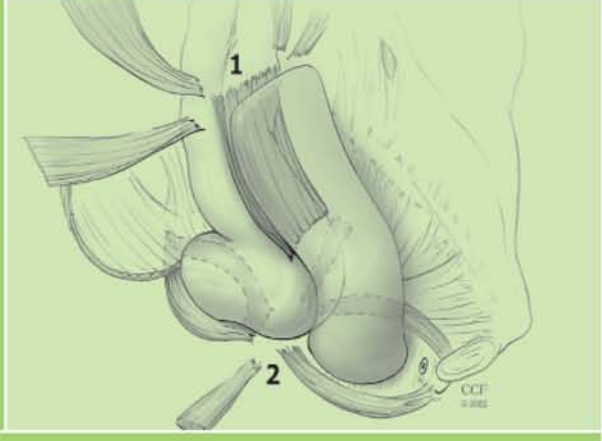
Practical Guide to



Female Pelvic Medicine

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Practical Guide to Female Pelvic Medicine

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Foreword

To follow

Preface

To follow

Chapter 1

Pelvic floor anatomy

Chahin Achtari and Peter L Dwyer

Introduction

The aim of this chapter is to present an overview of the normal anatomy of the pelvis. This will provide the clinician with a better understanding of the function and support of pelvic organs and their relevance to modern urogynecologic practice.

Bony pelvis and ligaments

The intra-abdominal cavity extends from the diaphragm cranially to the pelvic floor caudally. When humans adopted the standing position, the gravitational effect of intra-abdominal pressure was transferred from the abdominal (as in quadrupeds) to the pelvic floor musculofascial complex. Muscles that quadrupeds contract voluntarily to move their tail have progressively evolved into supportive structures that require continual involuntary tonic contraction but also need to provide rapid voluntary contraction for continence mechanisms to bladder and bowel.

The bony pelvis is composed by two coxal bones, the sacrum and the coccyx. Each coxal bone is composed by the fusion of the pubis, ischium, and ilium (Figure 1.1). Anteriorly, coxal bones are tightly attached to each other at the symphysis pubis and posteriorly to the sacrum at the sacroiliac junction. Pubic bones have two branches each: the inferior pubic rami fused with the ischium and the superior pubic rami fused with the ilium. The area circumscribed by the pubic rami and the ischium is the obturator foramen, which has a strong connective tissue membrane (the obturator membrane), with the obturator neurovascular bundle on its superior-lateral aspect (the obturator canal).

Two strong ligaments arise from the lateral margins of the sacrum: the sacrotuberous ligament, attaching to the ischial tuberosity; and the sacrospinous ligament, which attaches to the ischial spine (Figure 1.2). The pectineal ligament runs along the superior margin of the internal surface of the superior pubic rami. It has no supportive role but is used as an

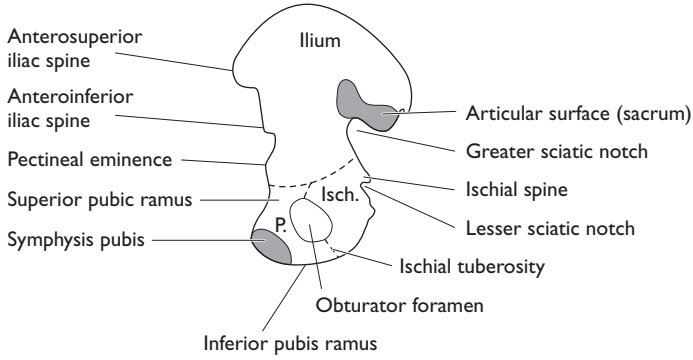

Figure 1.1 Right coxal bone, medial view. P = pubic bone, Isch = ischial bone, Il = iliac bone. Note that in the standing position, the anterior superior iliac spine and the anterior margin of the pubic bone lie in the same vertical plane.

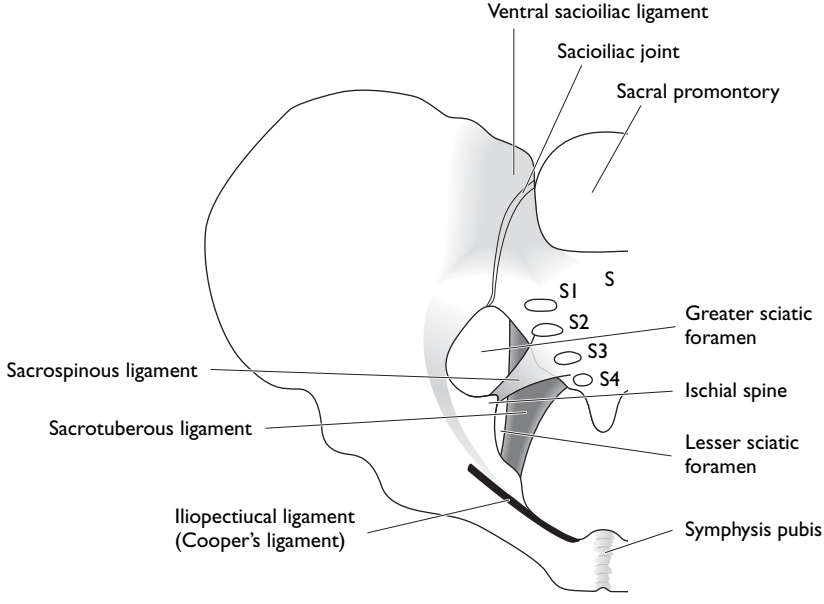

Figure 1.2 Right hemipelvis and ligaments, anterior superior view. S = Sacrum, S1–4 = Sacral foramina.

anchoring structure in some anti-incontinence procedures (e.g. Burch colposuspension).

The ischial spine is an important landmark and is easily palpable through the vagina or rectum. It plays a central role in pelvic floor support as an anchoring structure for several important ligaments. The *sacrospinous liga-*

ment has an important role in pelvic reconstructive surgery for it can be used as an anchoring structure during vaginal vault suspension (sacrospinous vaginal vault suspension). The sacrospinous ligament separates the greater from the lesser sciatic foramen. The *arcus tendineus levator ani* (ATLA) is the lateral tendinous attachment of the levator ani muscle and extends anteriorly from the internal aspect of pubic bone, running along the pelvic sidewall to attach posteriorly to the ischial spine. Finally, the endopelvic fascia that supports pelvic organs is attached to the *arcus tendineus fascia pelvis* (ATFP), a band of dense connective tissue running from the back of pubic symphysis to the ischial spine (Figure 1.3).

Pelvic floor muscles and nerve supply

Pelvic floor muscles (or levator ani muscle) are divided into two main portions: the pubovisceralis medially; the iliococcygeus and coccygeus laterally and posteriorly. These are paired structures that are fused together in the midline. Puborectalis muscle is bulkiest and most medial aspect of pubovisceralis muscle. It arises from the back of the pubic bone and runs almost horizontally to wrap like a sling around the back of the anorectal junction, elevating the rectum and other pelvic organs cranially and anteriorly. Its medial border forms the urogenital hiatus through which urethra, vagina,

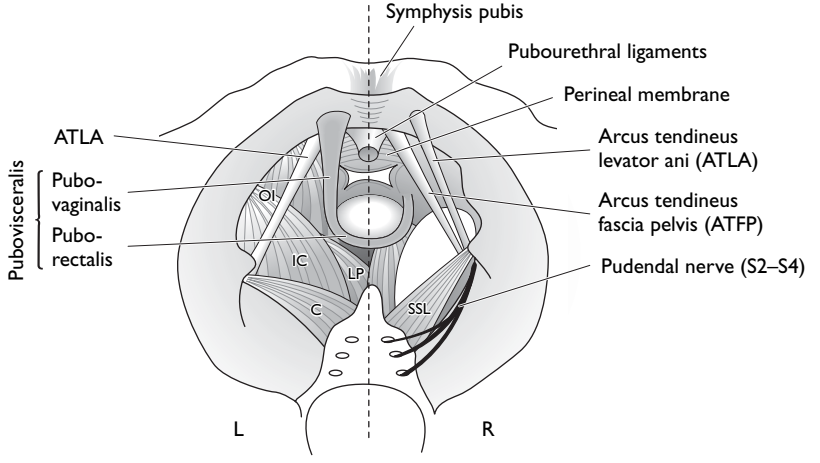

Figure 1.3 Pelvic floor muscles and ligamentous support, superior view. On the right side, pelvic floor muscles have been removed to demonstrate important ligaments inserting on the ischial spine (SSL = sacrospinous ligament, ATLA, and ATFP). The pudendal nerve exits the pelvic cavity through the greater sciatic foramen, turns around the ischial spine, and re-enters the pelvic cavity through the lesser sciatic foramen. On the left side, pubovisceralis gives fibers to the vagina and rectum. PC = pubococcygeus forming posteriorly with the iliococcygeus (IC) the levator plate (LP). OI = obturator internus muscle.

and anal canal pass. It gives muscular fibers to these structures and is therefore divided into specific portions called pubovaginalis and puborectalis (Figure 1.3).

Pubococcygeus is the lateral part of pubovisceralis muscle. It arises from the back of pubic bone and anterior part of the ATLA. Pubococcygeus connects pubis with coccyx and is fused with its counterpart along the median raphe, which runs from the back of the rectum to the coccyx. Laterally and posteriorly lies the iliococcygeus muscle, which is a thinner layer of muscle arising from the ATLA and is also fused with its counterpart along the median raphe and attached posteriorly to the coccyx. Together with the pubococcygeus, they provide a shelf called the 'levator plate' on which pelvic organs rest. The coccygeus muscle forms the posterior part of the pelvic diaphragm. It runs from the ischial spine to the coccyx and lower sacrum. Its superior and posterior aspect is made of dense connective tissue forming the sacrospinous ligament (Figure 1.3).

The pelvic diaphragm refers to the levator ani and coccygeus muscles with their superior and inferior fasciae. The perineal membrane (urogenital diaphragm) refers to a triangular layer of dense connective tissue lying inferiorly to the pelvic diaphragm in the anterior pelvic triangle. It attaches distal urethra, vagina, and perineal body to the inferior pubic rami. Superficial to the perineal membrane are the ischiocavernosus, the bulbocavernosus, and the superficial transverse muscles completing the inferior aspect of urogenital diaphragm (Figure 1.4). Posteriorly, there is no equivalent to the perineal membrane. The external anal sphincter lies in this plane attached anteriorly to the superficial transverse perinei and bulbocavernosus, forming the perineal body, and posteriorly to the coccyx.

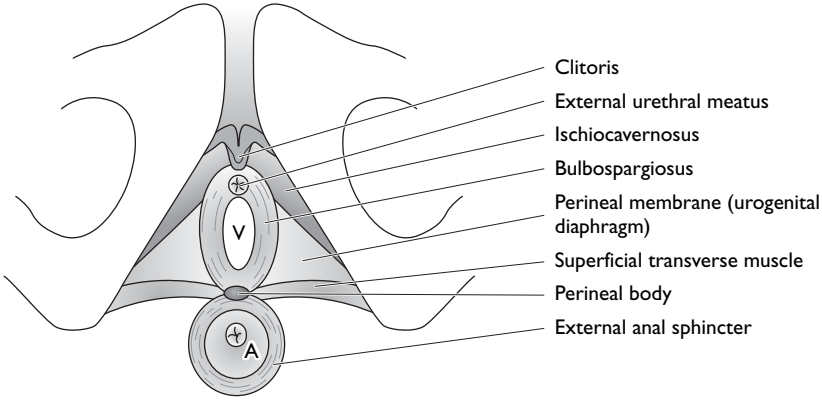

Figure 1.4 Superficial perineal muscles. V = vagina, A = anus.

The pudendal nerve provides the pelvic floor somatic innervation, arising from the sacral roots S2–S4. The pudendal nerve exits the pelvic cavity through the greater sciatic foramen, passes behind the ischial spine and sacrospinous ligament and re-enters the pelvic space through the lesser sciatic foramen. It then enters into the pudendal (Alcock's) canal formed by the duplication of obturator internus membrane along the inferior pubic ramus (Figure 1.5). The pudendal nerve gives three branches:

- The first branch is the inferior rectal nerve that arises at the beginning of the pudendal canal and penetrates the ischiorectal fossa. It gives motor branches to the lower rectum and the external anal sphincter and sensory branches to the skin anterior and lateral to the anus.
- The second branch of the pudendal nerve, the perineal nerve, arises from the middle of the pudendal canal and gives a sensory perineal branch and a motor branch for the external urethral sphincter and perineal muscles.

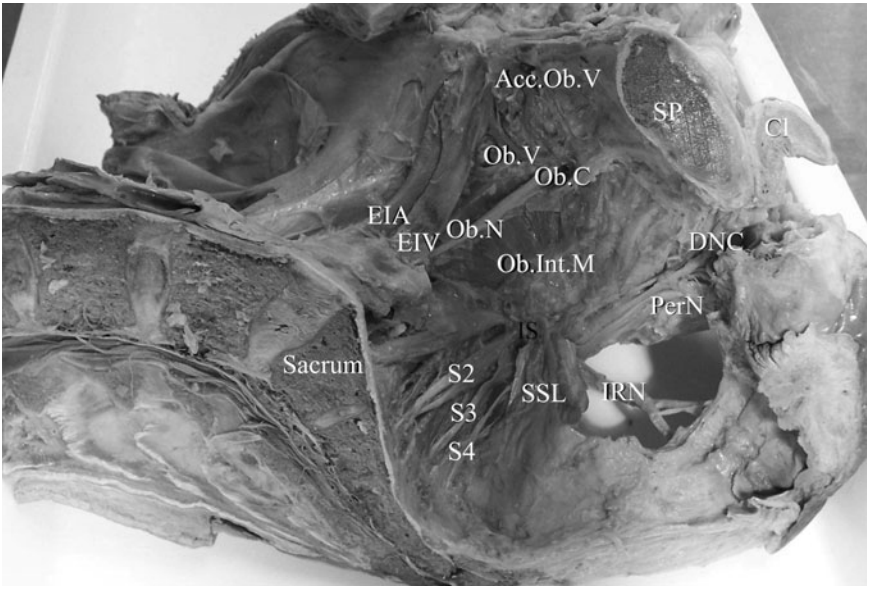

Figure 1.5 Left hemipelvis, medial view. The levator ani muscle has been removed and the Alcocks canal has been opened to demonstrate the branches of the pudendal nerve. IS = ischial spine, SSL = sacrospinous ligament, IRN = inferior rectal nerve, PerN = perineal nerve, DNC = dorsal nerve of clitoris. Cl = clitoris, SP = symphysis pubis, Ob.N = obturator nerve, Ob.C = obturator canal, Ob.Int.M = obturator internus muscle. Ob.V = obturator vein, Acc.Ob.V = accessory obturator vein, EIV = external iliac vein, EIA = external iliac artery, S2–S4, sacral roots.

- The terminal branch of the pudendal nerve is the dorsal nerve of the clitoris that crosses the infrapubic canal and supplies sensory innervation to the clitoral area.

Levator ani muscle is innervated on its internal surface by branches directly derived from S3 to S4 forming the levator ani nerve, without contribution from the pudendal nerve.[1,2]

The autonomic nerve supply of the pelvic organs plays an important role in their sphincter mechanism. The inferior hypogastric plexus is composed of a confluence of nerves from the superior hypogastric plexus (parasympathetic), the pelvic sympathetic plexus (a direct continuation from the lumbar trunk), and the pelvic splanchnic nerves (parasympathetic, nervi erigentes) arising directly from the second, third, and fourth sacral foramina. This nerve plexus runs along the lateral sides of the rectum, vagina, and bladder and provides autonomic innervation to these organs and to their sphincters.

Pelvic organs

The lower urinary tract and the rectoanal canal have both a storage and evacuation role. They distend without increase of pressure (high compliance) whilst maintaining continence by a sphincter mechanism that must provide both long-term tonic and rapid phasic contraction. In contrast during evacuation, the organs must be able to contract with sphincters relaxation in a coordinated fashion.

Ureters

Ureters are muscular tubes conveying urine from the kidneys to the bladder. Their abdominal course is retroperitoneal anteromedial to the psoas muscle. They cross under the ovarian vessels at variable level between the aortic and iliac bifurcation and then run parallel to them. The ureters enter the pelvic cavity by crossing over the external iliac vessels, and run along the pelvic sidewall in the pararectal space, anterior to the hypogastric artery and the uterosacral ligaments. They cross under the uterine artery along a distance of 2.5 cm about 2 cm lateral to the vaginal fornices, finally inclining medially to reach the base of the bladder in front of the vagina.

Bladder

Bladder is a preperitoneal organ composed of smooth muscle (the detrusor muscle), covered on its dome by a serosal layer and lined by a submucosa and transitional cell epithelium. The detrusor muscle is composed of three separate bundles of smooth muscle arranged in an internal and external

longitudinal and an intermediate circular layer. The bladder wall is traversed by the two ureters at its posterolateral angles. Ureters run obliquely within the bladder wall at a distance of 1.5–2 cm and open into the bladder cavity at the ureteric orifices. These ureteric orifices superiorly and the internal urethral meatus inferiorly mark the limits of the trigone at the base of the bladder. The bladder base rests posteriorly on the vagina. The dome of the bladder is covered by peritoneum (Figure 1.6), which extends posteriorly as far as the isthmus of the uterus, onto which it is reflected to form the uterovesical pouch. Anteriorly, the bladder lies in the retropubic space, which is filled with adipose and loose areolar tissue.

Urethra

Urethra is a fibromuscular tube measuring 3–4 cm that extends from the vesical neck to the external urethral meatus. Its mucosa is a transitional cell urothelium in its upper third and a nonkeratinizing squamous epithelium in its distal two-thirds. Urinary continence is maintained by urethral pressure that exceeds to the intravesical pressure. The sphincter is composed of an internal smooth and an external striated muscle distributed in different proportions along its course. Smooth muscle is present along the upper two-thirds of the urethral length. The striated urethral sphincter is circular on the upper two-thirds and includes the compressor urethrae and the urethrovaginal sphincter distally (Figures 1.7a, 1.7b), just above the urogenital diaphragm.[3] A well-developed layer of submucosal vessels also participates in the continence mechanism. Arteriovenous anastomoses

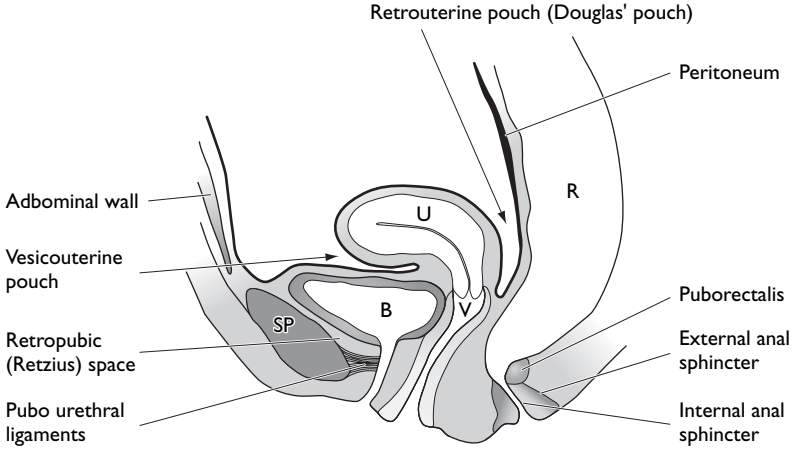

Figure 1.6 Pelvic organs and peritoneal lining. SP = symphysis pubis, B = bladder, U = uterus, R = rectum.

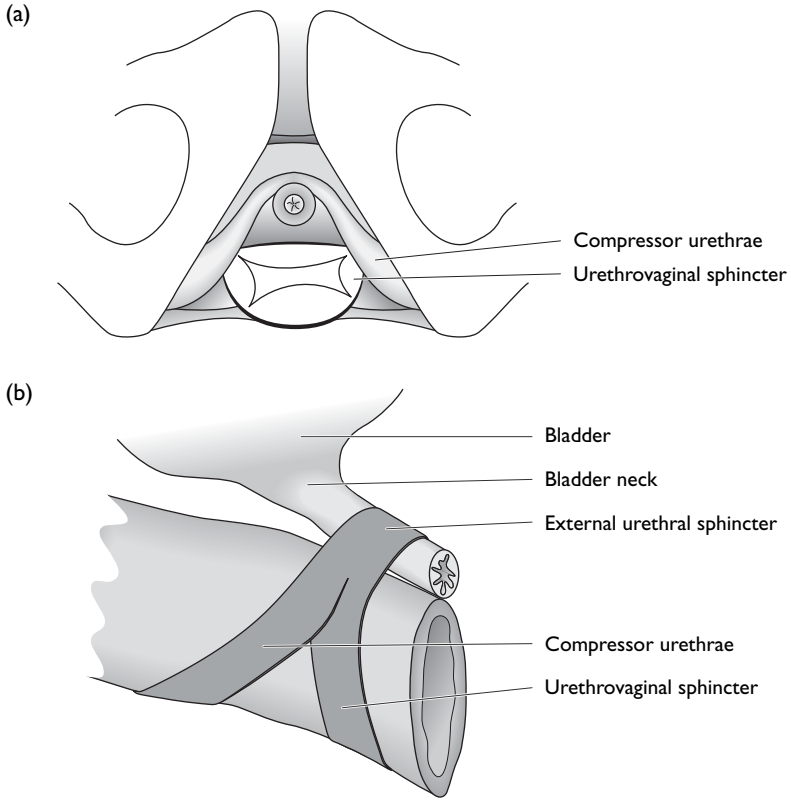

Figure 1.7 (a) Deep perineal muscles (after Oelrich[3]), interior view. (b) External urethral sphincter and deep perineal muscles, lateral view.

allow inflation of venules, which provide watertight mucosal coaptation and increase the closure pressure of the urethra. These vessels, as well as urethral and trigonal mucosa, have estrogen and progesterone receptors.[4]

Urethral sphincter muscles are under complex neurologic control, involving the pudendal (afferent) and autonomic nerves.[5] The smooth internal sphincter is innervated by sympathetic fibers arising from the ventral lumbar region that increase its tone via α-$_1$-noradrenergic receptors. The striated external sphincter is innervated by somatic nerves arising from the caudal lumbosacral region via cholinergic receptors. The afferent limb of this lumbosacral reflex is mediated by the pudendal nerve, which stimulates the efferent pathway during bladder filling. At the same time, this lumbosacral reflex (the guarding reflex) is modulated by reflex pontine and voluntary central control.

The urethra is supported posteriorly by the vaginal wall and is fused with it at its terminal third. Anteriorly, the urethra is suspended to the pubic bone by the pubourethral ligaments[6] and is attached laterally to the pubovisceralis muscle through a layer of endopelvic fascia. These muscular and ligamentous supports prevent urethral opening during rises of intra-abdominal pressure.[7]

Genital tract

The vagina, which is essentially a muscular tubular organ lined by a nonkeratinizing squamous epithelium, occupies a central position in the female pelvis. The bladder and urethra are positioned anteriorly to the vagina, the rectum and anal canal posteriorly, and the cervix cranially.

The uterus is divided into a body (corpus) and a cervix. The body is pear-shaped and narrows from its fundus at the level of the internal cervical os. On either sides of the fundus, uterine (Fallopian) tubes carry ova from the ovaries to the uterine cavity through the ostia. The round ligaments are attached to the fundus anteriorly and to the tubes and the utero-ovarian ligaments posteriorly. The uterus is covered by peritoneum (Figure 1.7) that extends laterally over the round ligament to form the broad ligaments, stretching from the sides of the uterus to the lateral pelvic sidewall.

The cervix is approximately 2.5 cm long. The vagina inserts onto the distal part of the cervix dividing it into an intravaginal and a supravaginal portion.

Rectum

The terminal digestive tract is formed by the rectum and the anal canal. As for the urinary tract, the rectum functions as a reservoir and the anal canal maintains continence. The transition between rectum and anal canal is at the level of the pelvic diaphragm. Peritoneum covers the upper two-thirds of the rectum anteriorly and is reflected onto the upper posterior vaginal wall, forming the rectovaginal pouch of Douglas. The rectal mucosa consists of columnar and mucous cells that also line the upper anal canal down to the dentate line. Under this line the anal epithelium is a nonkeratinized stratified squamous epithelium of the perianal epidermis.

Anal canal

The anal canal is approximately 4 cm long, and in its wall there is an internal anal sphincter of smooth muscle, which is a continuation of the circular rectal muscularis. The puborectalis muscle is fused with the deep or upper part of the external anal sphincter. The superficial portion of the external anal sphincter is circular and is wrapped around the terminal portion of the internal anal sphincter. The terminal part of the external anal sphincter is a

subcutaneous muscle, which is situated below the internal anal sphincter. In the intersphincteric space between the internal and external anal sphincter descends an extension of the longitudinal rectal muscularis, forming the conjoined longitudinal muscle.

The external anal sphincter is innervated by the inferior rectal nerve, a branch of the pudendal nerve. The internal anal sphincter has a sympathetic (motor) and parasympathetic (inhibitory) innervation. Distention of the rectum provokes relaxation of the internal anal sphincter (rectoanal inhibitory reflex) and contraction of the external anal sphincter (rectoanal contractile reflex).

Anal continence mainly relies upon anatomic and functional integrity of the anal sphincter mechanism. The internal anal sphincter provides about 80% of resting pressure. The external anal sphincter is composed of slow-twitch and fast-twitch fibers and contributes to about 20% of resting tone, although its role is to generate rapid voluntary contraction.[8]

The endopelvic fascia and pelvic floor support

Levator ani muscles are the primary pelvic organ supports and provide a muscular plate upon which they can rest. Levator ani is composed of slow-twitch, fatigue-resistant fibers that maintain constant tone and fast-twitch fibers that allow rapid contraction with sudden rises in intra-abdominal pressure. Loss of muscular support either caused by denervation or direct muscular damage will impose increased load on pelvic connective tissue and provoke a progressive sliding of pelvic organs through the urogenital hiatus. Pelvic organ prolapse is therefore closely related to the integrity of pelvic floor muscles and perivaginal connective tissue. Ligamentous support in the pelvis is provided by a retroperitoneal layer of connective tissue called endopelvic fascia (EPF), which represents the top layer of the pelvic floor. The term 'fascia' poorly defines the true composition of these local condensations of connective tissue that differs from other fasciae of the body. The composition of EPF varies with anatomic site but consists mainly of fibrocytes and fibroblasts, smooth muscle cells, collagen (mainly type I and III), elastin fibres, nerves, and blood vessels. EPF provides secondary support to the pelvic organs, by anchoring them to the pelvic sidewalls.

It is clinically useful to divide the upper vaginal and supravaginal cervix support into a posteromedial part, the uterosacral ligaments, and an anterolateral part, the cardinal ligaments. Uterosacral ligaments (USLs) have been extensively described by Campbell,[9] who divided them into a cervical, an intermediate, and a sacral portion (Figure 1.8). The cervical portion is attached to the posterolateral aspect of the cervix at the level of the internal os and to the lateral vaginal fornices. It is mainly composed of smooth muscle and connective tissue. It also contains sympathetic and parasympathetic nerve fibers. Its middle portion is made of a dense connective tissue

band, the 'stratum fibrosum' at its anterior margin and loose connective tissue posteriorly. Nerves and parasympathetic ganglia are also found at this level. The sacral portion is essentially made of loose connective tissue and fans out to insert on the presacral fascia. The direction of USLs is vertical and provides a suspension of the upper vagina and cervix. The cardinal ligaments (also called transverse cervical ligaments by Mackenrodt) are bands

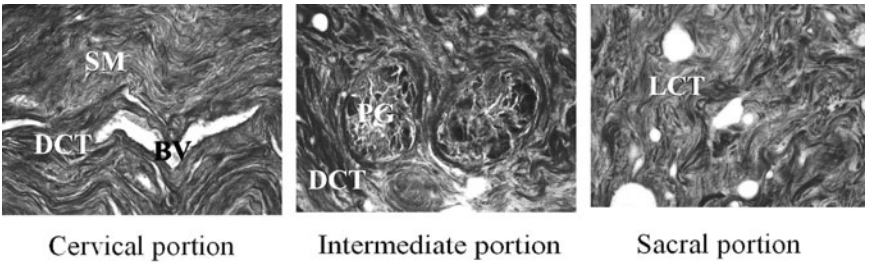

Figure 1.8 Microscopic view (40×) of the different portions of uterosacral ligaments. DCT = dense connective tissue made of collagen and elastin fibers. SM = smooth muscle fibers and fibroblasts, PG = parasympathetic ganglion, LCT = loose connective tissue, BV = ?.

of dense connective tissue attaching the lateral margins of the cervix to the pelvic sidewalls. The uterine artery runs within this mass of tissue.

It is currently considered that these two ligaments represent different parts of the same complex of ligamentous tissue (Figure 1.9), suspending the upper third of the vagina and the cervix (level 1). The paracolpium is the portion of EPF which attaches the vagina to the pelvic sidewall. The parametrium attaches the cervix laterally and posteriorly to the pelvic sidewall (Figure 1.10).[10] The paracolpium and parametrium prevent cervical and vaginal vault prolapse and are put under tension when traction is exerted on the cervix. The second third of the vagina (level 2) is attached laterally to the ATFP through a sheet of EPF (Figure 1.8). This attachment stretches the vagina laterally and forms a continuous layer of support for the anterior pelvic compartment. Bladder is therefore supported posteriorly by a continuous layer composed by the vagina itself and its lateral insertions on the ATFP. Bladder anteriorly and rectum posteriorly are separated from the mid-vaginal wall by areolar tissue only. The rectovaginal septum is a layer of EPF attaching the posterior vaginal wall to the aponeurosis of levator ani muscle along a line extending along the pelvic sidewall from the perineal body to the middle of the ATFP.[11] The distal part of the vagina is fused (level 3) with surrounding organs, anteriorly with the urethra, laterally to the pubovisceralis muscle and ischiopubic rami through the perineal membrane, and posteriorly with the perineal body.[12]

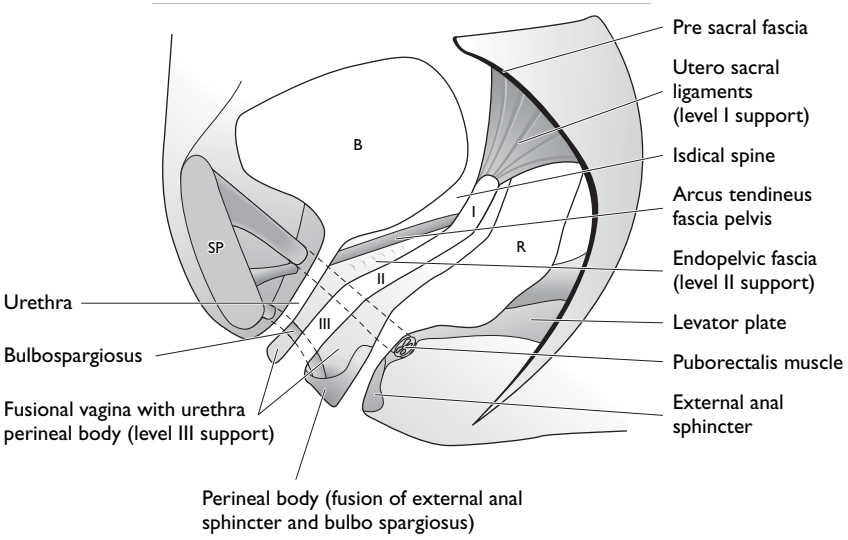

Figure 1.9 Vaginal support (after Delancey[10]). The vagina has three different levels of support. At level I, the vagina is suspended to the sacrum and pelvic sidewall by the paracolpos, the inferior extension of the uterosacral and laterocervical ligaments. At level II, the vagina lies in a more horizontal plane and is attached to the ATFP through a layer of endopelvic fascia. At level III, the vagina is again in a more vertical plane because of the action of the puborectalis muscle and is fused with surrounding organs and muscles.

Summary

- The pelvis is composed of the two coxal bones, the sacrum and the coccyx.
- The ischial spine is an easily palpable landmark on which several important ligaments insert: the arcus tendineus levator ani, the arcus tendineus fascia pelvis and the sacrospinous ligament.
- The levator ani muscles provide primary support to pelvic floor organs by elevating them anteriorly and providing a shelf (levator plate) on which they can rest posteriorly. The endopelvic fascia provides secondary support by attaching pelvic organs to the pelvic sidewalls.
- The urethral and anal sphincters are both composed of an internal smooth muscle layer that provides resting tone and an external striated layer that can be contracted voluntarily.