Chapter 18. Large Intestine and Anorectum

Introduction

The large intestine is formed by the following anatomic entities:

- Ileocecal valve
- Appendix
- Cecum
- Ascending colon
- Hepatic flexure
- Transverse colon
- Splenic flexure
- Descending colon
- Sigmoid colon
- Anorectum

In this book, the appendix has been presented in the preceding chapter.

Following our presentations on the above list of topics is a special section written by Professor Ahmed Shafik. Dr. Shafik, who is chairman of the Department of Surgery and Experimental Research at the medical school of Cairo University, Egypt, is such an original thinker in regard to the large intestine and anorectum that we invited him to share his unique perspective with our readers. We are grateful to him for interpreting his research and offering his philosophy to us, and we are honored to provide his excellent work on the large intestine and anorectum to our readers. We encourage careful thought about Dr. Shafik’s innovative ideas.
The retrorectal space, according to Jackman et al.,\textsuperscript{108} has the following boundaries:

- Anterior: Fascia propria of the posterior rectal wall
- Posterior: Presacral fascia
- Lateral: Iliac vessels, ureters, lateral rectal ligaments
- Superior: Peritoneum
- Inferior: Retrosacral fascia

**Mesorectum**

In *Embryology for Surgeons*,\textsuperscript{13} which was co-written by the senior author of this chapter, the mesorectum was neither mentioned nor discussed. *Gray’s Anatomy*\textsuperscript{26} refers to the “dorsal mesorectum...which does not form a true mesentery, however, but… a woven fibroreolar sheet with patterned variations in thickness and fibre orientation.” The rectum is said to differ from the sigmoid colon by having “no sacculations, appendices epiploicae or mesentery”\textsuperscript{26} (italics ours).

Heald and colleagues\textsuperscript{109} have published multiple excellent articles providing a complete education about the mesorectum. Heald\textsuperscript{110} defines the mesorectum as “the integral visceral mesentery surrounding the rectum …covered by a layer of visceral fascia providing a relatively bloodless plane, the so-called ‘holy plane’” (Fig. 18-42A & B). The dorsal mesentery is embryologically responsible for the genesis of the mesorectum.

**Fig. 18-42.**


In the lab, the senior author of this chapter has found this ‘holy plane,’ and he agrees with Heald about its several relations. Posteriorly, the plane is located between the visceral fascia which surrounds the mesorectum and the parietal presacral fascia (fascia of Waldeyer). In the male, Denovilliers’ fascia (Fig. 18-43) constitutes the anterior surface of the mesorectum, which is fused with the posterior surface of the fascia of Denovilliers’. Inferiorly, the mesorectum and the fascia of Waldeyer condense to form the rectosacral ligament in the vicinity of S4.

**Fig. 18-43.**

Schematic representation of the relationships of the mesorectum to the anatomic structures in the male. The neurovascular bundle contains the nerves responsible for erection and ejaculation, and aspects of bladder function. (Modified from Heald RJ, Moran BJ. Embryology and anatomy of the rectum. Semin Surg Oncol 1998;15:66-71; with permission.)

The senior author of this chapter is sure that the readers of the beautiful publications of Heald would have no objections to renaming the ‘holy plane,’ the Plane of Heald.

We quote from Konerding et al.:\textsuperscript{111}

The perirectal tissue gives rise to the rectal fascia or adventitia, also known as mesorectum. The connective tissue space between rectal and parietal pelvic fascia can be dissected as a plane free of vessels and nerves. Surgical dissection along this plane with complete mesorectum excision results in reliable excision of all relevant lymphatic pathways with extensive preservation of continence and sexual function.
Enker et al.\textsuperscript{112} presented four surgical planes for anatomic dissection of the rectum for the following oncologic surgeries (see the section “Anorectal Cancer Surgery” later in this chapter for details):

- Total mesorectal excision
- Total mesorectal excision with autonomic nerve preservation
- Mesorectal excision
- Extrafascial excision of the rectum

After low anterior resection with total mesorectal excision, Law et al.\textsuperscript{113} recommend routine creation of a stoma for males and selective use of diversion for females for the avoidance of lower anastomotic leakage.

Total or partial mesorectal excision for rectal carcinoma has been advocated by several authors.\textsuperscript{114-119} Maurer et al.\textsuperscript{120} stated that continence-preserving surgery on patients with rectal carcinoma may be performed in over 80\% of patients by partial or total removal of the mesorectum with positive results.

**Arterial Supply, Venous Drainage**

The following is a detailed presentation of the blood supply of the anorectum. Some of this material has already been presented in less detailed form in other sections of “Surgical Anatomy of the Colon”; because it is a complicated topic, some repetition is worthwhile.

The arteries of the rectum and anal canal are the unpaired superior rectal artery, the paired middle and inferior rectal arteries (Fig. 18-44), and the median sacral arteries. The superior rectal (hemorrhoidal) artery arises from the inferior mesenteric artery and descends to the posterior wall of the upper rectum. Supplying the posterior wall, it divides and sends right and left branches to the lateral walls of the middle portion of the rectum down to the pectinate (dentate) line.

Fig. 18-44.

Many surgeons are under the impression that the middle rectal (hemorrhoidal) arteries are always present in the lateral rectal stalks. Some authors\textsuperscript{30,121} have found these arteries to be inconstant; Michels\textsuperscript{122} found them to be constant, but varying in number and in origin. All originated (directly, or often indirectly) from the internal iliac artery. The number varied from three to nine and the diameter from 1.0 mm to 2.5 mm. In 58 percent of subjects, there was a grossly visible anastomosis between the middle and superior rectal arteries.

Boxall et al.\textsuperscript{123} found that the vessel in the lateral ligaments of the rectum, called the middle rectal artery by surgeons, was actually an “accessory” middle rectal artery that is present in about 25 percent of individuals. The main trunk of the middle rectal artery was inferior to the rectal stalk and could be endangered when the rectum is separated from the seminal vesicle, prostate, or vagina. In 12 cadavers, the arteries entered the rectal wall with the levator ani muscle; in 9 it was 2-4 cm higher. These findings may explain why some surgeons feel that the lateral ligaments may be cut with impunity.

In our experience, the middle rectal artery is usually absent in the female. It is probably replaced by the uterine artery. In the male, the chief beneficiaries of the artery are the rectal musculature and the prostate gland. Last\textsuperscript{124} agrees.

Vogel and Klosterhalfen\textsuperscript{125} reported that the middle rectal artery supplies the rectum accessorially and stated that this is the reason for suture leaks at the dorsocaudal area of the profunda. However, Goligher\textsuperscript{126} reported that the rectum and anus can survive divisions of the superior and middle rectal arteries.
The *inferior rectal (hemorrhoidal)* arteries arise from the internal pudendal arteries and proceed ventrally and medially to supply the anal canal distal to the pectinate line.

The median sacral artery arises just above the bifurcation of the aorta and descends beneath the peritoneum on the anterior surface of the lower lumbar vertebrae, the sacrum, and the coccyx. It sends several very small branches to the posterior wall of the rectum.

Venous drainage of the rectum and anal canal is discussed in “Vascular Supply” of the large intestine.

**Lymphatics**

Lymph channels of the rectum and anal canal form two extramural plexuses, one above and one below the pectinate line (see Fig. 18-24). The upper plexus drains through posterior rectal nodes to a chain of nodes along the superior rectal artery to the pelvic nodes. Some drainage follows the middle and inferior rectal arteries to hypogastric nodes. Below the pectinate line, the plexus drains to the inguinal nodes.

There is considerable disagreement about connections between the two plexuses across the pectinate line, but if such connections exist, they are small. Regardless of this, drainage above the pectinate line from any part of the rectum is upward to the pelvic nodes; drainage below the line is to inguinal nodes. The importance of this line is that 85 percent of pathology is located in this area. External drainage to inguinal nodes appears to be limited to lesions involving the skin of the anal or perianal region.11

The watershed of the extramural lymphatic vessels is at the pectinate line (Fig. 18-44). The watershed for the intramural lymphatics is higher, at the level of the middle rectal valve (Fig. 18-45). These two landmarks may be kept in mind by the mnemonic “two, four, eight,” meaning:

- 2 cm = anal verge to pectinate line
- 4 cm = surgical anal canal (above and below the pectinate line)
- 8 cm = anal verge to middle rectal valve

**Fig. 18-45.**

The anatomy of metastasis of malignant tumors of the colon and rectum is perhaps as follows (Fig. 18-46):

1. **Intramural stage.** Cancer begins in the epithelium of the colon wall. Longitudinal spread in the submucosa is not common and, when present, extends only a few centimeters.106 Until the tumor has penetrated the mucosa and submucosa and involved the muscular and serosal layers, no metastasis occurs.

2. **Direct extension.** The pericolic fat is usually the first of the neighboring structures to be involved.

3. **Venous drainage.** Metastasis to the liver and lungs by way of the inferior mesenteric vein and the portal veins is an obvious pathway. A second pathway is from pelvic veins to the vertebral veins.127 This explains metastases to the vertebral column.

   We quote from Koch et al.128:

Metastatic disease in colorectal cancer results from hematogenic dissemination of tumor cells...The significantly higher detection rate in mesenteric venous blood emphasizes the importance of the filter function of the liver for circulating tumor cells in the portal venous blood. Tumor cell detection in central and peripheral venous blood, however, shows
Davies\textsuperscript{127} reported the following about the innervation of the rectum, bladder, and internal genitalia in anorectal dysgenesis in the male.

Using a posterior sagittal approach to expose retroperitoneal viscera and nerves, the anatomy of the pelvic autonomic nerve plexus was studied in normal and abnormal male cadaver specimens. This plexus is found on the anterolateral surface of the lower rectum surrounded by endopelvic fascia. The autonomic nerves that supply the plexus reach it from posterior, lateral to the midline by passing over the surface of the rectum. The nerves of this plexus are distributed with the terminal branches of the internal iliac arteries, mainly with the vessels of the inferior vesical plexus. The rectum receives its autonomic nerves with its arterial blood supply, the superior rectal artery. The nerves of the pelvic plexus supply the genitourinary viscera that lie anterior to the rectum and in front of the fascia of Denonvilliers. The named fascial layers of the pelvis play a major role in determining the anatomic plane of these structures. In anorectal agenesis the plexus becomes a more midline structure. Because the pelvic fascia is often deficient in these cases these nerves lie vulnerable to inappropriate midline dissection (Figs. 18-47, 18-48, and 18-49).

\textbf{Fig. 18-47.} The dissection planes in front and behind the normal rectum. (Modified from Davies MRQ. Anatomy of the nerve supply of the rectum, bladder, and internal genitalia in anorectal dysgenesis in the male. J Pediatr Surg 32:536-541, 1997; with permission.)

\textbf{Fig. 18-48.} The anatomy of the pelvic nerve plexus in the presence of a normal rectum and anal canal. (Modified from Davies MRQ. Anatomy of the nerve supply of the rectum, bladder, and internal genitalia in anorectal dysgenesis in the male. J Pediatr Surg 32:536-541, 1997; with permission.)
Fig. 18-49. The anatomy of the pelvic nerve plexus in anorectal agenesis with a rectovesical fistula. (Modified from Davies MRQ. Anatomy of the nerve supply of the rectum, bladder, and internal genitalia in anorectal dysgenesis in the male. J Pediatr Surg 32:536-541, 1997; with permission.)

Motor innervation of the internal rectal sphincter is supplied by sympathetic fibers that cause contraction and by parasympathetic fibers that inhibit contraction. The parasympathetic fibers are carried by pelvic splanchnic nerves which also convey the afferent nerve fibers that mediate the sensation of rectal distention. The external rectal sphincter is innervated by the inferior rectal branch of the internal pudendal nerve and by the perineal branch of the fourth sacral nerve.

The pelvic splanchnic nerves (parasympathetic and sensory) and the hypogastric nerve (sympathetic) supply the lower rectal wall. These two sources together form the rectal plexus. The levator ani muscles are supplied by the nerve to the levator ani, usually a branch from S4, with variant contributions from S3 and S5.

The inferior rectal branches of the internal pudendal nerve follow the inferior rectal arteries and supply the sensory innervation of the perianal skin.

Remember that the pudendal nerve innervates the external sphincter and possibly the puborectalis muscle. The sympathetic nerves have no influence on the muscular wall of the rectum. Evacuation is accomplished by the pelvic splanchnic nerves; continence is maintained by the pudendal and the pelvic splanchnic nerves.

Since the pelvic parasympathetic nerves are responsible for erection and the sympathetic nerves of the hypogastric plexus are responsible for ejaculation, the surgeon should be familiar with the pathway of these nerves and dissect the posterior rectal wall from the sacrum, the prostate, and the lateral pelvic wall as close to the posterior rectal wall as possible.

The topographic anatomy of the nervi erigentes was studied by Stelzner et al., who reported that the nerves are located along the diaphragmatic part of the urethra before entering the cavernous bodies. During proctocolectomy, in order to preserve sexual function, these authors advised leaving a piece of the rectal muscle that covers the diaphragmatic part of the urethra.

Williams and Slack studied the sexual function of males and females after rectosigmoid and rectum excision by examining the specimens for the presence of nerve tissue. Their results suggest that as the amount of nerve tissue in the specimen increases, impaired sexual activity increases.

For a conceptual picture of the “flow” of pelvic autonomic nerves which cannot be seen during mobilization of the rectosigmoid, and to help surgeons avoid inadvertent injury to these nerves, we recommend reading a brief review by Pearl et al. of the structure and function of these nerves.

Defecation and Continence

Distention of the rectum is the initial stimulus for defecation. Distention (Fig. 18-50A), with a rise in pressure, acting on mural receptors, produces reflex contraction of the rectal musculature. At the same time, the internal sphincter relaxes. This portion of the process is mediated by the intrinsic nerves only, with no contribution from extrinsic nerves.
Embryology and Anatomy of the Rectum

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Rectal cancer surgery is difficult due to the rectum’s relatively inaccessible pelvic position and its direct relation to many vital structures. The surgeon is challenged to restore intestinal continuity while working in a confined space. Despite the importance of these issues, the embryology and surgical anatomy of the rectum have been poorly understood. In recent years, cadaver dissections and operative resection under direct vision have provided a clearer picture of the structure of the rectum and mesorectum, their innervation, blood supply, and surrounding structures. New imaging techniques will shed further light on the anatomy of these structures and their anatomic variations.

INTRODUCTION

Background

The aims of treatment of rectal cancer are to cure the patient and, if possible, preserve the sphincter mechanism in order to retain control of fecal evacuation. Surgical management is the mainstay of rectal cancer treatment, although there is a limited role for adjunctive radiotherapy and chemotherapy [1]. In recent years, practitioners have recognized that the surgical technique to remove rectal tumors may have a substantial effect on patient prognosis [2,3]. Consequently, a clear understanding of the surgical anatomy of the rectum is required for successful treatment. In addition, we believe that an appreciation of the embryology of the organ helps this understanding.

The rectum is a “straight” organ in lower mammals; hence, the name derived from Latin. However, it is curved in man and fits into the sacral hollow, starting at the sacral promontory and ending beyond the coccyx [4]. The rectum is interposed between the sigmoid colon proximally and the anal canal distally. Its relationship to the anal canal is of paramount importance because the sphincter complex which controls fecal evacuation is supplied by nerves which are at risk during deep pelvic surgery. Because of its pelvic position, the rectum is both relatively inaccessible and in direct anatomic relationship to many vital structures. Thus, the difficulty for the surgeon results from the need to restore intestinal continuity while working in a confined space within the pelvis.

Despite the importance of these issues, the surgical anatomy has been poorly understood. Much information, however, has been derived from cadaver dissections and operative resection under direct vision. A clearer picture of the structure of the rectum, mesorectum, their innervation and blood supply and their surrounding structures is only recently emerging. New developments in imaging techniques such as endorectal ultrasound (ERUS) and magnetic resonance imaging (MRI; Fig.1) will undoubtedly shed further light on the “normal” anatomy of these structures and the frequency of anatomic variations.

EMBRYOLOGY OF THE RECTUM

Introduction

The gastrointestinal tract develops as three identifiable portions: the foregut comprises the mouth, esophagus, stomach, and duodenum as far as the bile duct; the midgut extends from this point to the distal transverse colon, and the hindgut extends from the distal transverse colon to the anal canal. The primitive gut tube is suspended dorsally by a mesentery throughout its length which persists in the foregut as the lesser omentum, in the midgut as the mesentery to the small bowel and proximal large gut, and for the hindgut as the mesorectum. The blood supply and the venous and lymphatic drainage traverse and are defined by this dorsal mesentery. Consequently, an understanding of the detailed

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The mesorectum is not described as an identifiable structure in most human anatomy texts, although it is referred to by some embryologists. However, its importance for the rectal cancer surgeon is increasingly recognized [2,3,5,6].

The mesorectum, derived from the dorsal mesentery, is the integral visceral mesentery surrounding the rectum and is covered by a layer of visceral fascia providing a relatively bloodless plane, the so-called “holy plane” referred to by Heald [3]. The objective of surgery should be to gain access to and remain on this fascial plane. Posteriorly, this plane lies between the visceral fascia surrounding the mesorectum and the parietal (presacral) fascia. The latter is usually referred to as Waldeyer’s fascia. Inferiorly, at the level of S4, these fascial layers (mesorectal and Waldeyer’s) condense into the rectosacral ligament, which must be divided during rectum mobilization.

The conventional method of the “manual extraction technique” may result in the rupture of tumor tissue within the mesorectum anterior to this plane. Posteriorly, the presacral plexus of veins is at risk of damage. Bleeding from this presacral venous plexus is difficult to control because the veins partly retract into the sacral foramina and remain open since their adventitia is united to the sacral perios teum at the opening of the foramina [7].

While anatomists can usually readily define fascial layers, they are likely to overlook the mesorectum because of the structural distortion found in postmortem specimens and the obliteration of the plane between these fascial layers caused by conventional fixatives. Our attempts to dissect the rectum in fixed cadavers using total mesorectal excision (TME) techniques have demonstrated the difficulty in outlining these planes around the rectum. As mentioned already, new imaging techniques, MRI in particular (Fig.1), are now providing excellent pictures of the mesorectum and its investiture, confirming the anatomy seen under direct vision during surgery. These imaging techniques will help define the field of cancer spread and clarify areas of controversy concerning tumor fixity to surrounding structures.
Most of the rectum is extraperitoneal, although anteriorly, the upper rectum is covered by a thin layer of visceral peritoneum down to the peritoneal reflection in the floor of the pelvis. When considering surgery for rectal cancer, it is useful to divide the territory into six areas to describe the specific details of the bowel and its mesentery, along with its investing perimesenteric planes, all of which need “clean excision” to produce the most effective en-bloc resection. The six areas are as follows:

1. **Above the pelvic brim.** Here the “pedicle package” is located: contained within a thin fascial envelope are the inferior mesenteric artery (IMA), inferior mesenteric vein (IMV), and the lymphatics. This package lies on the pre-aortic nerve plexus centrally and is related to the ureter and gonadal vessels more laterally. It is of considerable importance that the ureter can be exposed completely along its anterior surface without compromising its blood supply, which tends to enter posteriorly. In complex pelvic surgery it may be necessary to mobilize the ureter completely, down to its insertion into the bladder.

2. **Below the aortic bifurcation.** The widening bi-lobed mesorectum behind the upper third of the rectum is related to the bifurcation of the hypogastric nerves and the presacral fat pad (Fig. 6). Anteriorly, the rectum is covered by peritoneum, and therefore is related to loops of small bowel.

3. **Along the pelvic sidewalls.** Here lie the hypogastric nerves, the fascia over the internal iliac vessels, and the piriformis muscle. More distally, the pelvic splanchnic nerves, particularly those coming from the S3 root of the sacral plexus (the erigent nerves), join the hypogastric nerves and form the flattened inferior hypogastric plexus (Fig. 5). The inferior hypogastric plexus is often penetrated by small vessels which only occasionally become large enough to justify their being called the “middle rectal” artery. Sato and Sato have noted, in their careful anatomical dissections, that the middle rectal artery is present in only 22% of hemipelvises, usually occurring on one side [8]. Thus, the so-called “lateral ligaments” are points of adhesion between the mesorectum and the nerve plexus and have been found by tissue biopsy to be predominantly composed of nerve fibers, containing the autonomic nerve supply to the rectum. The middle rectal artery, when present, is usually distal to the lateral ligament and can be a branch of the internal pudendal, the inferior gluteal, or the internal iliac arteries [8]. Thus, for the surgeon the largest vessel is often much deeper than conventional anatomical descriptions of the middle rectal artery. In our experience, the “lateral ligament” can be cut with scissors or diathermy with minimal bleeding, and a middle rectal artery, if present, can usually be controlled by diathermy coagulation and only occasionally needs to be ligated.

4. **Anterior dissection.** The mid-rectum is covered by Denovillier’s fascia; it lies behind the seminal vesicles in the male and behind the vaginal wall in the female. Lower down in the male, the mid-rectum lies very close to the posterior surface of the prostate, and during resection of a low anterior cancer, this proximity creates one of the most difficult technical problems in rectal cancer surgery.

5. **Posterior and distal dissection.** The most distal mesorectum comprises two expanding lobes of fat with a medial groove caused by the ano-coccygeal raphe. Each lobe expands a little below the lateral wall ridge created by the pelvic splanchnic nerves, which puts these nerves at special risk during the dissection.

6. **Extreme distal dissection.** On all aspects, the mesorectum tapers to reveal a clean tube of anorectal muscle as the rectal wall becomes the thick, smooth white muscle of the internal anal sphincter. Thus, the “holy plane” of perimesorectal dissection ends in the intersphincteric plane between the internal (smooth muscle) and external (skeletal muscle) sphincters. It is this smooth muscle tube which is used for a stapled colo-anal anastomosis [9].

**CONCLUSIONS**

Detailed knowledge of the embryology and anatomy of the rectum is fundamental to successful surgical resection of rectal cancer. Paradoxically, the anatomy contin-