Anatomy of the Colon, Rectum, and Anus

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Embryology of the Colon and Anorectic Area

A complete understanding of the colorectal anatomy is closely related to understanding its embryological development. The primitive gut develops from the yolk sac's endoderm. At the beginning of the third week of the fetus, the gut tube divides into three sections. Its sections are named from cranial to caudal as foregut, midgut, and hindgut. The development of the primary intestinal loop occurs with a rapid elongation of the midgut and its mesentery [1].

As a result of this rapid growth in the intestinal length and the simultaneous growth of the liver, the abdomen cannot accommodate all the intestines within itself for a temporary period of time. Thus, the intestinal loops go into the extraembryonic coelomic cavity within the umbilical cord in the sixth week. That is called as physiological umbilical herniation. During the tenth week, herniated intestinal loops begin to return to the abdominal cavity. Although the factors initiating this return are not known clearly, the regression of the mesonephyric kidney, the decline in the growth rate of the liver, and the actual enlargement of the abdominal cavity are considered to play a significant role. The distal 1/3 of the transverse colon, the descending colon, the sigmoid colon, the rectum, and the upper parts of the anal canal develop from the hindgut [2].

The endoderm of the hindgut is also the origin of the bladder and the mucosa of the urethra (Fig. 1.1a). In the later phases of the development, a transverse ridge which is called the urorectal septum arises in the angle between the allantois and the hindgut (Fig. 1.1b). This septum grows downward separating the cloaca into two sections as the primitive urogenital sinus in the anterior and the anorectal canal in

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O. Engin (ed.), *Colon Polyps and Colorectal Cancer*,
https://doi.org/10.1007/978-3-030-57273-0_1

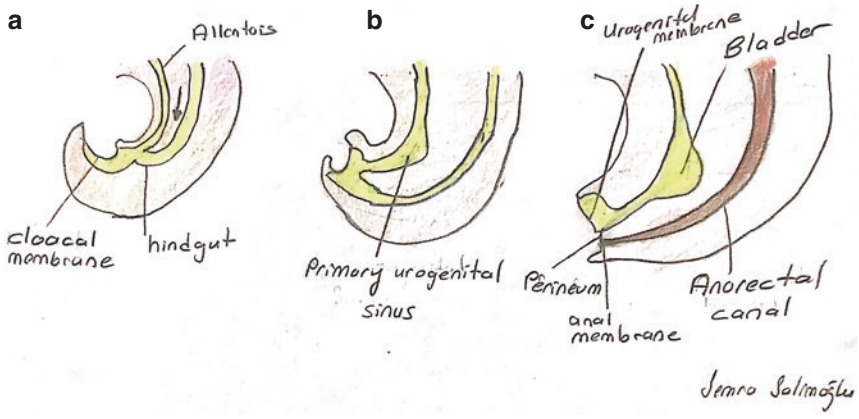


Fig. 1.1 Foregut-derived structures end at the second portion of the duodenum and are supplied by the celiac (coeliacus) artery (Fig. 1.2). The midgut extends from the duodenal ampulla to the transverse colon and takes blood perfusion from the superior mesenteric artery. The distal one-third of the transverse colon, descending colon, and rectum arise from the hindgut fold and take blood perfusion from the inferior mesenteric artery. Venous and lymphatic canals are the same as their arterial equivalents [3]

the posterior. In ninth week, the anal membrane ruptures and the rectum opens to the outside (Fig. 1.1c), which will create the anus later [3].

At the dentate line, endoderm-derived tissues come together with the ectoderm-derived "proctodeum." The development of the distal rectum is a little different. The cloaca is a specialized part of the primitive distal rectum which is composed of endoderm- and ectoderm-derived tissues. The cloaca continues to exist in the hindgut. However, around the sixth week, it starts to divide and separate into anterior and posterior urogenital canal and sphincter elements. With the caudal migration of the urogenital septum, urogenital and gastrointestinal canals become separated. Around tenth week, the descent of the urogenital septum is completed, and the external anal sphincter is formed from the posterior cloaca. By 12th week, the internal anal sphincter develops from the enlarged circular muscle layer of the rectum [3, 4].

The intestines occupy all around the abdomen. Over time, proximal colon meso is reabsorbed on the left side of the abdomen and takes a fixed state. Transverse colon and sigmoid colon mesos remain. Thus, the longest mesos are seen in the transverse and sigmoid colons. In embryological terms, cecum, the ascending colon, and the right half of the transverse colon originate from the midgut whereas the left half of the transverse colon, the descending colon, the sigmoid colon, and the anus originate from the hindgut. Clinically and practically, the first section is called the right colon and the second section is called the left colon [4, 5].

While explaining the colon, rectum, and anal canal anatomy, the pectinate line should be mentioned separately. The pectinate line is formed by the margins of the anal valves which are the small mucosal pockets between the five or ten folds of the mucosa that are known as the anal columns of Morgagni. It is the most critical mark

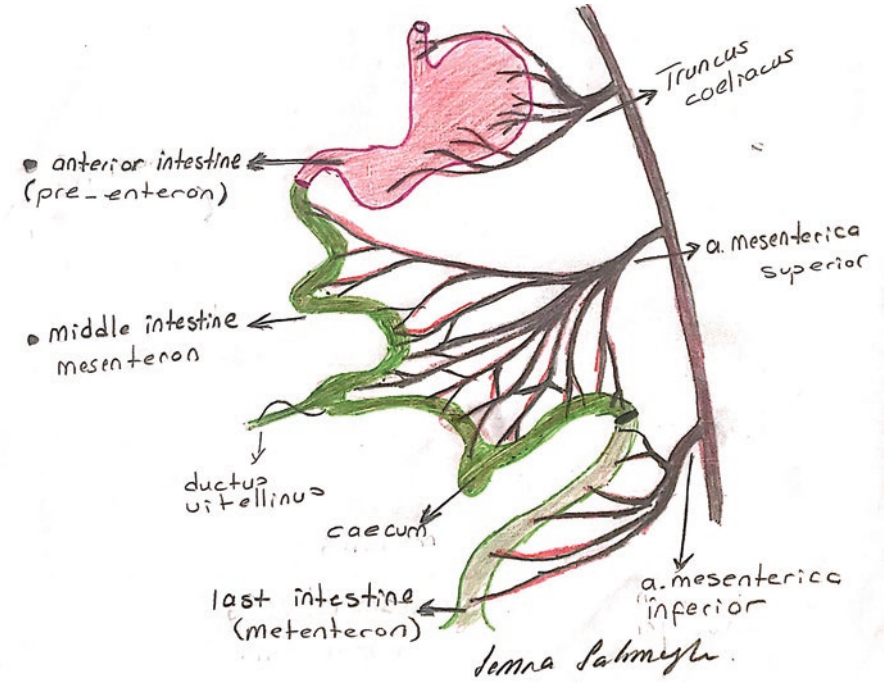


Fig. 1.2 Arterial supply of the digestive system in fetus

in the anal canal. It shows the transition location between the visceral and the somatic area. The course of arteries, veins, lymphatics, nerves and the character of the internal surface of anal canal change after the pectinate line. The anal canal has three histological sections. The cutaneous zone, which ends up to the anal verge, is covered by pigmented skin and contains hair follicles and sebaceous glands. The transitional zone which is located at the proximal part of the anal verge has sebaceous glands without hair follicles. It extends up to the pectinate line which is formed by the free edges of the anal valves [5].

The lower part of the pectinate line originates from ectoderm, and its inner surface is covered by stratified squamous epithelium. Its blood supply comes from inferior rectal artery and venous drainage goes through the inferior rectal vein. Lymphatic drainage goes to the inguinal lymph nodes. It is innervated by the inferior rectal nerves. The pathological type of the tumor of this area is squamous cell carcinoma. External and internal hemorrhoids develop as varicose changes. The upper part of the pectinate line is derived from the endoderm. Its epithelium is columnar epithelium. Arterial supply comes through the superior rectal artery, and the venous drainage goes through the superior rectal vein to the portal system. Lymphatics drain to the pelvic and lumbar nodes. The nerves are autonomous nerve fibers. The pathological tumor type is adenocarcinoma [6, 7].

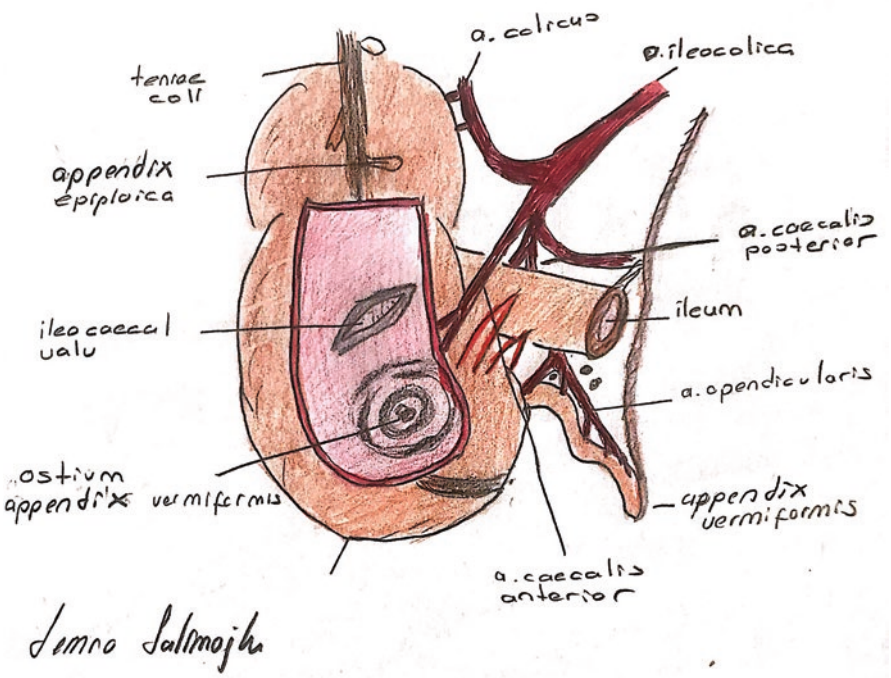


Fig. 1.3 Schematic appearance of the cecum and appendix

Colon, Rectum, and Pelvic Floor Anatomy

The colon is approximately in 120–200 cm length. The diameter of the cecum is 7.5 cm, and the colon becomes 2.5 cm at the point where the sigmoid colon ends. The terminal ileum drains into the cecum through a nipple-shaped structure called ileocecal valve [7–9].

Cecum is a large segment of the proximal colon with a diameter of 7.5 cm and a length of 10 cm (Figs. 1.3 and 1.4). Three longitudinal taenia arise from the cecum. The cecum is completely covered by peritoneum. It has a small meso which limits its movements. On the other hand, it can become very mobile with a long mesentery and be in an abnormal position. The ileocecal sphincter is placed where the terminal ileum binds to cecum. This prevents the contents of the ileum passing rapidly into the cecum. Although the cecum can enlarge to a great extent, dilatations greater than 12–14 cm may cause ischemic necrosis and perforation of the bowel wall. Surgery may be needed when cecal distention occurs due to obstruction or pseudo-obstruction [9, 10].

The appendix is placed at the posteromedial wall of the cecum and is located 3 cm below the ileocecal junction. The end of the anterior longitudinal taenia is always located at the tip of the appendix. The appendix is a blind-ended tube with an average length of 8–12 cm [10, 11].

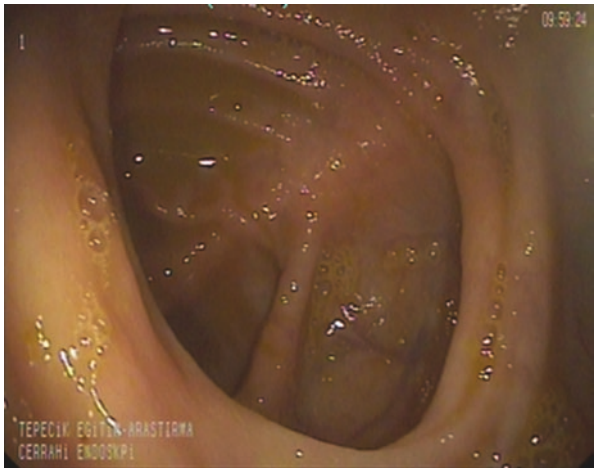


Fig. 1.4 Endoscopic view of the cecum

Localizations of the appendix by frequency are as follows:

1. Retrocecal-retrocolic, free or fixed
2. Pelvic or descendant
3. Subcecal, descending to the right
4. Ileocecal, ascending to the left of the ileum
5. Ileocecal, to the posterior of the ileum

Appendix mesentery derives from the posterior side of the mesentery of the terminal ileum. The mesentery attaches to the cecum and contains the appendicular artery. It takes its artery from the ileal branch of the ileocolic artery or the cecal artery (Fig. 1.3). The appendicular vein also follows the artery in the mesentery. Lymphatic drainage in the ileocecal region extends to the celiac lymph ganglia and cisterna chyli through the lymph ganglia in the appendical, ileocolic, and superior mesenteric artery. Appendicular neoplasms are uncommon. While adenocarcinoma is seen extremely rare (0.5%), carcinoids are the most frequent neoplasms. They are asymptomatic and most of them are smaller than 1 cm; therefore, they can be found by chance in tests. In these patients simple appendectomy is adequate. Surgery depends on the localization in tumors with 1–2 cm. If the tumor is invaded at the base of the appendix or mesentery, the treatment is right hemicolectomy. Appendectomy may be normally sufficient for tumors between 1 and 2 cm because distant metastases are rarely seen in these tumors. In order to decrease locoregional and distant metastasis, the treatment for tumors larger than 2 cm is a right hemicolectomy [12, 13].

The ascending colon is located between the cecum and the right hepatic flexure, with an average length of 15 cm. It is placed along the right side of the abdominal cavity from the cecum to the bottom of the lower right lobe of the liver. It is covered with a peritoneum on the anterior and on both sides. The back side is attached to the abdominal wall. Its lateral peritoneal connections are an

embryological junction between the parietal and visceral peritoneum. Twenty-six percent of individuals have mesentery. The upper part of the ascending colon turns left under the liver and then it turns downward to the medial to make the hepatic flexure on the lateral side of gallbladder. Mobility of this flexure changes between 2.5 and 7.5 cm in breathing. Toldt's white line represents the fusion of the mesentery and the posterior peritoneum. This boundary marker is a good guide in mobilizing the colon and mesentery from retroperitoneum [12, 13].

Transverse Colon

It is the part of the colon with a downward slope of varying degrees between hepatic flexure and splenic flexure. Its average is 40–50 cm and it is completely covered with the visceral peritoneum. It has a long mesentery. The transverse mesocolon attaches the transverse colon to the posterior abdominal wall and allows it to be the most mobile part of the colon. The large curvature of the stomach is connected to the transverse colon by the omentum. Just below the lower corner of the spleen, the transverse colon turns down and makes the splenic flexure. Splenic flexure is the most immobile part of the colon except for the rectum. The lateral surface of the splenic flexure is connected to the diaphragm with the phrenicocolic ligament at the level of the 10th and 11th ribs. This connection makes supportage to the spleen. The transverse mesocolon clings to the tail of the pancreas with its left end. Splenic flexure is deeper than hepatic flexure, and its angle is narrower than hepatic flexure. Also it is partially covered with stomach under the costal margin [13, 14].

The splenic flexura is typically accessed by dissecting the colon descending below the Toldt fascia. After that we can separate the omentum from the transverse colon and enter into the bursa omentalis. This maneuver allows flexure mobilization with minimal traction. The large omentum, which is attached to the upper edge of the transverse colon, consists of two layers of visceral and parietal peritoneum. It is clinically useful to prevent adhesions between surgical abdominal incisions and intestinal surface. The omentum can be mobilized and placed between the rectum and the vagina after the repair of high rectovaginal fistulas. It can also be used to fill the perineal space after rectum resection. It acts as a good patch in difficult situations such as duodenum perforation, where it is impossible to close inflamed and edematous tissues [13–15].

Descending Colon, Sigmoid Colon

It extends along the ventral face of the left kidney between the splenic flexure and pelvic ring and is approximately 25 cm in length. It is smaller than the ascending colon in diameter. It has a relatively thinner wall and stable at the pelvic entrance level. Deep muscle group (levator ani) plays the most important role in pelvic floor muscle structure. Pelvic organs are supported by the connections

they make with pubic bones, muscles, and connective tissue and are controlled by central and peripheral nerves. The term "pelvic floor" refers not only to the levator muscles but it also includes all the structures joining the support in the pelvic cavity. Pelvic floor consists of layers of muscles and fascia supporting the points where the vagina, rectum, and urethra open outside together with the abdominopelvic cavity. Pelvic floor gives active support to pelvic organs through muscular contraction and passive support via fascia and ligaments [14, 15]. The functions of the pelvic floor include preventing prolapse, maintaining continence, facilitating micturition and defecation, sexual function, and being a part of the birth canal in women. The pelvis floor attaches to the pelvis both directly and indirectly and has the top-down layers of endopelvic fascia, pelvic diaphragm, perineal membrane (urogenital diaphragm), and superficial layer [14, 15].

The sigmoid starts from the pelvic ring and ends in the rectosigmoid junction. The sigmoid colon is a small-diameter muscular tube on a long hanging mesentery usually forming an omega turn on the pelvis. The rectosigmoid junction is the part where the sigmoid mesentery ends at the third sacral vertebra level. The sigmoid colon is divided into two sections as the fixed and mobile segments. The pelvic segment is long and omega shaped continuing with the rectum at the bottom. Pelvic mesocolon is attached to the pelvis wall. The mesenteric line of attachment forms a reverse V shape. The sigmoid colon is 15–20 cm long and its terminal 10 cm portion can be seen during the proctoscopic examination. The mesosigmoid usually attaches to the left lateral wall of the pelvis, and the recess called the intersigmoid fossa is formed. It is an essential landmark for surgery as having the underlying left ureter. The two narrowest points of the GIS canal are the terminal ileum and the sigmoid [14, 16].

The Rectosigmoid Junction Has Six Anatomical Features

1. Narrowing in the diameter.
2. The absence of the peritoneal pattern below this point.
3. The absence of the real mesentery below the rectosigmoid.
4. Distribution of three longitudinal taenia over the rectum to form a constant longitudinal muscle layer in the rectosigmoid junction.
5. Appendices epiploicae are located in the sigmoid, but they are not found below the rectosigmoid junction.
6. Internally big morphological changes in the mucosa can be easily seen on sigmoidoscope.

The sigmoid is narrower than the ileum. Foreign bodies cause obstruction in either the terminal ileum or the sigmoid such as gallstone ileus, or obstructions associated with bezoars in patients with stomach resection. For example, a foreign body (bezoar etc.) that is passed from the terminal ileum without crushing may lead to obstruction and perforation in the sigmoid [16, 17].

Characteristics Distinguishing the Colon from the Small Intestine

1. Taenia coli (taenia libera, taenia omentalis, taenia mesocolica): These are three longitudinal muscular strips. They extend from the end of the cecum up to the rectosigmoid. They are formed by the longitudinal muscle fibers of the colon. They are 6 mm wide and are located at equal distance.
2. Haustral sacculations of the colon wall: These sacculations are formed by the adaptation of the longer bowel wall to the shorter longitudinal taenia.
3. Appendices epiploicae: They are the small fatty appendices of the peritoneum covering the external surface of the colon. They are relatively decent at the proximal part of the colon. Toward the sigmoid, they take an elongated and pedicled shape [15–17].

Rectum acts as a fecal reservoir together with the sigmoid colon. The rectum is 12–15 cm in length and lacks taenia and appendices epiploicae. It is settled in the pelvic concavity, and since its posterior surface remains outside the peritoneum cavity by attaching the presacral soft tissue, it is always completely extraperitoneal. The anterior face of the proximal one-third of the rectum is covered by visceral peritoneum. Peritoneal reflection is located at a 7–9 cm distance from the anal canal in men and 5–7.5 cm in women. This peritoneum-covered anterior area is called the pouch of Douglas or the pelvic cul-de-sac. The upper two thirds of the rectum is in association with the small intestine and the sigmoid colon in men, while the lower one-third associates with the prostate, seminal vesicles, vas deferens, ureter, and bladder in the front. In women, on the other hand, the lower one-third associates with the posterior vaginal wall in the front and the upper two thirds is related with the uterus, fallopian tubes, ovaries, small intestine, and the sigmoid colon [17, 18].

The rectum has three folds known as the Houston valves. The valve in the middle is folded to the left whereas the valves located above and below are folded to the right. These folds disappear in surgical mobilization which is an operation that gives an additional 5 cm length to the rectum. The posterior part of the rectum is firmly surrounded by a thick and adjacent mesorectum. This cover, which is usually in collagen form, is thicker in the posterior and thinner in the anterior. The fat tissue, veins, nerves, lymph glands, and lymph vessels located on the posterior and lateral sides of the rectum are surrounded by this cover and form the mesorectum defined by Heald. Presacral fascia (Waldeyer fasyası) is formed by the thickening of the parietal leaf of the endopelvic fascia. It covers the sacrum, coccyx, mid-sacral artery, and presacral vein. Between the two covers is located a cellular and veinless tissue. Some fascia leaves moving away from the Waldeyer fascia join the perirectal fascia right above the anorectal ring proceeding downward-forward at the sacral vertebral level. This extension in the tissue structure is called the rectosacral fascia or sacrorectal ligament. The section of the rectum posterior remaining under the peritoneum is covered by the perirectal fascia. Denonvillier fascia, which is located in front of the perirectal fascia and extends from the peritoneal reflection toward the urogenital diaphragm, is between the rectum and prostate and seminal vesicles in

men and between the rectum and vagina in women. Parietal fascia thickens in the right and left at the lower sections of the rectum. These anatomic formations located on the lateral pelvic floor wall with their ends at the side of the rectum supporting the rectum on both sides are called the lateral ligaments of the rectum. Although the middle rectal artery does not traverse these lateral ligaments, in 25% of the cases, it sends out small branches to one side or both sides. When these ligaments are cut, it has the risk of mild bleeding. A strong presacral fascia covers the sacrum and coccyx to contain the middle sacral artery, nerves, and presacral veins below. A postoperative damage to the presacral fascia may lead to bleeding caused by these veins which is difficult to control. This avascular fascia must be dissected very carefully during mesorectal dissection [17–19].

Anus is the last part of the digestive system extending 4 cm from the anorectal ring to the hairy skin of the anal line. In a normal individual, the anal canal is kept closed in the anteroposterior direction as a result of the tonic contractions of the anal sphincter. Its borders are attached with the fatty, connective, and muscular tissue to the coccyx. Ischiorectal fossa and contents (fatty tissue, hemorrhoidal branches, and nerves) are formed bilaterally, perineal body in the anterior, vagina in women, and urethra in men. The internal lining of the anal canal has changed in two main directions: mucosa is covered by columnar epithelium above. Below, it is covered by shaded colored squamous epithelium lacking hair and glands. The margin between the two linings is called linea pectinea or linea dentata. The valves along this line are formed by proctodermal membrane residuals. Each valve has a minor dent on it (Morgagni sinus, crypt, anal sinus). Musoca makes 8–14 longitudinal turns along the linea pectinea. Two adjoining colons come together at the linea pectinea level. The difference between the rectal columnar mucosa lining and the anal squamous lining has important clinical outcomes. For instance, diseases like ulcerative colitis affecting the rectal mucosa may progress up to the transition point while they do not reach the distal of the dentate line. Cancers in the dentate line proximal are typically adenocancer and those in the distal are squamous or cloacogenic. Anal canal epithelium has normal skin structure with apocrine glands. Inflammatory complications of the apocrine glands and hidradenitis suppurativa are observed. In addition, this difference varies in sensory perception affecting the surgical approach in anorectal diseases. For example, internal hemorrhoids can be treated with a rubber band application without requiring local anesthesia. External hemorrhoids, on the other hand, require local anesthesia on the sensitive perianal skin [18, 19].

Colon Wall Is Composed of Three Layers

The inner side of the colon is covered by a lining layer. The lining covering the inner side of the intestine is called the mucosa. This layer has the function of digesting and absorbing of the nutrients. The middle part contains the muscular layer. Nutrients are moved forward by this layer. The outermost layer of the bowel wall is the serosa layer. The surface of the serosa layer is smooth. This prevents the intestines from adhesion to each other within the abdominal cavity and the bowels

function within an order. The waste of the nutrients travels along the colon and is moved to the rectum, which is the terminal end of the colon where the stool is stored. When the stool stored here arouses the feeling of defecation, the individual defecates (sometimes the natural contractions and rhythm of the large intestine may change. Waste materials may progress quickly or very slowly. Stress, medications, pregnancy, disease, a constant feeling of defecation, lack of exercise, and a diet poor in fiber and liquid disturb the functions of the intestine) [19, 20].

The mouth where the colon opens outside is called the anus. This region has muscles that control stool. These stool-controlling muscles are called sphincters. There are two sphincters; one inside, one outside. The sphincter inside contains smooth muscle fibers and works involuntarily. The sphincter inside is called the internal anal sphincter. The one outside (external anal sphincter) has striated muscles and is controlled voluntarily [19, 20].

Arterial Supply, Venous and Lymphatic Drainage

Arterial supply of the cecum is provided by anterior and posterior cecal artery. Veins accompany arteries and are drained into superior mesenteric vein. The appendix receives its blood supply from the appendicular artery, a branch of the posterior cecal artery. The arterial supply of the ascending colon is provided by the two branches of the superior mesenteric artery called ileocolic artery and right colic artery. Veins accompany arteries and flow into the superior mesenteric vein. The proximal 2/3 of the transverse colon arterial supply comes from middle colic artery which is a branch of superior mesenteric artery. The distal 1/3 is supplied by left colic artery which is a branch of the inferior mesenteric artery. Veins accompany arteries and flow into the superior mesenteric vein and inferior mesenteric vein. The descending colon is supplied by the branches of left colic artery and sigmoid artery which are the branches of the inferior mesenteric artery. Veins accompany arteries. The terminal branch of the inferior mesenteric artery, the superior rectal (hemorrhoidal) artery, reaches the upper rectum within the colon meso, entering into the rectal wall as small branches divided into two sub-branches as right and left. The middle rectal (hemorrhoidal) artery (it is reported to be absent in 40–80% of the cases in the specimen studies carried out) is a sub-branch of the internal iliac artery which supplies the 1/3 of the lower rectum and the upper part of the anal canal. It progresses along the lateral ligament and reaches the rectum. The inferior rectal (hemorrhoidal) artery arises from the internal pudendal artery, passes the ischiorectal fossa and reaches the anal sphincters. The main artery of the rectum is the superior rectal artery. Although superior and middle rectal arteries are ligated during the rectal mobilization the perfusion of the rectal stump is not affected due to the submucosal collateral network. The middle sacral artery arises 1 cm above the aortic bifurcation, progresses downward passing in front of the last two lumbar vertebra, sacrum, coccyx, and behind the aorta, left common iliac artery, presacral nerve, superior rectal artery, and the rectum (Fig. 1.5). Its terminal branches reach the anococcygeal raphe and the anal canal [20, 21].

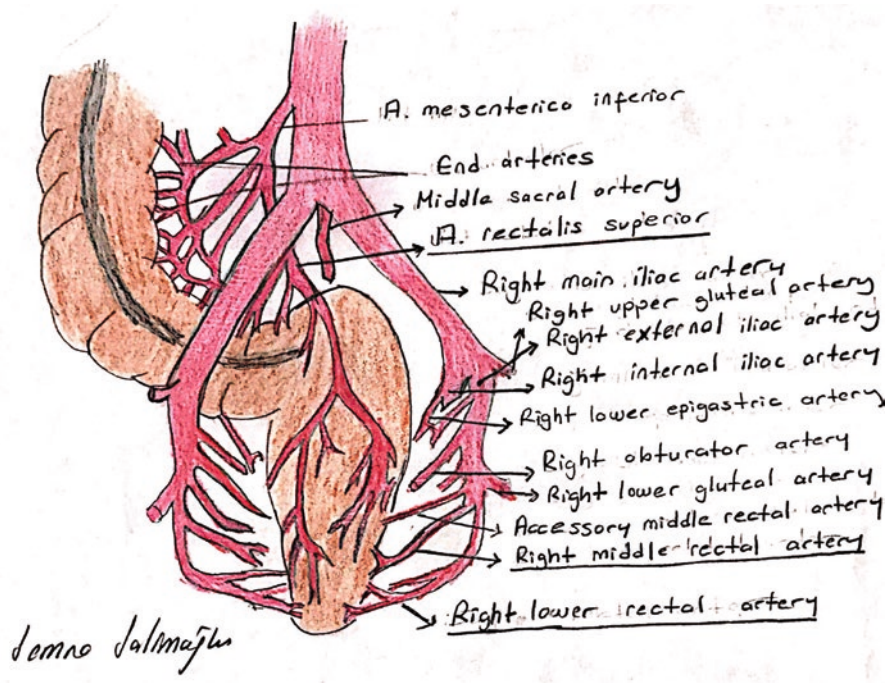


Fig. 1.5 The arterial supply of the rectum

As for the venous circulation, superior hemorrhoidal vein flows into the portal system through inferior mesenteric vein. Middle hemorrhoidal vein and inferior hemorrhoidal vein drain into the systemic circulation through the internal iliac vein. Thus, a portal-systemic natural shunt is formed around the anal canal. The importance of this shunt is that if portal hypertension develops for any reason in patients, venous distention and further rectal varicosis can occur in the distal part of the portal system (that is the anal canal) and that should not be confused with hemorrhoidal disease. From an epidemiological point of view, it was seen that in patients with portal hypertension the incidence of hemorrhoidal disease is not different from the normal population. Rectal varices account for only 1% of the gastrointestinal bleeding seen in patients with portal hypertension. The upper hemorrhoidal plexus is located in the submucosa, in the section above the linea dentata of the anal canal. The external hemorrhoidal plexus lies below the linea dentata of the anal canal beneath the skin. The two plexuses are connected to each other. Enlargements in the internal plexus form internal hemorrhoids while enlargements in the external plexus form external hemorrhoids [20, 21]. The arterial supply of the anal canal is provided by the inferior rectal (hemorrhoidal) artery arising from the internal pudendal artery. It supplies the arterial circulation of the section below the pectinate line. Its venous circulation is through the middle and inferior rectal veins to the internal iliac vein and then to the inferior vena cava. This

bilateral drainage of the anal canal is responsible for the differences in the metastases of the tumors developing in this region (Fig. 1.5).

SMA and IMA Have Three Main Connections

1. The marginal artery of Drummond (parabolic arcade) is located at a distance of 1–8 cm to the colon wall with a parallel progression. (The marginal artery may end at the superior rectal artery). Two to six sigmoid branches are collateralized with the left colic artery for forming an arch that supplies blood to the sigmoid colon.
2. The central anastomotic artery: The larger and centrally located artery.
3. Riolan's arc is the anastomosis between the left colic artery as a branch of the IMA and the middle colic artery as branch of the SMA. It acts as a vital canal when the principal arteries of the colorectal area are occluded. The presence of an enlarged Riolan's arc in imagings supports the occlusion of one of the major mesenteric arteries (Fig. 1.6) [21, 22].

Venous drainage of the colon (Fig. 1.7), as stated above, accompanies the arteries. On the left, veins come together forming the superior mesenteric vein. Veins from descending colon, sigmoid colon, and superior rectal area form the inferior mesenteric vein. This drainage continues toward the portal system. The middle and inferior rectal veins join the internal iliac veins which are a part of the systemic circulation [21, 22].

The Lymphatics of the Colon

They are divided into four groups: epicolic lymphatics are below the serosa of the bowel wall, paracolic lymphatics are above the marginal artery, intermediate lymphatics are along superior and inferior mesenteric arteries, and the lymphatics are in the radix of the principal superior and inferior mesenteric artery. The last group includes the mesenteric root nodes (which also collect the lymph coming from the small intestine), aortic nodes, and the left lumbar nodes (Figs. 1.8 and 1.9). They all drain into the cisterna chyli. A wide resection of the colon should involve the whole segment supplied by a major artery. This would resect a large part of the lymphatic drainage of the segment. The lymphatic drainage of the cecum flows into the superior mesenteric lymph nodes. The lymphatic drainage of the appendix flows into the superior mesenteric lymph nodes through the mesoappendix lymphatics. The lymphatic drainage of the ascending colon flows into the nodes extending along the blood vessels and then to the superior mesenteric lymph nodes. The lymphatic drainage of the transverse colon follows the same path as well. Two-third proximal part of the colon lymphatics flow into the superior mesenteric lymph nodes, and 1/3 distal part of the colon lymphatics drain into the inferior mesenteric lymph nodes. The lymphatic drainage of the descending colon also follows the vessels and drains into the inferior mesenteric lymph nodes. Lymphatics follow the arteries (Fig. 1.10).

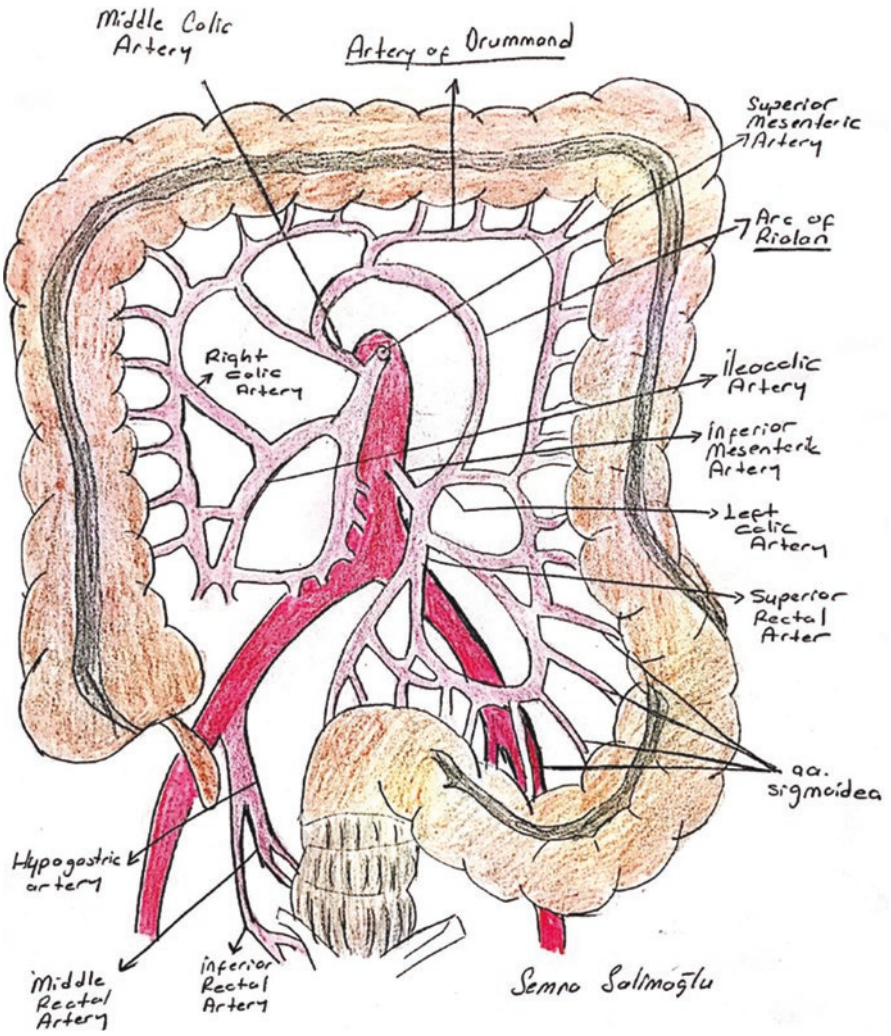


Fig. 1.6 Arterial supply of the colon

The lymphatics of the upper 1/3 and middle 1/3 section of the rectum drain into the inferior mesenteric lymph nodes. The lymphatics of the lower 1/3 part of the rectum drains into the inferior mesenteric lymph nodes. The lymphatic drainage of the part of anal canal below the linea dentata is toward the perianal lymphatic plexus and then to the inguinal lymph nodes (Figs. 1.8 and 1.9) [20, 21]

The extramural lymphatic drainage is separated by the pectinate line. The distance from the anal opening to the pectinate line is approximately 2 cm. The margin separating the intramular lymphatic drainage is at the level of the middle rectal valve located 8 cm above the anal opening.

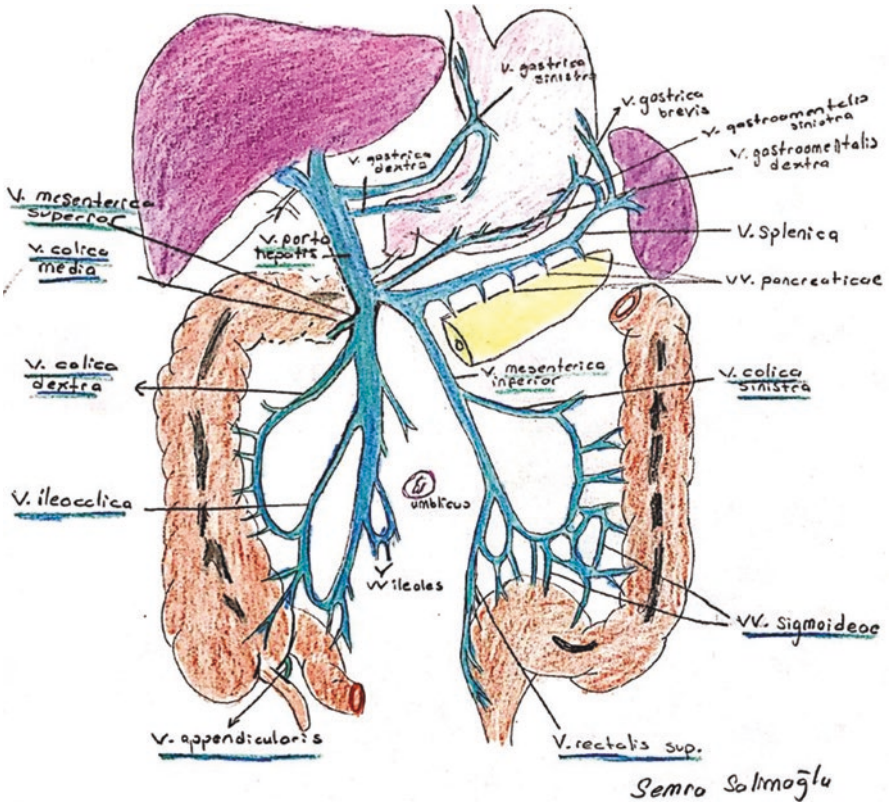
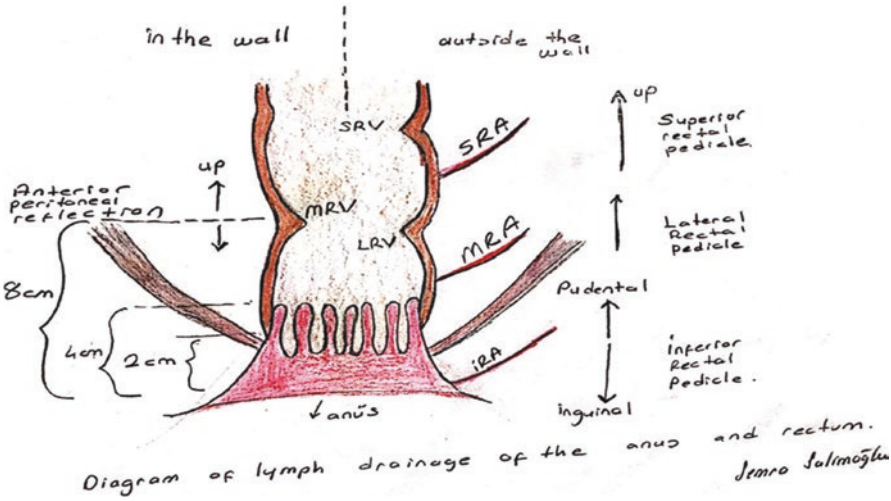


Fig. 1.7 Venous drainage of the colon

Downward spread of rectum lesions is extremely rare. Only 2% of them spread downward. Anterior resections should go at least 2–3 cm distal of the lesions. The invasion of the lymph node with metastatic cancer is a significant prognostic factor for colorectal cancer. The correct pathological evaluation is essential for staging, which is decisive in the treatment of patients. While the lymphatics of the colon and proximal 2/3 of the rectum eventually open to the sisterna chile through the para-aortic lymph nodes, the distal rectum and anal canal lymphatics can drain both to the para-aortic lymph nodes and the internal iliac and superficial inguinal lymph nodes. Although the dentate line clearly shows the level at which the lymphatic drainage is separated, studies have shown that in color injections allied even from a 10 cm distance to the dentate line, lymphatics could drain via the lymphatics of the neighboring organs such as the vagina and the round ligament of the uterus (Figs. 1.8 and 1.9). The drainage of the proximal part of pectinate line is to the inferior mesenteric lymphatics. Distal part of the line drains to the inguinal nodes (Fig. 1.10) [21, 22].



IRA:Inferior rectal artery
MRA:Middle rectal artery
SRA:Superior rectal artery
LRV:Lower rectal valve
MRV:Orta rectal valve
SRV:Superior rectal valve

Fig. 1.8 Diagram of lymph drainage of the anus and rectum. *IRA* inferior rectal artery, *MRA* middle rectal artery, *SRA* superior rectal artery, *LRV* lower rectal valve, *MRV* middle rectal valve, *SRV* superior rectal valve

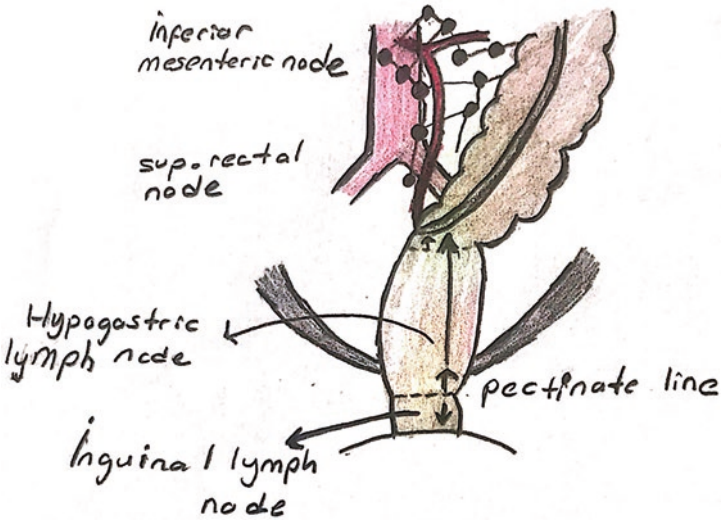


Fig. 1.9 Diagram of lymph drainage of the anus and rectum (*S. Salimoglu*)

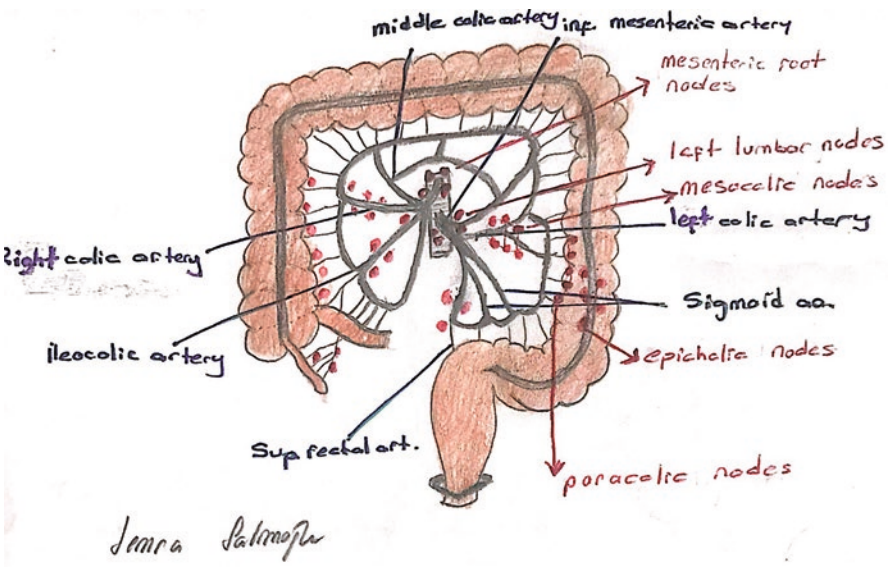


Fig. 1.10 The lymphatics of the colon

Innervation of the Colon, Rectum and Anal Canal

Preganglionic sympathetic fibers come from the T6–T12 synapses in the preaortic ganglion. Postsympathetic fibers progress along the blood vessels to reach the right and transverse colon. The parasympathetic innervation of the right and transverse colon come from the right vagus nerve. Parasympathetic fibers follow the SMA branches, making a synapse within the bowel wall. The left colon and the rectum take their sympathetic stimuli from the L1–L3 preganglionic lumbar splanchnics. They form synapses in the preaortic plexus located above the aortic bifurcation, and postganglionic extensions follow the branches of the IMA and the upper rectal artery to reach the left colon, sigmoid, and rectum. The innervation of the rectum is composed of sympathetic and parasympathetic nerves. Sympathetic nerves taken from the thoracic columnar segments come together below the inferior mesenteric artery and form the inferior mesenteric plexus. These purified sympathetic nerves go down to the superior hypogastric plexus right below the aortic bifurcation and to the pelvis making a bifurcation and form the hypogastric nerves. The lower rectum, bladder, and genital organs take their innervations from the hypogastric nerves. Inferior mesenteric plexus damage is seen following the high attachment of the inferior mesenteric artery. The sacral third, fourth, and fifth parasympathetic roots merge and form the nervus erigentes (located behind the Waldeyer's fascia). However, they might get hurt at the point they join the pelvic plexus (high attachment and connection of the lateral ligament to the lateral). They combine with the hypogastric nerves at the rectum anterior and lateral forming the pelvic plexus and progress along the lateral wall of the pelvis. Periprostatic plexus originates from the pelvic plexus and the complex

fibers in this plexus innerve the rectum, internal anal sphincter, bladder, prostate, and penis. The pudendal nerves (S2, S3, S4) provide the penis and clitoris with sensory stimulus via the dorsal nerve. Both parasympathetic and sympathetic nerves are needed for penile erection. Since parasympathetic nerves increase blood flow in the corpus cavernosum and cause vasodilatation, they cause erection. Sympathetic nerves cause erection by making vasoconstriction. Also they cause contraction of the seminal vesicle, ejaculation ducts, and prostate which cause ejaculation [23, 24].

The periprostatic plexus might be damaged during rectal surgery. Bladder dysfunction and/or impotence may be seen in the damage of the pelvic autonomic nerves. The internal anal sphincter is innerved by both the sympathetic and parasympathetic nerves. The internal anal sphincter has a constant tonus that increases as rectal pressure increases. Internal sphincter tonus increases again when the rectum is empty. The external anal sphincter and levator ani muscles are innerved by the inferior rectal branch of the internal pudendal nerve (S2, S3, S4), and the perineal branch of the fourth sacral nerve. In case of any distention of the rectum, the internal sphincter loosens, the external sphincter can voluntarily contract, and in this case it can remain for about 1 min. Superficial heat, coldness, pain, and tactile senses below the dentate line are innerved by the perineal branch of the pudendal nerve and the inferior rectal nerve. Above the dentate line, the senses of ligation or mucosal stimulation of the internal hemorrhoids are possibly done by the parasympathetic fibers. Resection of the sacrum by protecting the sacral nerves can be performed during pelvic tumor surgery. Protection of at least one fiber of the third sacral nerve would be sufficient for an acceptable anal continence. On condition that the upper three roots of one side and the upper two roots of the other side are protected, a near-normal continence can be obtained. If all the sacral fibers are lost on one side while those on the other side are protected, continence could be maintained; if S3 roots are damaged on both sides, the patient has incontinence. The upper half of S1 is necessary for the stability of the spine and pelvis. Bladder and erection dysfunction may be as high as 45% following rectal surgery [23, 24].

In colon surgery, the margins of resection may vary by the location of the lesion in malign diseases. It has to cover the whole area supplied by a major artery along with the lesion itself. The anatomy of vessels and lymphatics should be well understood. In cancer surgery, vessels must be tied where they originate. It is essential to avoid ureteral injury. In order not to cause internal hernia, defects in the mesentery must be closed. In elective operations, intestinal cleaning should be done properly. This is limited in emergent operations, but requires utmost care. There are two important points in intestinal clean up. The first one is cleaning the fecal content (mechanical preparation) and using antibiotics against colon bacteria. A poorly prepared colon has the risk of anastomotic leakage [23–25].

Ten Golden Rules of Good Colon Surgery

1. Intestinal cleaning should be performed properly.
2. Intravenous antibiotics should be given during and after the surgery for 24–48 h.

3. Nasogastric tube and Foley catheter should be used.
4. The anatomy of the vessels and lymphatics should be understood well. During cancer surgery, vessels should be resected where they come out.
5. A good anastomosis technique involves the following:
   (a) Intestinal segments cut at ends should be pink in color, soft and flexible in form, and mild bleeding must be monitored. In addition, there should be arterial blood flow with visible pulsation at the incision margin of both intestine segments. Since hematoma formation along the anastomosis line or at the mesentery would reduce blood flow, mobilization, resection, and anastamosis should be performed with utmost care on the intestine and mesentery.
   (b) All the fatty tissue at the field of anastomosis should be cleaned without removing the appendices epiploicae and mesenteric margin.
6. Tension on the anastomosis line should be prevented.
7. Anastomosis should be covered with omentum if possible.
8. The whole surgical intervention and its modifications should be known.
9. Urethral injury should be avoided.
10. Mesenteric defects should be closed to avoid internal hernia. Complete seromuscular joining must be ensured in anastomosis. All the stitches should be passed through the submucosa as well making the connective tissue here support the power of anastomosis. Anastomosis leakages usually occur at the antimesenteric part of the intestine. This probably happens due to insufficient cleaning of the mesenteric fatty tissue. If manual stitching technique is to be used, all the layers of the intestine must be inverted so as to avoid narrowing. It is important not to use excessive force while pulling tissues together by placing the sutures because it could lead to the development of strangulation on the bowel wall due to pressure and the resulting anastomosis dehiscence. Similarly, blood (or serum) accumulation in the anastomosis neighborhood does not only decrease circulation, but it also forms a focus of infection. The following localized sepsis may cause abscess development and anastomosis dehiscence. It is critical to make sure that no occlusion or narrowing is present in the distal prior to anastomosis [25, 26].

Histology of the Colon

The whole of the gastrointestinal canal has some structural characteristics. In the center there is a lumen varying in diameter. This lumen is surrounded by a wall consisting of four layers. These layers are the mucosa, submucosa, muscularis, and serosa from inside out (Fig. 1.11). Mucosa is composed of the epithelium, lamina propria, and muscularis mucosa. Lamina propria is a connective tissue rich in blood and lymph vessels. Muscularis mucosa is made up of a circular muscle inside and a longitudinal outside separating the musoca from submucosa. Mucosa is also called the membrane. Submucosa is a loose connective tissue containing a large number of blood and lymph vessels as well as a submucosal nerve plexus (Meissner). The muscularis layer is composed of two muscle layers. The internal part of this muscle is circular and the

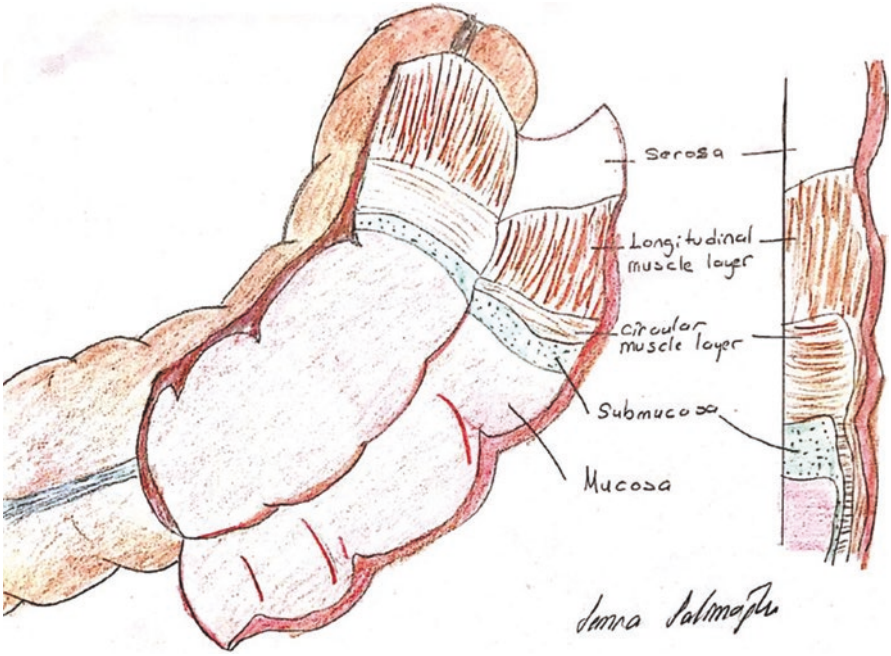


Fig. 1.11 Histologic layers of the colon (*S. Salimoğlu*)

external part is longitudinal. Between these two muscle layers is the myentric (Auerbach's) nerve plexus and the loose connective tissue containing blood and lymph vessels. Serosa is covered by a thin and loose connective tissue [27, 28].

Mesothelium is covered by a single-fold flat epithelium. Colon mucosa does not contain layers except rectum. This portion of the bowels does not have villi. Intestinal glands are long and characterized by a large number of goblet and absorptive cells with a small number of enteroendocrine cells. The absorptive cells have cylindrical and short irregular microvilla. This matches very well with the main functions of the organ and allows for water absorption, stool consistency regulation, and mucus secretion. Mucus has a watery gel form which not only lubricates the intestine surface but also covers bacteria and particulate material. Lamina propria is rich in lymphatic cells and nodules. Nodules are usually found within the submucosa. The reason for the high amount of the lymphoid tissue is the dense population of bacteria in the colon. Muscularis is composed of longitudinal and circular muscle layers. Different from the small intestine, longitudinal muscle fibers come together in the form of three thick longitudinal strips called taenia coli. There are small tissues called appendices epiploicae formed by the fatty tissue in the intraperitoneal section of the colon [27, 28].

There is a range of longitudinal folds in the anal region which are called the rectal columns of Morgagni. At 2 cm of the anal opening, lamina propria contains a large blood vessel plexus an extraordinary enlargement of which forms hemorrhoids. Differentiation and proliferation of the cells located 1/3 below the colon mucosa glands occurs approximately every 6 days. Colon mucosa is responsible for digestion and

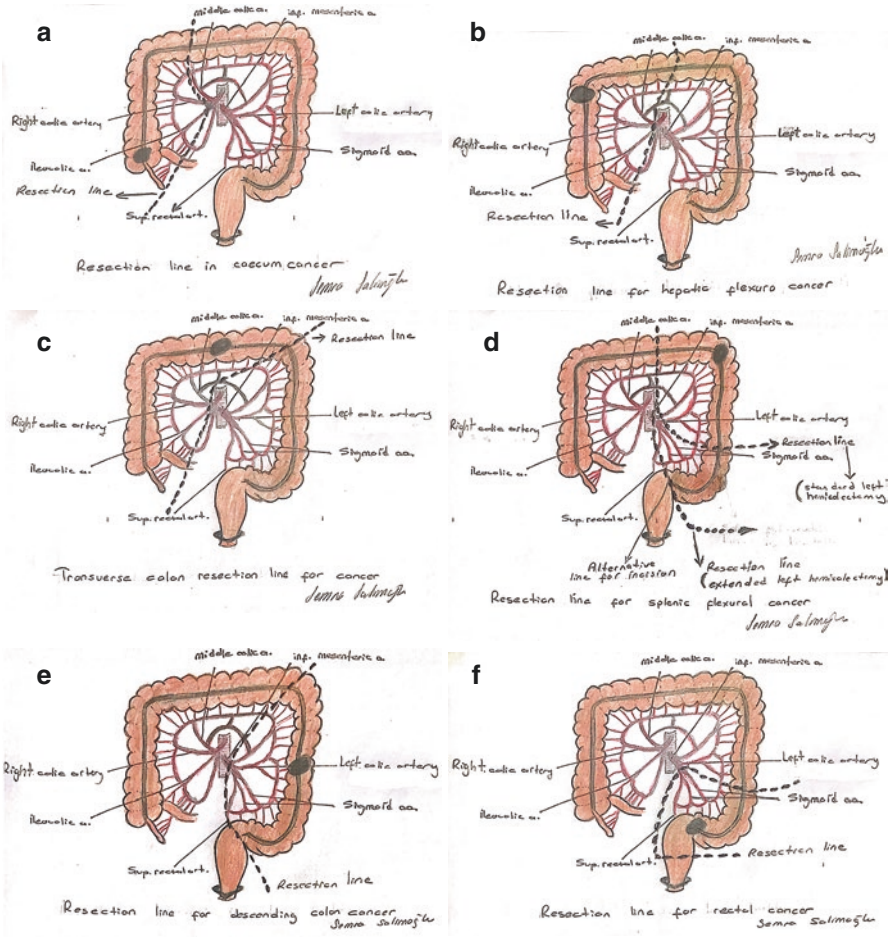


Fig. 1.12 (**a**) Cecum cancer. (**b**) Hepatic flexura Ca. (**c**) Transverse colon Ca. (**d**) Splenic flexura Ca. (**e**) Descending colon Ca. (**f**) Rectal Ca

blood absorption of nutrients. The muscle layer in the middle pushes the nutrients forward. Serosa layer has a smooth surface. This prevents intestinal adhesion in the abdominal cavity and intestines function in an order. Waste material travels along the large intestine and is taken to the rectum, the terminal section of the large intestine where stool is stored. When the waste stored here arouses the feeling of defecation, the individual defecates (sometimes the natural contractions and rhythm of the colon may change). Stress, medications, pregnancy, disease, a constant feeling of defecation, lack of exercise, and a diet poor in fiber and liquid disturb the functions of the intestine. The region where the colon opens outside is called the anus. This region has muscles that control stool. These stool-controlling muscles are called sphincters. There are two sphincters: one inside and one outside. The sphincter inside contains smooth muscle fibers and works involuntarily. The sphincter outside is called the external anal sphincter. The one outside has striated muscles and is controlled voluntarily [28, 29].

In colorectal tumors, incision lines depending on the location of lesion is important for a safe tumor surgery (Fig. 1.12a–f). With a better understanding of the importance of proximal, distal, and radial margin and lymphadenectomy, the concept of therapeutic resection has improved considerably. Resection in colon cancers is usually performed based on vascular anatomy in order to endure the removal of the whole lymphatic region. For a successful lymphadenectomy, generally colon resection performed from 4 to 5 cm distance should include the whole area supplied by a major artery together with the lesion itself [30, 31].

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