2 Applied Anatomy

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Introduction

A thorough understanding of anorectal anatomy is essential for the surgeon treating a patient with an anorectal fistula. Proper surgical decision-making mandates intimate knowledge of factors such as the architecture of the sphincter muscles, the distribution of anal glands, and the geography of the anorectal spaces. This chapter begins with a brief overview of current concepts of anorectal anatomy with emphasis on structures contributing to the etiology and surgical management of fistulas. It is followed by a discussion of practical guidelines such as operative recommendations as to the amount of sphincter that can be divided safely at one setting, when to use marking or dividing setons, tips to avoid nerve injury, and the anatomic reasons why certain treatment options fail.

Overview of Pelvic Floor and Anorectal Anatomy

The Pelvic Floor

The pelvic floor is formed by overlapping paired musculotendinous sheets of predominantly striated fibers known as the levator ani muscles (Fig. 2.1). The major components of this pelvic diaphragm are the pubococcygeus and the iliococcygeus muscles, although the posteriorly situated coccygeus muscles are sometimes included in this group. Recent evidence suggests that the puborectalis sling, which functions to angulate the anorectal junction anteriorly, is actually an integral part of both the levator ani and external anal sphincter complexes [1]. The levator ani is innervated from branches of the fourth sacral nerves on its pelvic surface and by the perineal branch of the pudendal nerve on its underside. The puborectalis receives additional innervation from below through the inferior rectal nerves.

The pubococcygeus originates from the posterior inferior aspect of the pubis and the inner anterior surface of the obturator fascia, including a portion of the arcus tendineus of the levator ani. Its anterior fibers insert medially into the central tendon of the perineum (hiatal ligament), where they fuse with the musculature of the prostate, vagina, and perineal body to form the levator prostate, pubovaginalis, and pubourethralis muscles. Some of these intermediate fibers also travel caudally along the intersphincteric plane and contribute to the conjoined longitudinal coat of the anal canal. The muscular fibers of the pubococcygeus merge posteriorly into the broad fibrous band that inserts into the anococcygeal ligament, anterior sacrococcygeal ligament, and coccyx.

The iliococcygeus arises from the arcus tendineus of the fascia of the internal obturator muscle posterior and caudal to the origin of the pubococcygeus. The fibers run posteromedially, where they merge and insert into the anococcygeal ligament and the last two segments of sacrum.

The puborectalis is the most caudal and controversial component of the levator ani complex. It arises from the posterior aspects of the body of the pubis, the inferior pubic ramis, the superior fascia of the urogenital diaphragm, and the adjacent obturator internus fascia and loops around the rectum to form a strong U-shaped sling. Medial fibers of the puborectalis fan out and insert into the central tendon of the perineum where they intermingle with fibers from the pubococcygeus and contribute to the conjoined longitudinal muscle of the anal canal. The puborectalis sling, together with the upper borders of the internal and external sphincters, forms the anorectal ring, which delineates the surgical anal canal from the rectum.

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H. Abcarian (ed.), *Anal Fistula: Principles and Management*, DOI 10.1007/978-1-4614-9014-2_2,

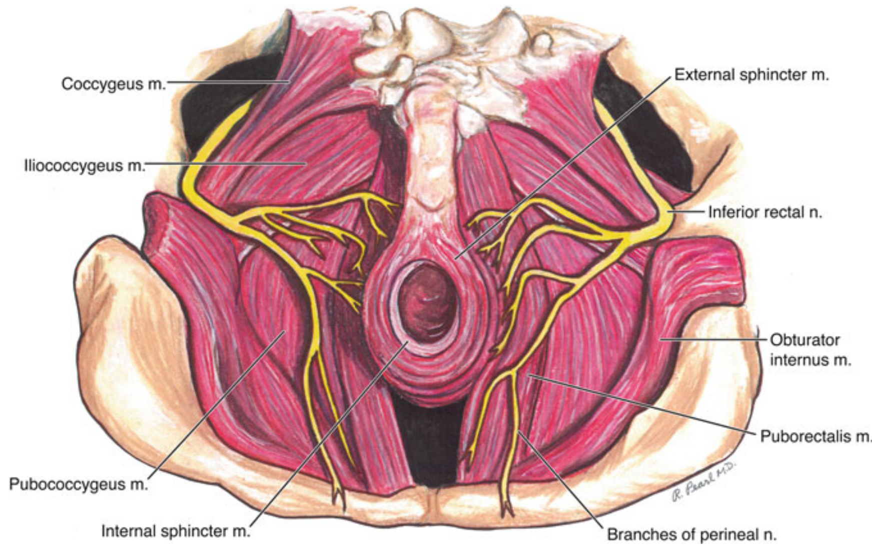

Fig. 2.1 Overview of the pelvic floor muscles and anal sphincters seen from below

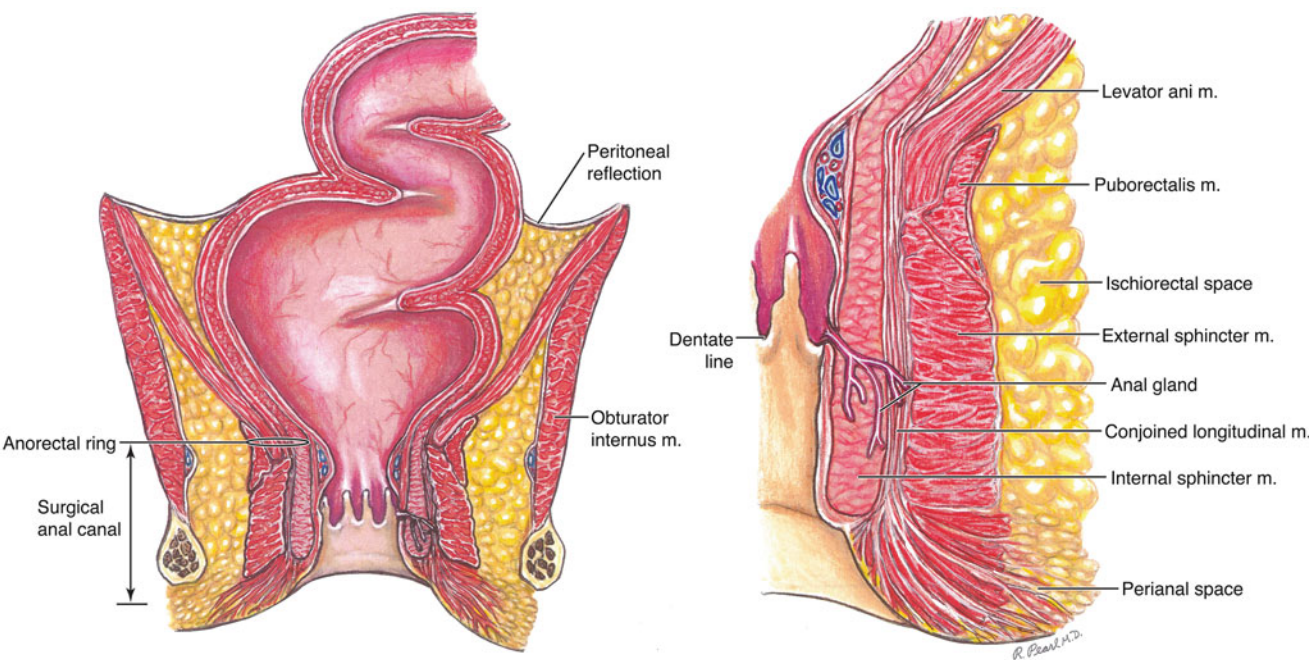

Fig. 2.2 Coronal view of the anal canal, lower rectum, and surrounding spaces. The enlarged view on the right highlights the architecture of the sphincter muscles and anal glands

Rectum and Anal Canal

The rectum begins at the level of the third sacral vertebra and in general follows along the curvature of the sacrum and coccyx for its entire length of 12–15 cm (Fig. 2.2). In addition, it has three lateral curves; the upper and lower ones are convex to the right, the middle one convex to the left. The inner aspects of these three transverse infoldings correspond to the rectal valves of Houston. At the rectosigmoid junction, the fibers of the taenia spread out to form the longitudinal muscle layer of the rectum, which surrounds the inner circular muscle layer. The outer muscle coat is slightly thicker on the anterior and posterior rectal walls than on its lateral surfaces, contributing to the formation of three lateral curves.

The upper surface of the rectum is covered by the peritoneum on its anterior and lateral surfaces. The middle third is covered on its anterior surface only, and the lower third is entirely below the peritoneal reflection. The middle valve of Houston is approximately at the level of the anterior peritoneal reflection.

The posterior wall of the rectum is covered with a thick layer of pelvic fascia (fascia propria). A strong sheet of fascia (Waldeyer's or rectosacral fascia) arises from the fourth sacral segment, tracks forward and downward, and attaches to the fascia propria on the posterior surface of the rectal wall at the anorectal junction. The lower portion of the rectum is supported on each side by reflections of endopelvic fascia known as the lateral stalks of the rectum. The anterior extraperitoneal surface of the rectum is covered by Denonvilliers' visceral pelvic fascia which extends to the urogenital diaphragm running between the rectum and prostate or vagina.

As the rectum passes through the pelvic diaphragm at the level of the anorectal ring, it changes its name, shape, and direction. The anal canal begins at this point and extends for approximately 4 cm to the anal verge (surgical anal canal). The circular lumen of the rectum flattens into an anteroposterior slit because of its attachment to the perineal body and coccyx along with the medial pressure exerted by the ischiorectal fat pads. The puborectalis sling in its normal contracted state angulates the anorectal junction forward to create an 80° bend, the perineal flexure, which may assist the external sphincter mechanism in maintaining fecal continence.

The internal sphincter is a continuation of the involuntary layer of circular smooth muscle of the rectum that begins at the level of the anorectal ring. As it proceeds distally, it becomes appreciably thicker, and its rounded lower margin can usually be palpated about 1–2 cm below the dentate line. The internal sphincter, like the puborectalis, is tonically contracted "at rest".

The conjoined longitudinal muscle coat that surrounds the internal sphincter arises from medial fibers of the pubococcygeus and puborectalis. These striated voluntary fibers course along the intersphincteric plane, fan out through the subcutaneous portion of the external sphincter, and attach to the anoderm and perianal skin, constituting the corrugator cutis ani muscle.

Several versions of the musculature of the external sphincter have been proposed, ranging from the single continuous muscle sheet model of Goligher to the three distinct loop theory of Shafik [2, 3]. The inconsistencies of these various descriptions are most likely based on differences in age, sex, and individual variation among the subjects, as well as on differences in points of orientation among investigators (anatomists, physiologists, radiologists, clinical surgeons). For example, a clinical surgeon repairing a sphincter injury with an overlapping sphincteroplasty generally does not appreciate several subdivisions of the external sphincter. In addition, the external sphincter complex acts as a single functional unit, as demonstrated by electromyography. More recently anal sphincter anatomy has been investigated by high-spatial-resolution endoanal MR imaging [4]. These findings will be discussed in more detail later in this chapter.

Perhaps all that can be stated definitively with respect to structure is that the external anal sphincter is an elliptical cylinder of striated muscle that surrounds the anal canal, and at least the large central portion (superficial component) is firmly tethered to the coccyx, forming the anococcygeal ligament.

Of particular interest is the composition of the fibers of the external sphincter. It is made up of two different types of striated muscle, type I and type II which function independently, even though they are fully integrated with each other. The type I muscle fibers, although voluntary in appearance, behave as involuntary smooth muscle by maintaining a state of tonic contraction in much of the same manner as the internal sphincter. The type II muscle mass is capable of powerful contractions far exceeding the baseline level of the type I fibers. However, these type II fibers can only maintain this maximal level of contraction for a short time before they become fatigued.

The mucosa of the upper portion of the anal canal is lined primarily by columnar epithelium. The lower portion or anatomic anal canal extends from the dentate line to the anal verge and is lined with anoderm, a thin layer of stratified squamous epithelium that lacks sweat glands and hair follicles. Interspersed between the mucosa of the proximal anal canal and the serrated margin of the dentate line is a narrow indistinct band of cuboidal epithelium known as the transitional zone, which represents the embryological remnants of the cloacal membrane.

Several longitudinal mucosal folds, the columns of Morgagni, arise in the proximal anal canal and terminate at the dentate line, where they surround the anal crypts. The majority of the branched tubular anal glands that originate from the depths of these crypts are located in the posterior quadrant of the anal canal, and will be discussed in more detail later. In addition, the normally pink mucosa of the upper anal canal appears purple where it overlies the three vascular anal cushions often referred to as the internal hemorrhoids.

The mucosa proximal to the dentate line lacks somatic innervation. In contrast, the anoderm is richly endowed with cutaneous sensory nerve endings. The blood supply to the rectum and anal canal originates at three levels (Fig. 2.3). The superior rectal artery, the principal blood supply to the upper and middle portion of the rectum, begins as the terminal branch of the inferior mesenteric artery, where it crosses over the left common iliac vessels. As it descends within the sigmoid mesocolon, it bifurcates at the level of the third sacral vertebra into right and left branches that course along and within either side of the rectal wall. Each vessel divides further so that an average of five small mucosal arteries terminate at the level of the anal valves. There appears to be a paucity of anastomoses on the anterior and posterior surfaces of the rectum between the two collateral branches of the superior rectal artery.

The middle rectal arteries usually arise from the internal iliac arteries, travel along the anterolateral surface of the

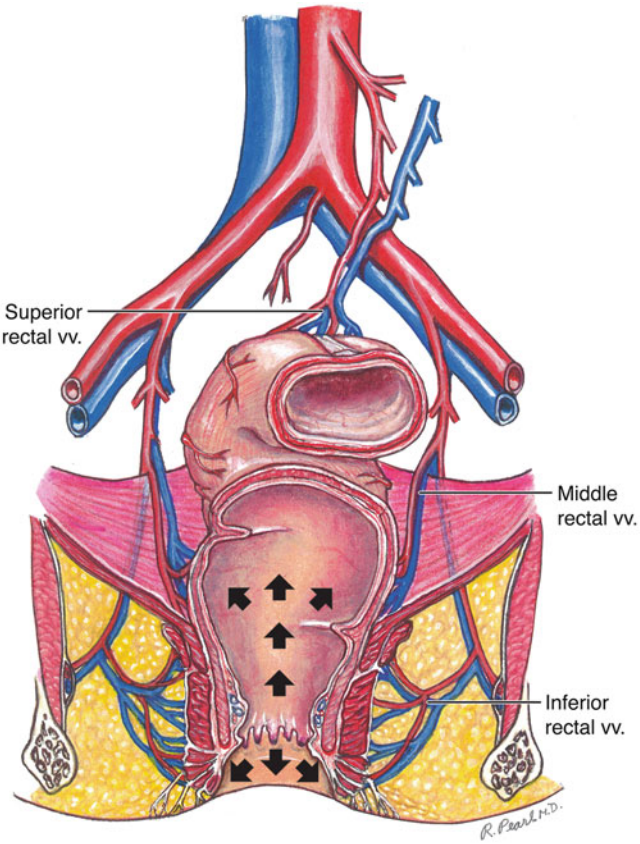

Fig. 2.3 The blood supply and venous drainage of the rectum and anal canal. The *arrows* indicate the direction of lymphatic drainage

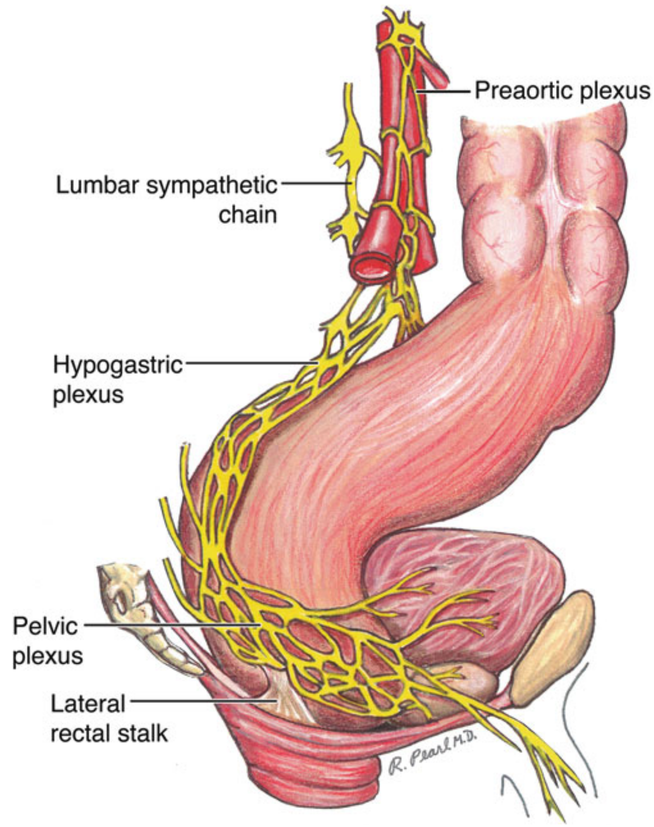

Fig. 2.4 Lateral view of the rectum and anal canal illustrating the course and distribution of the pelvic autonomic nerves. Note the proximity of the pelvic plexus to the lower third of the rectum

lower rectum, traversing Denonvilliers' fascia, and enter the rectal wall at the level of the anorectal ring. Although the middle rectal arteries do not run within the lateral stalks, accessory branches may occasionally be found coursing through these ligaments.

The inferior rectal arteries enter the posterolateral aspects of the isciorectal fossae as offshoots of the internal pudendal arteries, which run in Alcock's canals. Each of these arteries divides further into two to four vessels that supply the external and internal sphincter, as well as the lining of the anal canal.

Although the degree of confluence between the vessels supplying the rectum and anal canal is controversial, it appears that all three vascular systems are interconnected by a rich intramural plexus. The contribution of the middle sacral artery to this network is at best small and variable.

The venous drainage of the rectum and anal canal parallels the arterial supply. Therefore, blood from the rectum and upper part of the anal canal returns through the superior rectal vein into the portal system, whereas the middle and inferior rectal veins empty into the caval circulation. The submucosal veins of the distal anal canal do not have a special connection with the portal circulation. Contrary to earlier beliefs, there is no significant increase in the incidence of symptomatic hemorrhoids in patients with portal hypertension.

The lymphatic system of rectum and anal canal follows the course of the regional blood supply. Lymphatic drainage from the anal canal proximal to the dentate line courses cephalad along the superior rectal vessels and laterally by way of the middle rectal lymphatics to the internal iliac nodes. Lymph from the anal canal below the dentate line usually drains to the inguinal lymph nodes.

The rectum, upper portion of the anal canal, bladder, and genitals are innervated by fibers of the autonomic nervous system (Fig. 2.4). The external sphincter and anoderm are supplied by somatic nerves.

The sympathetic nerves to these pelvic structures originate from the lower thoracic and upper lumbar spinal segments as preganglionic sympathetic fibers that synapse with postganglionic fibers in the preaortic plexus and lumbar sympathetic chains. They then course the pelvis adjacent to the ilicac vessels, ureters, and lateral pelvic wall. The preaortic plexus is adherent to the anterior wall of the aorta and the common iliac arteries. The lumbar sympathetic chains pass underneath the common iliac vessels and join the fibers from the preaortic plexus to form the left and right hypogastric plexuses just distal to the bifurcation of the aorta. These plexuses are covered by pelvic peritoneum and are generally adherent to the posterolateral pelvic walls.

Preganglionic parasympathetic nerves that arise from the second, third, and fourth sacral segments (nervi erigentes) descend into the pelvis and intermingle with the sympathetic fibers from the hypogastric nerves to form the pelvic plexuses [5]. The pelvic plexuses are at the level of the lower third of the rectum just above the levator ani muscles and are situated well lateral to the pararectal reflections of the endopelvic fascia known as the lateral stalks of the rectum. This dense reticulum of sympathetic and parasympathetic nerves continues anterolaterally around the bladder and into the prostate and penis.

Sensation to the perianal region and anal canal distal to the dentate line is conveyed by afferent fibers of the inferior rectal nerves. The mucosa of the rectum and proximal anal canal lacks somatic sensory innervation so that mucosa injury caused by biopsy, cauterization, polypectomy, or rubber bands ligation is not perceived as painful. The dull, aching sensation sometimes experienced in this region during transanal procedures is probably mediated via the pelvic parasympathetic nerves.

Anatomic Considerations Relating to Fistula Surgery: Anal Glands

Situated within the 4–12 pockets or anal crypts found at the dentate line are the openings to a variable number of straight and branched anal glands (Fig. 2.2) [6]. These glands are lined with stratified squamous epithelium and were first described by Chiari in 1878. More than one gland may open into the same crypt, while half the crypts have no communication with the gland. These tubular glands extend into the submucosa in a downward and outward direction with two-thirds of them entering the internal sphincter. In addition, half of them extend out as far as the intersphincteric plane. Parks first addressed their role in the pathogenesis of anorectal abscesses and fistulas [7]. Immunochemical staining methods have confirmed the presence of mucous secreting cells as well as intraluminal secretions within the glands. It is controversial whether these glands have a definite active secretory function such as lubricating stool as it passes through the anal canal, or merely are static outgrowths of the anal crypts that can potentially become blocked with debris. Regardless, it seems logical that an obstructed gland extending into the intershincteric space can develop into an abscess that can track along or through adjacent tissue planes and upon spontaneous or surgical drainage develop into a fistula. This concept is substantiated clinically since most internal fistulous openings are found within the crypts at the dentate line.

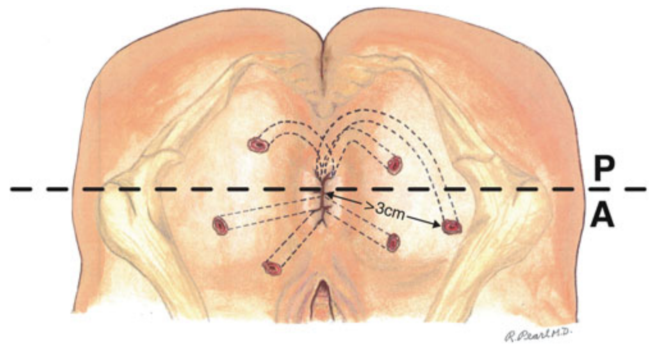

Fig. 2.5 Illustration of Goodsall's rule

The majority of the anal glands are located in the posterior midline, which explains the prevalence of anorectal abscesses in this region. When these posterior midline abcesses erode into the adjacent deep postanal space, the septic process gains access to the left and right ischiorectal spaces to form a horseshoe abscess/fistula. The high concentration of anal glands in this region helps explain Goodsall's rule, which is often useful in identifying the primary opening of a fistula (Fig. 2.5). This guideline states that if the secondary opening is situated around the posterior half of the anus or more than 3 cm away from the anus, the primary opening will usually be located at the posterior midline. Conversely, if the secondary opening is found within the anterior half of the anus, the internal opening will be directly in line (radially located) with the secondary opening at the dentate line. However, there is evidence suggesting that Goodsall's rule is less accurate for identifying fistulas with an anterior external opening [8].

Sphincter Architecture Based on Refined Imaging Techniques

Traditional descriptions of sphincter architecture were based on anatomic dissections and operative observations. With the advent of endoanal ultrasound, in vivo evaluation of anal anatomy and pathology became available. However, the shortcoming of this technique was suboptimal delineation of the external sphincter and levator ani muscles. High-spatial-resolution endoanal MR imaging using a coil affords excellent resolution of all of the sphincter muscles. By utilizing this technique, normal sphincter anatomy in both men and women was definitively presented. Among the major findings in this study were that the anterior part of the external sphincter was about half as long in women compared with men (14.0 mm vs. 27.0 mm). The thickness of each sphincter component was roughly equivalent between the sexes, and that there was a substantial difference in the arrangement of muscle fibers anterior to the sphincter. In men the central perineal tendon is a strong insertion point directly anterior to the external sphincter, whereas in women it is a less well-defined insertion area of woven muscle fibers slightly superior to the external sphincter. The significance of this finding is that during vaginal delivery this tissue becomes markedly attenuated predisposing it to obstetrical tears which can clearly impact fecal continence. This anatomic arrangement in women along with the fact that the puborectalis muscle is absent anteriorly should alert the surgeon to exercise caution when encountering an anterior fistula tract. Unless the fistula is extremely superficial, primary fistulotomy should probably be avoided.

The Geography of the Anorectal Spaces

There are several spaces and potential spaces surrounding the rectum and anal canal that are of surgical significance (Fig. 2.6). The ischiorectal fossa is divided into the perianal space and ischioanal space. The perianal space surrounds the lowest portion of the anal canal and is confined by the radiating elastic septae of the conjoined longitudinal muscle attachments to the anoderm and perianal skin and contains finely lobulated fat, delicate branches of hemorrhoidal vessels, nerves, and lymphatics. When blood or pus accumulates in this closed space the stretching and irritation of the many nerve endings results in the severe anal pain associated with perianal abscesses and thrombosed external hemorrhoids.

The ischioanal fossa surrounds the upper portion of the anal canal to the level of the anorectal ring. The roof of this pyramid-shaped space is composed of the levator ani muscles, and laterally it is bounded by the obturator internus muscle which lines the pelvic sidewalls. It is filled with coarsely lobulated fat and contains the inferior rectal vessels and nerves. It is a relatively large space and can harbor a substantial abscess with only minimal involvement of the overlying gluteal skin. These clinical findings can mislead an

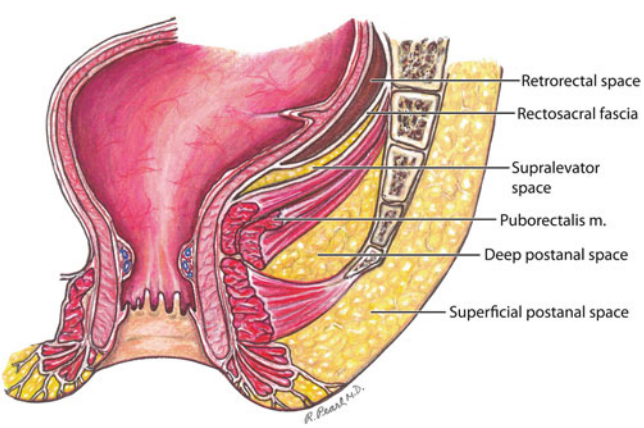

Fig. 2.6 Mid-sagittal view of the lower rectum and anal canal emphasizing the anorectal spaces

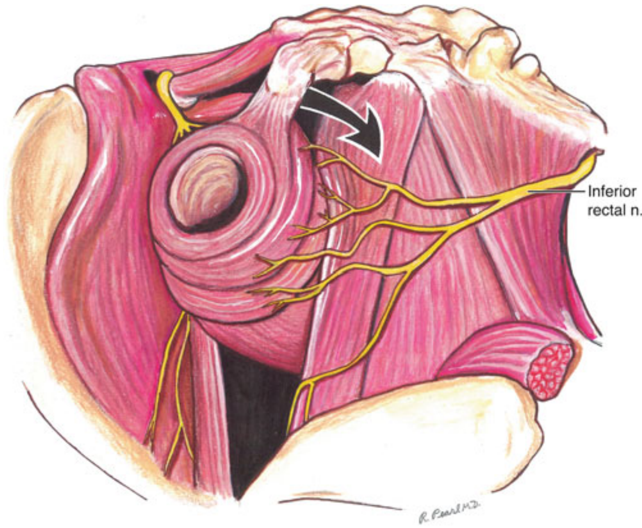

Fig. 2.7 Partial oblique view of the pelvic floor and anal sphincter muscles from below. The *arrow* illustrates how the deep postanal space serves as a window to the left and right ischiorectal spaces, which is how horseshoe abscess/fistula forms. The location and course of the inferior rectal nerves are shown to emphasize how they can be readily avulsed by overaggressive spreading of curved clamps during drainage of ischiorectal abscesses

inexperienced clinician into making the diagnosis of cellulitis rather than a drainable abscess with disastrous results especially in the case of a diabetic of immunocompromised patient. The abscess cavity may extend around one-half the circumference of the anus (horseshoe) or extend completely around the anus (floating freestanding anus).

Another pitfall that sometimes occurs when draining a large ischiorectal abscess is inadvertently mistaking the fanned out array of branches of the inferior rectal nerve as "loculations" inhibiting adequate drainage. Tearing these branches by recklessly spreading a large curved clamp can result in significant injury to the nerve supply to the external sphincter. If this procedure is carried out on both sides as in the case of a horseshoe abscess, complete denervation of the sphincter can occur.

The superficial postanal space is located in the posterior midline between the skin and anococcygeal ligament and is frequently involved with anorectal abscesses. The deep postanal space (retrosphincteric space of Courtney) located deep to the anococcygeal ligament and the upper portions of the external sphincter and levator muscles is of special surgical significance first because of the frequency of abscesses occurring in this region, and secondly because the deep postanal space serves as a window to the left and right ischiorectal spaces which can result in horseshoe abscesses or fistulas (Fig. 2.7).

In longstanding horseshoe fistulas, the deep postanal space can become quite indurated and rigid. Attempts to sterilize and completely fill this infected cavity with collagen plugs or fibrin glue often fail because residual contaminated space is left behind to reactivate the septic process.

The supralevator space is sandwiched between the upper surface of the levators and pelvic peritoneum. Abscess presenting in this location may be difficult to diagnose especially when there are no visible clinical findings around the perineum. Approximately 9 % of large ischiorectal abscesses have an associated supralevator component, which resulted from the septic process eroding through the adjacent levator ani muscle resulting in an hourglass-shaped abscess [9, 10].

When to Avoid Primary Fistulotomy

Anorectal examination under anesthesia is an important step to assess the location and extent of the abscess/fistula process, as well as a means to determine how much sphincter muscle is encircled by the tract. There are several circumstances where these findings can be particularly helpful in preventing overly aggressive fistulotomy which may result in fecal incontinence. In each of the following cases complete primary fistulotomy should be avoided and be replaced by more conservative procedures such as the judicious use of setons, fistula plugs, fibrin glue, or eventually mucosal or cutaneous advancement flap procedures:

1. The presence of a high transsphincteric fistula which can be defined as involving more than 50 % of the external sphincter posteriorly or laterally or 30 % of the external sphincter anteriorly.
2. A transsphincteric fistula in cases of massive anorectal sepsis (floating, freestanding anus) where the normal anatomic landmarks have been severely distorted such that primary fistulotomy may compromise proper wound healing resulting in a large gap or step-off deformity.
3. The existence of an anterior, high transsphincteric fistula in a woman. The external sphincter is quite tenuous and the puborectalis is absent in this region. Primary fistulotomy may result in fecal incontinence.
4. The presence of a high transsphincteric fistula in a patient with poorly controlled acquired immunodeficiency syndrome (AIDS). Healing of anorectal wounds is notoriously poor in these individuals. Moreover, many patients with AIDS have chronic diarrhea, which further exacerbates the problem.
5. The presence of a high fistula in a patient with Crohn's disease. In these instances, it is prudent to mark the fistula tract with a long-term seton such as a silastic vessel loop to promote drainage and deter the development of recurrent abscesses.
6. A marking seton should be placed whenever there is a reasonable clinical suspicion that primary fistulotomy will disrupt fecal continence.

Summary

- Anatomic considerations relating to fistula surgery
- Sphincter architecture based on refined imaging techniques
- Geography of the anal glands and anorectal spaces
- When to avoid primary fistulotomy

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