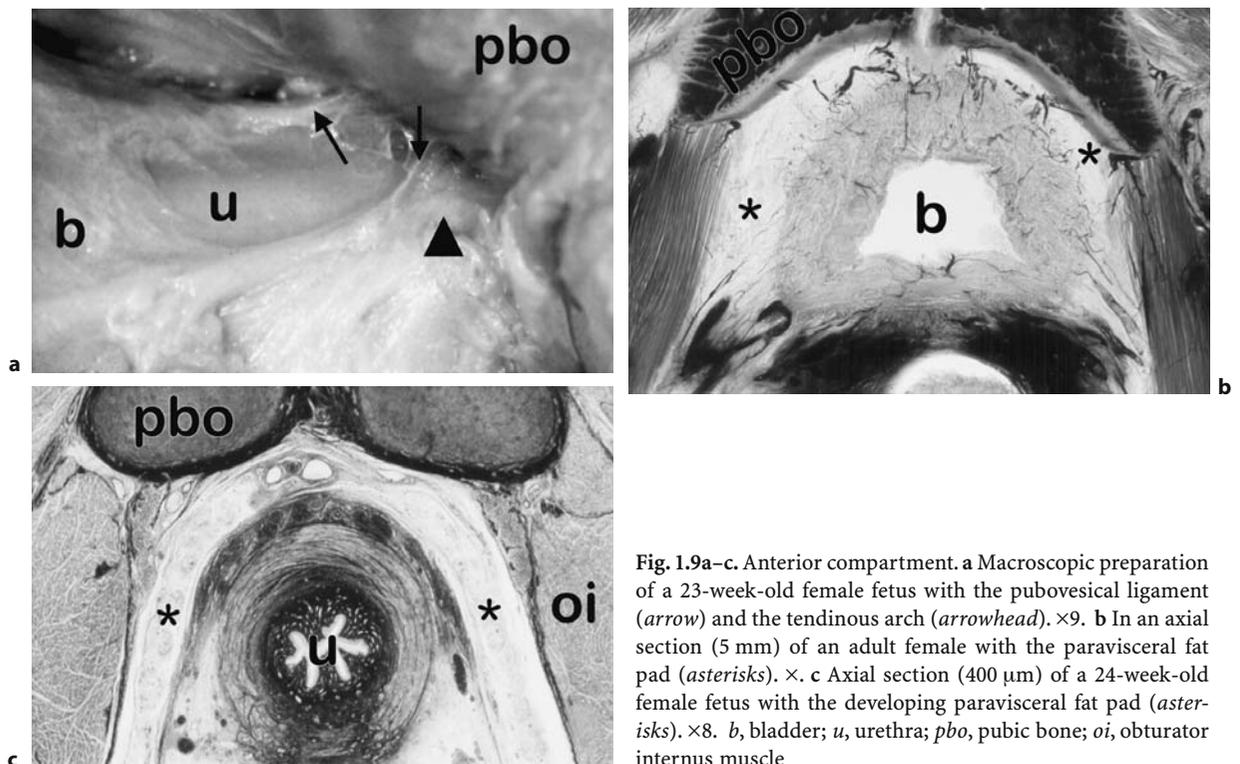


Fig. 1.9a–c. Anterior compartment. **a** Macroscopic preparation of a 23-week-old female fetus with the pubovesical ligament (arrow) and the tendinous arch (arrowhead). $\times 9$. **b** In an axial section (5 mm) of an adult female with the paravisceral fat pad (asterisks). \times . **c** Axial section (400 μm) of a 24-week-old female fetus with the developing paravisceral fat pad (asterisks). $\times 8$. *b*, bladder; *u*, urethra; *pbo*, pubic bone; *oi*, obturator internus muscle

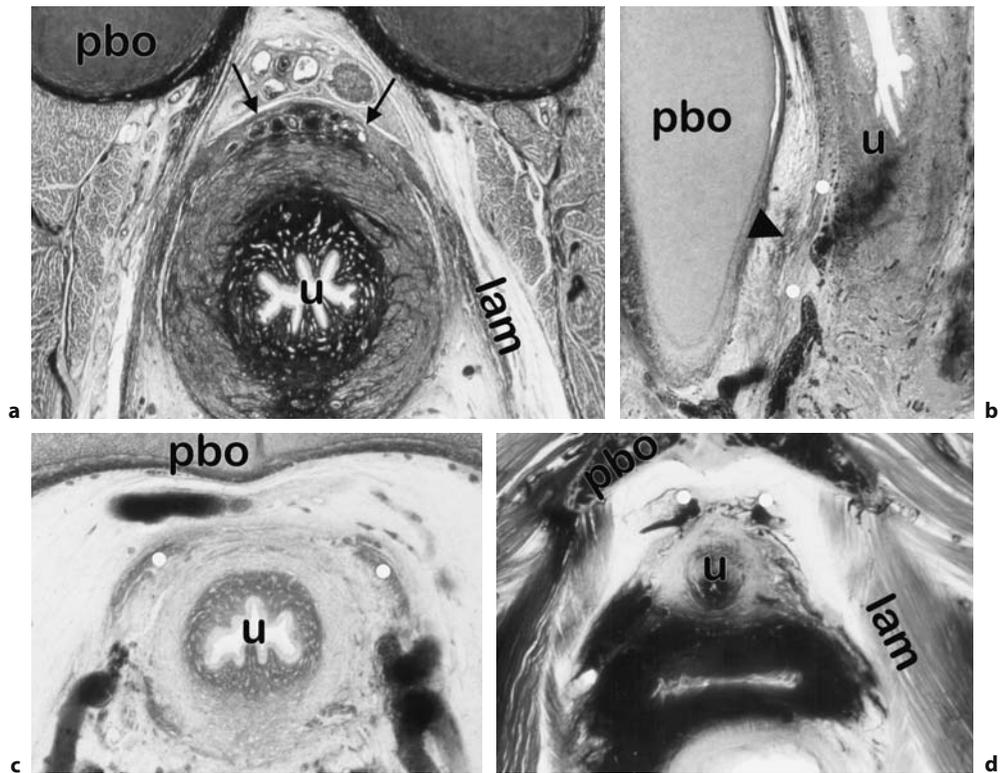


Fig. 1.10a–d. Anterior compartment and the so-called ligaments of the urethra. **a** Axial section (400 μm) of a 24-week-old female fetus with the semicircular urethral sheath (*arrows*). $\times 12$. **b** Sagittal section (500 μm) of a 13- to 14-week-old female fetus with the pubovesical ligament (*white spots*) and the origin of the tendinous arch (*arrowhead*). $\times 25$. **c** Axial section (400 μm) of a 17-week-old female fetus with the pubovesical ligaments (*white spots*). $\times 12$. **d** Axial section (5 mm) of an adult female with the pubovesical ligaments (*white spots*). $\times 7.5$. *pbo*, pubic bone; *u*, urethra; *lam*, levator ani muscle

wall of the bladder and the urethra. As the sheath is strong ventrally it can be considered as an incomplete ventral vesical or urethral fascia. Whereas the ventral vesical fascia has absolutely no fixation to the lateral pelvic wall, at a level of the urogenital hiatus the ventral urethral fascia, but not the urethra [37], is attached to the fascia of the levator ani muscle laterally (Fig. 1.10a). Thus, within the hiatus a fibrous bridge connects the fasciae of the levator ani muscles of both sides. To summarize: the fibrous structures of the anterior compartment build up a hammock-like [12] construction for bladder and urethra. These findings can most clearly be shown in fetuses and are matching but not so evident in the adult. It is important to know that there is absolutely no kind of a lateral bony fixation for bladder or urethra. In a dorsocranial direction, the ventral fascia of bladder and urethra is continuous with the connective tissue sheath of the internal iliac vessels. Ventrally, the hammock-like construction is indirectly fixed to the pu-

bic bone by means of the tendinous arch and by the so-called pubovesical ligament (Fig. 1.10b–d). The latter is composed of cholinergic innervated smooth muscle cells [57] and is connected to the vesical neck cranially (see above).

An additional fibrous structure can be found to close the hiatus ventrally: a plate of dense connective tissue fills the space between pubic bone and urethral sphincter, thus constituting the perineal membrane (Fig. 1.11a).

1.3.2.2 Muscles

The striated muscles of the anterior compartment are the ventral parts of the levator ani muscle (see Table 1.1), i.e. the pubococcygeus and puborectalis muscle of each side. As they are covered by the superior fascia of the pelvic diaphragm, they are clearly separated by the adjacent organs (Fig. 1.10a,d and

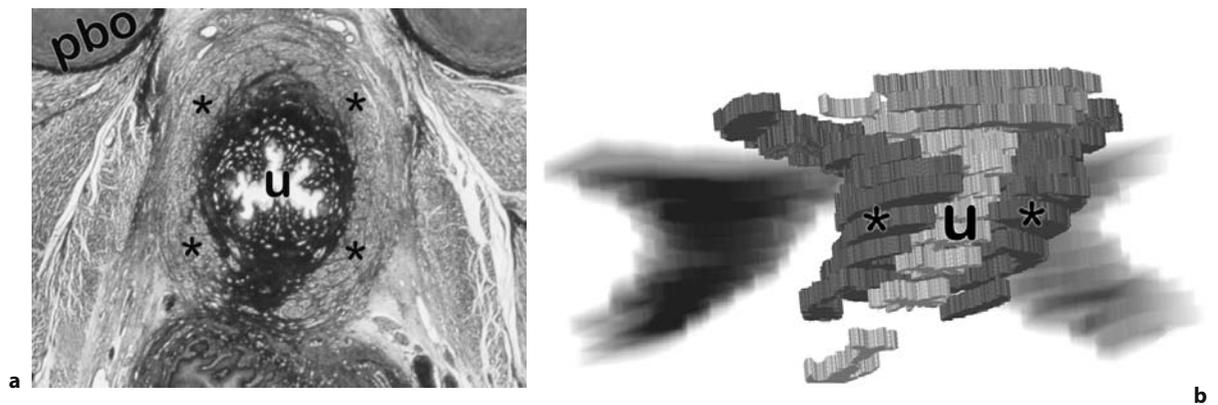


Fig. 1.11a,b. External urethral sphincter (*asterisks*). **a** Axial section (400 μm) of a 24-week-old female fetus, embedded in the transverse perineal membrane. $\times 9$. **b** Computer-assisted three-dimensional reconstruction of a female fetus. *pbo*, pubic bone; *u*, urethra

Fig. 1.11a) and the external urethral sphincter. As has been reported previously [37], this muscle is horse-shoe- or omega-shaped during fetal development and incompletely covers the urethra (Fig. 1.11). The dorsal ends of this muscle are connected by a plate of dense connective tissue that is small in the female where it is firmly attached to the ventral wall of the vagina (Figs. 1.10d, 1.11a). Whereas most of the fibers of the external urethral sphincter run semicircular, the most caudal fibers nearly run in a transverse plane. This portion predominates in the male and therefore has been considered as the male's deep transverse perineal muscle. However, it does not exist in the female [42].

As has been described above, smooth muscles are found outside the walls of the urogenital organs constituting parts of the pubovesical ligament in front of the ventral wall of the urethra.

1.3.2.3

Reinterpreted Anatomy and Clinical Relevance

The extent of the fat pad described here is identical to the anterior portion of the paravisceral space as reported by GASPARRI and BRIZZI [25]. It is obvious that the main function of the semicircular, paravisceral fat pad is to constitute a gliding pad for the bladder [33]. The fat pad accompanies the bladder whenever moving.

DORSCHNER et al. [14] pointed out the fact that the smooth muscle bundles of the pubovesical ligaments are continuous with longitudinal muscle fibers of the neck of the bladder that they call dilatator urethrae. Maybe again there is a similarity to the anorectum, where we also found smooth muscle bundles and autonomic nerves outside the ventral wall, which we

think work in functional coactivity to the longitudinal internal bundles [1]. Nevertheless, it seems to be sure that the function of the so-called pubovesical ligaments which receive a presumptive cholinergic innervation [57] is not fixing the urethra to the pubic bone but maintaining its position relative to the bone during micturition [26]. In contrast the contraction of the levator ani muscle and the external urethral sphincter leads to a narrowing of the preurethral space and to an ascending movement of the urethra as can be seen in dynamic MRI [16, 48].

Due to our results that in principle support the hammock hypothesis of DELANCEY [12], an operative "refixation" of the urethra and the bladder neck should result in an ascending dorsocranial traction (nerve guiding plate), as well as a descending ventro-caudal traction (tendinous arch of the pelvic fascia). Though there are innovative ideas regarding the surgical reconstruction of the female urinary tract [55], most procedures are not performed according to the morphological needs, because they mostly consider only one part of the so-called fixation system.

1.3.2.4

Important Vessels, Nerves and Lymphatics of the Anterior Compartment:

- Inferior vesical artery
- Branches to the ureter
- Superior vesical artery
- Vesical lymph nodes
- Internal iliac lymph nodes
- Internal iliac artery
- Inferior hypogastric plexus
- Paravesical fat pad
(Veins have a corresponding course.)

1.3.3 Middle Compartment

1.3.3.1

Connective Tissue Structures

In macroscopic dissections of the adult female pelvis it is impossible to isolate ligaments fastening the cervix uteri or the vagina to the lateral pelvic wall and thus separating the middle compartment from the anterior or the posterior one laterally. In a refined macroscopic dissection performed with a binocular dissecting microscope it is possible – as well as in any other part of the pelvic subperitoneal tissue – to isolate connective tissue septa within the adipose tissue surrounding uterus and vagina [9, 10]. Our study of female fetal and adult pelvic sections reveals the true nature of the connective tissue structures surrounding uterus and vagina. The only connective tissue belonging to the middle compartment accompanies the vessels of uterus and vagina thus running parallel to the lateral walls of these organs. In fetuses, the connective tissue is still loose and without a differentiated structure, in the adult it mainly consists of adipose tissue with regular connective tissue septa (Fig. 1.12a–d) and it is continuous with the broad ligaments (see Table 1.1) laterally. The paracervical connective tissue abuts to the paravesical adipose tissue laterally and the paravaginal connective tissue abuts to the pelvic parietal fascia caudally (Fig. 1.12a,b). The broad ligaments themselves are part of the recto-uterine and the vesico-uterine folds (see Table 1.1) that tangentially cover the anterior and posterior uterine walls [18]. Apart from dense subperitoneal connective tissue that covers the recto-uterine pouch (see Table 1.1) (Fig. 1.12e) and mainly consists of collagenous fibers, no supportive ligaments are found for the female fetal uterus. In the adult, this condensation of subperitoneal connective tissue has developed to the uterosacral ligaments (see Table 1.1). They are visible in the transparent sections as well as on MRI and form semicircular cords varying in thickness individually. They originate from the lateral margin of the cervix uteri and the vaginal vault and course dorsocranially where they are connected to the pelvic parietal fascia covering the sacrospinous ligaments and the sacrum. As they are part of the recto-uterine ligaments they cover the perirectal tissue laterally. Our study undoubtedly confirmed the existence of the round ligaments as well as their course and their components. However, ligamentous structures constituting cardinal or transverse ligaments (see

Table 1.1) [34, 38] that are to be supposed to fasten the cervix uteri and the vaginal vault with the lateral pelvic wall can not be found in the adult pelvis. Our findings that have been taken from anatomic sections of elder specimens unrestrictedly correlate with the results of the MRI taken from young adult female pelvis (Fig. 1.13).

Subperitoneally, the middle compartment and its organs abut the anterior compartment ventrally. This area is predominated by the dense connective tissue bridge intimately connecting the ventral vaginal wall with the dorsal urethral wall (Fig. 1.12b) (see also Sect. 1.3.2).

Dorsomedially, the middle compartment abuts the posterior compartment. The border between these compartments is demarcated by the rectovaginal fascia/septum (see also Sect. 1.3.1), that is composed of dense connective tissue, elastic fibers [44] and smooth muscle cells that belong to the longitudinal layer of the rectal wall.

The uterine tubes lie on each side of the uterus in the upper margin of the broad ligament (see Table 1.1; broad ligament). Each tube is attached on its inferior surface to a double fold of peritoneum called mesosalpinx (see Table 1.1). The lateral and superior part of the tube is the ampulla that opens into the funnel-shaped infundibulum with its fimbria at the abdominal orifice. The ovaries lie in the ovarian fossa, i.e. close to the lateral pelvic wall and are suspended by a double fold of peritoneum, the mesovarium (see Table 1.1). The latter is attached to the broad ligament posteriorly. Behind the ovarian fossa are extraperitoneal structures, especially the ureter and the internal iliac vessels as well as the origin of the uterine artery (Fig. 1.14).

1.3.3.2

Muscles

The middle compartment does not have any specific striated muscles. The lateral vaginal wall comes in close contact to the puborectalis portion of the levator ani muscle. Both structures are always separated by the superior fascia of this muscle (Fig. 1.6b).

1.3.3.3

Reinterpreted Anatomy and Clinical Relevance

Though there are a lot of anatomical and clinical terms describing the tissue surrounding uterus and vagina, neither their definitions nor their origins are clear. The mesometrium (see Table 1.1) for example may be considered to be the largest part of the broad ligament extending from the pelvic floor to the

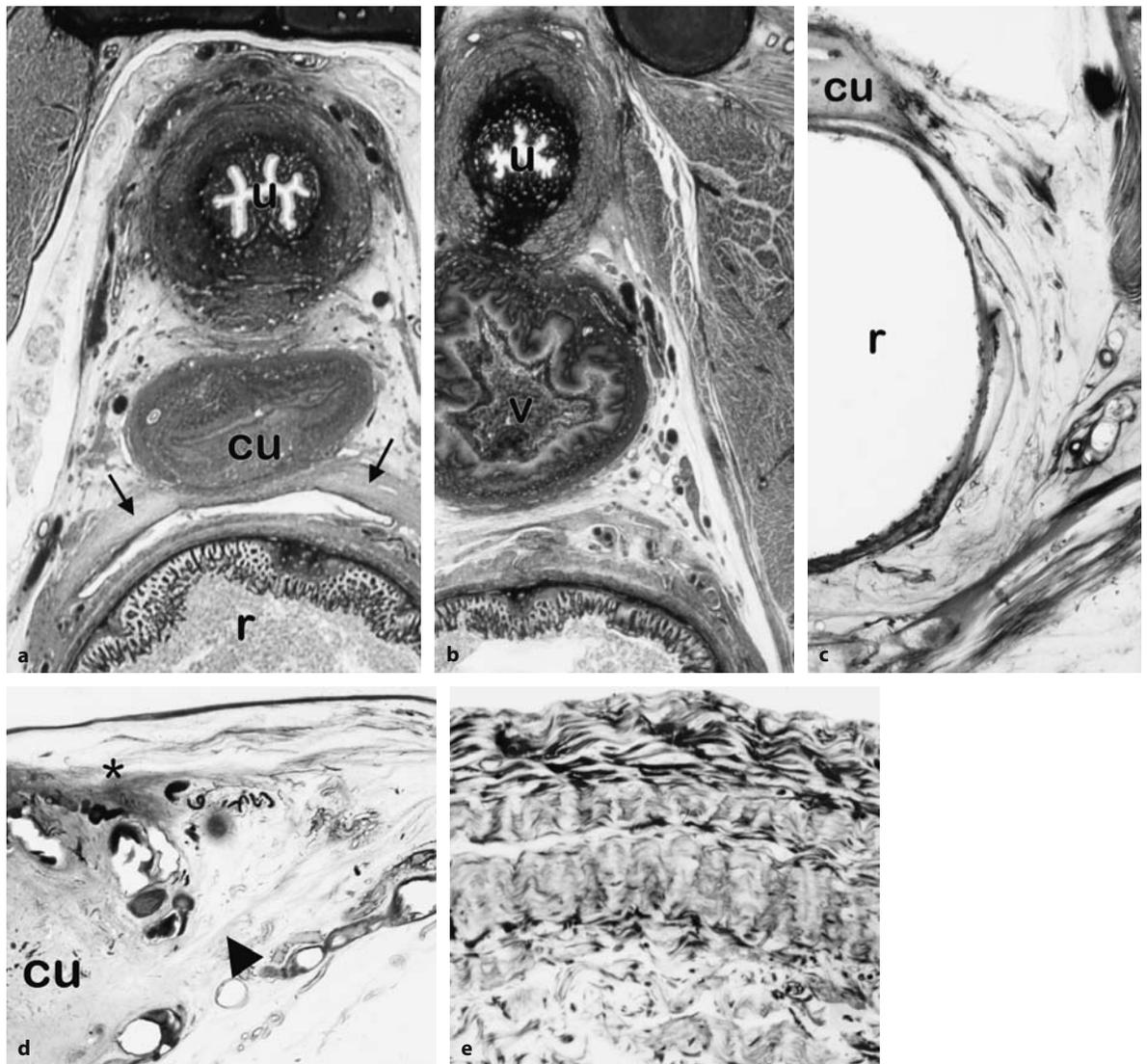


Fig. 1.12a–e. Paracervical and paravaginal tissue. **a** Axial section (400 μ m) of a 24-week-old female fetus at a level with the recto-uterine pouch covered by dense connective tissue (*arrow*). $\times 8$. **b** Axial section (400 μ m) of the same fetus at a level with the vagina embedded in loose paravaginal tissue. Vagina and urethra are intimately connected. $\times 8$. **c** Axial section (3 mm) of an adult female with the paracervical tissue. $\times 0.8$. **d** Enlargement of an axial section (3 mm) of the same specimen with origin of the round ligament (*asterisk*) and the uterosacral ligament (*arrowhead*). $\times 3.5$. **e** Enlargement of (a) with parallel oriented connective tissue fibers constituting the subperitoneal part of the uterosacral ligament. $\times 40$. *u*, urethra; *cu*, cervix uteri; *r*, rectum; *v*, vagina

uterine body enclosing the uterine artery or the connective tissue lying directly beneath the peritoneal covering of the uterus. As has been re-emphasized by HÖCKEL et al. [29] the knowledge of the possible extent of local tumour spread is essential for the planning of surgery and radiotherapy, especially in the female pelvis. Like the posterior compartment with its mesorectum, the “mesometrium” (see Table 1.1) has been redefined and was identified to

be the anatomical territory derived from common precursor tissues. Thus a new operation technique was proposed to operate carcinoma of the uterine cervix (stages IB–IIA). It is termed total mesometrial resection and is identified as the morphogenetic unit for the cervix and the proximal vagina including its neurovasculature.

Surgical techniques for the fixation of uterus and vagina are numerous. They all depend on the idea

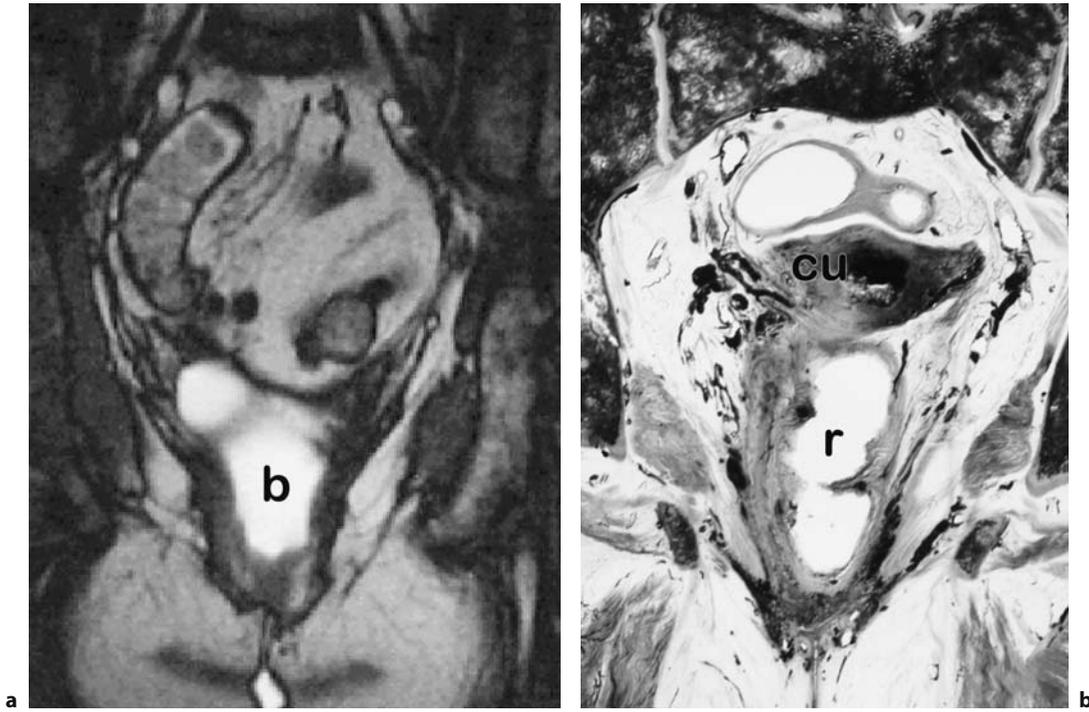


Fig. 1.13a,b. Subperitoneal connective tissue and nerve vessel guiding plate. a Coronal section (3 mm) of an adult female with pararectal and paracervical tissue. $\times 0.4$. b Coronal MR image of an adult female with paravesical and paracervical tissue



Fig. 1.14. Axial section (400 μm) of a 24-week-old female fetus at a level with the ovarian fossa (arrow). $\times 4$

that there are sheath-like condensations within the pelvic cavity that are commonly called fascia. Moreover, these fasciae are thought to be responsible for acting as supportive structures to the uterus and vagina and thus they need to be reconstructed during operation. We think this point is one of the most critical to be discussed in this chapter.

Our reinterpreted anatomy of the connective tissue surrounding uterus and vagina is:

- In accordance with former Anglo-American authors [5, 32, 54] we do not find any visceral fascia covering uterus and vagina. Both organs are accompanied by adventitial connective tissue. The rectovaginal fascia/septum develops in situ [36] and is connected to the uterosacral ligaments, to the longitudinal muscular layer of the rectum and to the perineum (see Sects. 1.3.1 and 1.4).
- As has been clearly summarized by BASTIAN and LASSAU [2] various ligaments are supposed to exist in the pelvis of the adult female. Our results show that – apart from the uterosacral and the round ligaments – no ligaments of the uterus can be found in conventional anatomical specimens, sections or by MRI. We showed, however, that the paracervical and paravaginal region contains adipose tissue, numerous vessels, nerves and connective tissue septa. All together these components may be confounded with a ligamentous structure, especially in the older female. The connective tissue septa have carefully been described by new morphological approaches [10, 13], but they have been over-interpreted as to their functional meaning. There is no doubt that some of these connective tissue septa are connected to the fascia of the levator ani muscle and the contraction of this muscle is directly transferred to the septa and thus also to the vagina. But due to their morphological characteristics they are not supposed to act as supportive structures.

Our results are still in disagreement with the classical descriptions found in clinical and anatomical textbooks. We are aware of the fact that the variability of nomenclature is also misleading. But, nevertheless, the only fixation of the uterus is provided by the sacrouterine ligaments running in a dorsocranial direction. These ligaments are connected to the pelvic parietal fascia at a level with the sacrospinous ligaments, thus producing an upward traction for the whole uterovaginal complex.

There are various surgical procedures to reconstruct the so-called supportive ligaments in patients with

genital prolapse. Due to our morphological data, it is useful to carry out a sacral fixation of the uterovaginal complex in terms of prolapse [39, 52], taking into account that the pudendal vessels and the pudendal nerve are not injured during operation [41]. New techniques include meshes that are suggested to support all female pelvic organs [6]. The results of these techniques seem to open the field of female hernia surgery.

1.3.3.4

Important Vessels, Nerves and Lymphatics of the Middle Compartment:

- Uterine artery
- Inferior hypogastric plexus. (Veins have a corresponding course)

1.4

Perineal Body

1.4.1

Connective Tissue Structures and Muscles in the Female

The perineal body separates the urogenital and anal hiatus. It is situated between rectum and vagina, i. e. between the posterior and middle compartments. Within the region of the perineal body the skin is firmly attached to the underlying connective tissue. The perineal body consists of dense connective tissue. It does not possess its own musculature, but it serves muscles of the perineal region to originate or to attach (Fig. 1.15a). Whereas the external anal sphincter is attached to it dorsally (Fig. 1.15a), the muscles of the cavernous tissue are attached ventrally (Fig. 1.15b). A deep transverse perineal muscle that may be attached ventrally does not exist in the female [42]. As has already been pointed out above (see Sect. 1.3.1) the additional smooth rectal muscle bundles that are situated in the rectovaginal fascia/septum are integrated and attached to the connective tissue of the perineal body (Fig. 1.15c). As the region of the female's perineal body is of high clinical interest in terms of damage during childbirth and/or episiotomies [58], again it is described according to the gynecologist's point of view, i.e. from outside (inferior) to the inside (superior): At a level below the orifice of the vagina the external anal sphincter is attached to the perineal body (Fig. 1.15a), whereas at a level with the orifice

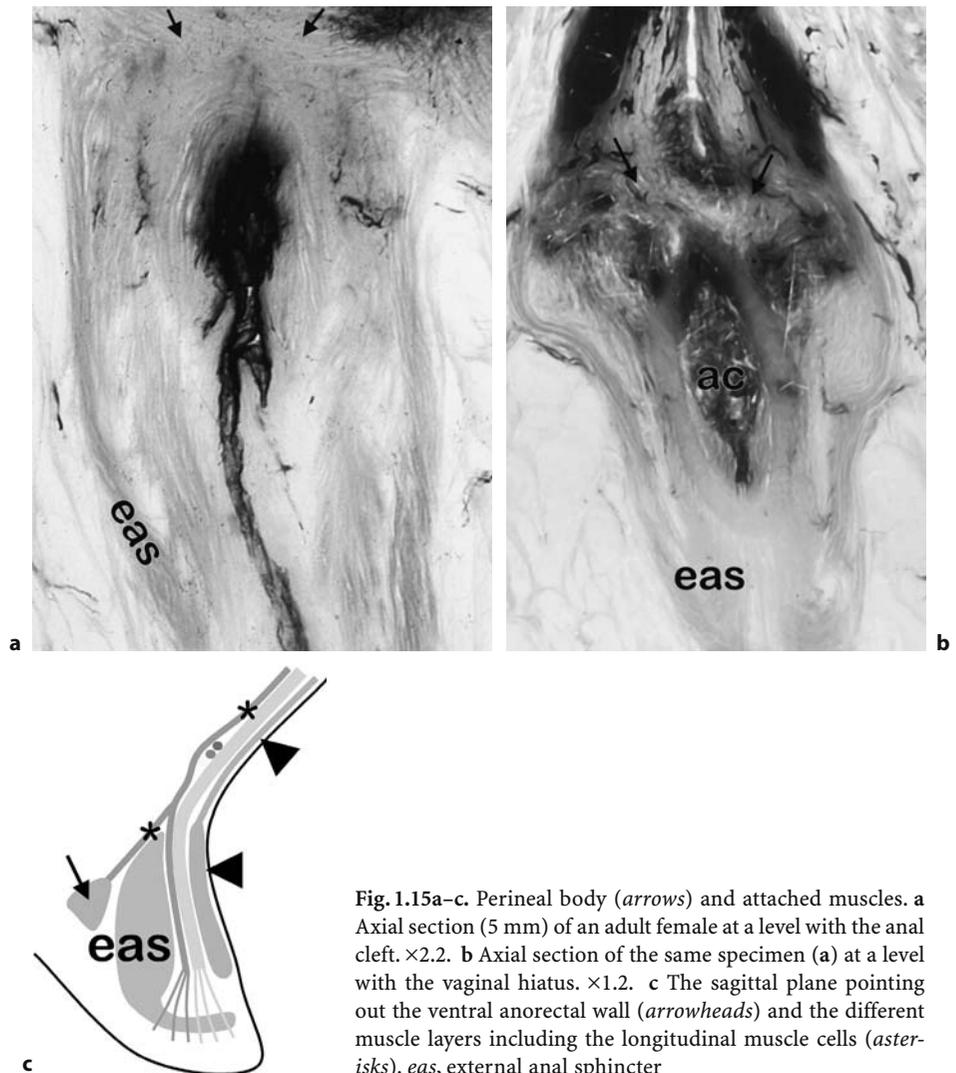


Fig. 1.15a–c. Perineal body (*arrows*) and attached muscles. **a** Axial section (5 mm) of an adult female at a level with the anal cleft. $\times 2.2$. **b** Axial section of the same specimen (**a**) at a level with the vaginal hiatus. $\times 1.2$. **c** The sagittal plane pointing out the ventral anorectal wall (*arrowheads*) and the different muscle layers including the longitudinal muscle cells (*asterisks*). *eas*, external anal sphincter

of the vagina and above the internal sphincter abuts the perineal body and thus indirectly the dorsal wall of the vagina (Fig. 1.15b). At these levels the external sphincter embraces the anal canal, the perineal body and the dorsal wall of the vagina laterally.

The intralevatoric side of the perineal body is connected with connective tissue septa of the ischioanal fossa [11] that are also connected to the inferior fascia of the levator ani muscle [30].

1.4.2 Reinterpreted Anatomy and Clinical Relevance

A detailed knowledge of the anatomy of the perineal body has become of interest since transperineal or even dynamic transperineal ultrasound [3] have been

carried out. With the help of these techniques, the infralevatoric viscera, the soft tissues and the puborectalis can be viewed and defined.

For a long time there has been no doubt about the existence of the fibrous components of this region. However, defined in the actual *Terminologia Anatomica* [15], the perineal body should be a fibromuscular rather than a tendinous structure. We categorically disagree with this opinion. The perineal body itself is a fibrous structure, but it is intermingled with all originating and inserting muscles. It has to be considered as a tendinous center for all the muscles that do not have a bony origin or attachment. There is no doubt that it is an important region for absorbing part of the intrapelvic (intraabdominal) pressure. A stretched or even destroyed perineal body may be the cause for urogenital or rectal prolapse [59].

From a morphological as well as a functional point of view there is need for discussion as to how and whether a surgical approach through an intact perineal body should be performed.

The discussion of pelvic floor damage during vaginal delivery and/or after episiotomies has been kindled through the remarkable statistics of SULTAN et al. [51], who showed that episiotomies do not prevent tearing. We think that the indication for episiotomies should clearly be defined by an international committee and it should be restricted to special cases. Perineal damage

may occur not only spontaneously but also iatrogenically through the execution of an episiotomy. It is not at all “old-fashioned” to protect the perineum during vaginal delivery by hands-on methods.

We recommend not carrying out median and lateral episiotomies and being careful with mediolateral ones: As can be seen from a pathological specimen in Fig. 1.16, a perineal tear and/or a lateral episiotomy has led to a scar of the perineal body and the external anal sphincter. The connective tissue septa of the ischioanal fossa are irregular (Fig. 1.16a). At the border between

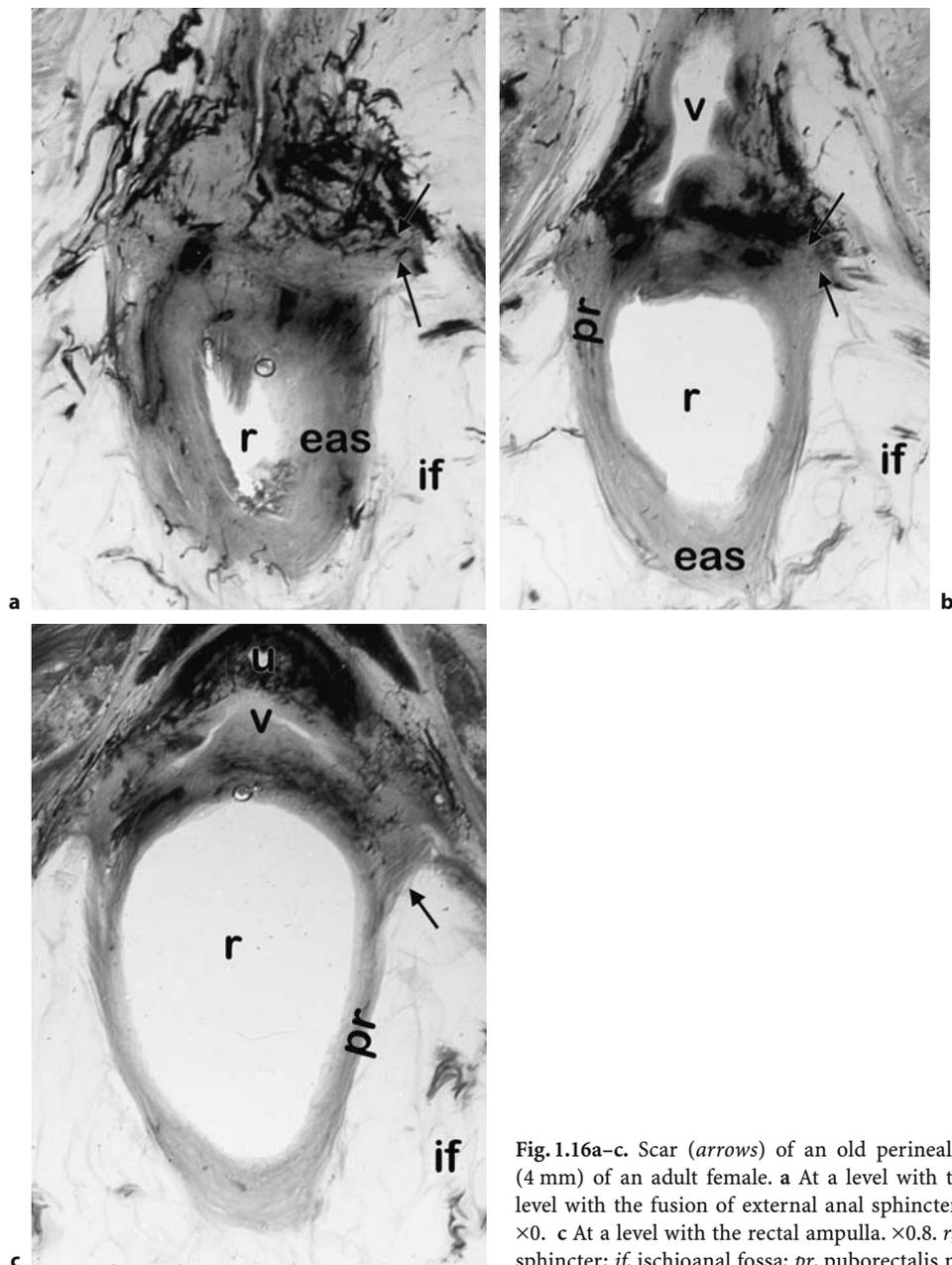


Fig. 1.16a–c. Scar (arrows) of an old perineal rupture in axial sections (4 mm) of an adult female. a At a level with the perineum. $\times 0.8$. b At a level with the fusion of external anal sphincter and puborectalis muscle. $\times 0$. c At a level with the rectal ampulla. $\times 0.8$. r, rectum; eas, external anal sphincter; if, ischioanal fossa; pr, puborectalis muscle; v, vagina

the infralevatoric and levatoric level, it becomes visible that the vaginal wall is slightly displaced, the puborectalis is rather thin and the ischioanal fossa is not symmetric with the contralateral side (Fig. 1.16b), a diagnosis that still remains on supralelevatoric levels (Fig. 1.16c). Refined and functional surgical treatment of perineal tears seems to be necessary to avoid such situations. As modern imaging techniques allow a fast and reliable examination, it is the gynecologists' task to improve the surgical treatment.

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