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Pelvic Anatomy for Distal Rectal Cancer Surgery

Sanghyun An and Ik Yong Kim

Abstract

Worldwide, colorectal cancer is the third most common cancer and one of the leading causes of cancer-related deaths. Currently, total mesorectal excision (TME) is considered as the gold standard surgical procedure for rectal cancer. To achieve a good oncologic outcome and functional outcome after TME in distal rectal cancer, exact knowledge regarding the pelvic anatomy including pelvic fascia, pelvic floor, and the autonomic nerve is essential. Accurate TME along the embryologic plane not only reduces local recurrence rate but also preserves urinary and sexual function by minimizing nerve damage. In the past, pelvic floor muscles and autonomic nerves could not be visualized clearly, however, the development of imaging studies and improvements of minimally invasive surgical techniques such as laparoscopic and robotic surgery can clearly show the anatomy of the pelvic region. In this chapter, we will provide accurate anatomy of the rectum and the anal canal, pelvic fascia, and the pelvic autonomic nerve. This anatomical information will be an important indicator for performing an adequate operation for distal rectal cancer.

Keywords: rectal neoplasms, anatomy, colorectal surgery, autonomic nervous system, pelvic floor

1. Introduction

Colorectal cancer is the third most common cancer and the fourth leading cause of cancer-related deaths worldwide [1]. Especially, rectal cancer accounts for 30–40% of colorectal cancer, and the treatment strategy is different and more complicated compared to colon cancer because of its anatomical features. Although the treatment outcome of rectal cancer has greatly improved with the development of multimodality treatment including neoadjuvant radiotherapy, cytotoxic chemotherapy, and target agents, surgery remains the mainstay of therapy. Since the concept of total mesorectal excision (TME) was first described by Richard Heald in 1979, this procedure became the gold standard technique for rectal cancer surgery until now [2]. The fundamental principle of TME is en bloc resection of the rectum with its surrounding fatty tissue complex which contains the blood vessels and lymphatics down to the pelvic floor. To achieve complete TME and sphincter preserving surgery in low-lying rectal cancer, knowledge for regarding the pelvic fascia (mesorectal, parietal) and autonomic nerves, a thorough understanding of the pelvic floor anatomy is essential.

2. Pelvic anatomy

2.1 Basic anatomy of the rectum and mesorectum

The rectum is the most distal part of the large intestine that exists from the sacral promontory level to the anorectal ring. The anterior and lateral portion of the upper one-third of the rectum is covered with peritoneum, and the middle one-third of the rectum is covered with peritoneum on its anterior portion. The lower one-third cannot be observed in the intraperitoneal space because it is located in the extraperitoneal space. The taenia coli disappears in the rectum, forming one longitudinal muscle layer surrounding the rectum. The length of the rectum is approximately 12-15 cm and has three curvatures, which is related to Houston's valves. The upper and lower part are convex to the right, and the middle portion is convex to the left. The middle valve is the most prominent and is located approximately equal to the level of peritoneal reflection [3].

The rectum is surrounded by a fatty tissue complex called the mesorectum, which corresponds to the mesentery of the rectum. Mesorectum contains abundant blood vessels, lymphatics, and lymph nodes, and it is enveloped by thin visceral pelvic fascia [4]. It is developed thickest in the posterolateral side and the anterior part is formed relatively thin. In addition, the volume of the mesorectum decreases as it approaches the pelvic floor, and disappears approximately 2 cm above the levator ani muscle (**Figure 1**). A number of studies have revealed that the mesorectum is an important structure for tumor spreading, and en bloc resection through sharp dissection of mesorectum is very important in improving treatment outcomes [2, 5, 6].

2.2 Fascia structures around the rectum

Dissecting the correct anatomical plane can lead to good oncological outcomes and preserve the autonomic nerves to prevent postoperative urinary, sexual, and defecatory dysfunction. If pelvic dissection is performed along the exact embryologic fascial plane, the operation can be done without bleeding. To perform precise total mesorectal excision, a thorough understanding of the fascia around the rectum and pelvic cavity is essential. **Figure 2** shows the anatomical relationship of the fascia around the rectum.
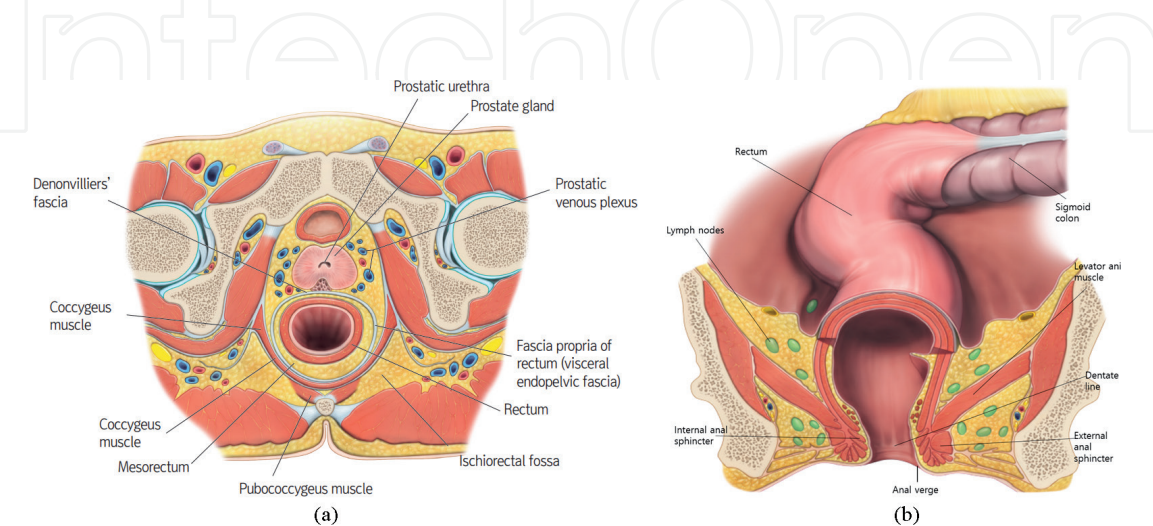

Figure 1.
Anatomy of the rectum and mesorectum. (a) Structures around the rectum. The rectum is surrounded by mesorectum, and the rectum and mesorectum are enveloped by the fascia propria of the rectum. (b) Total mesorectal excision (TME). En bloc resection of mesorectum is important.
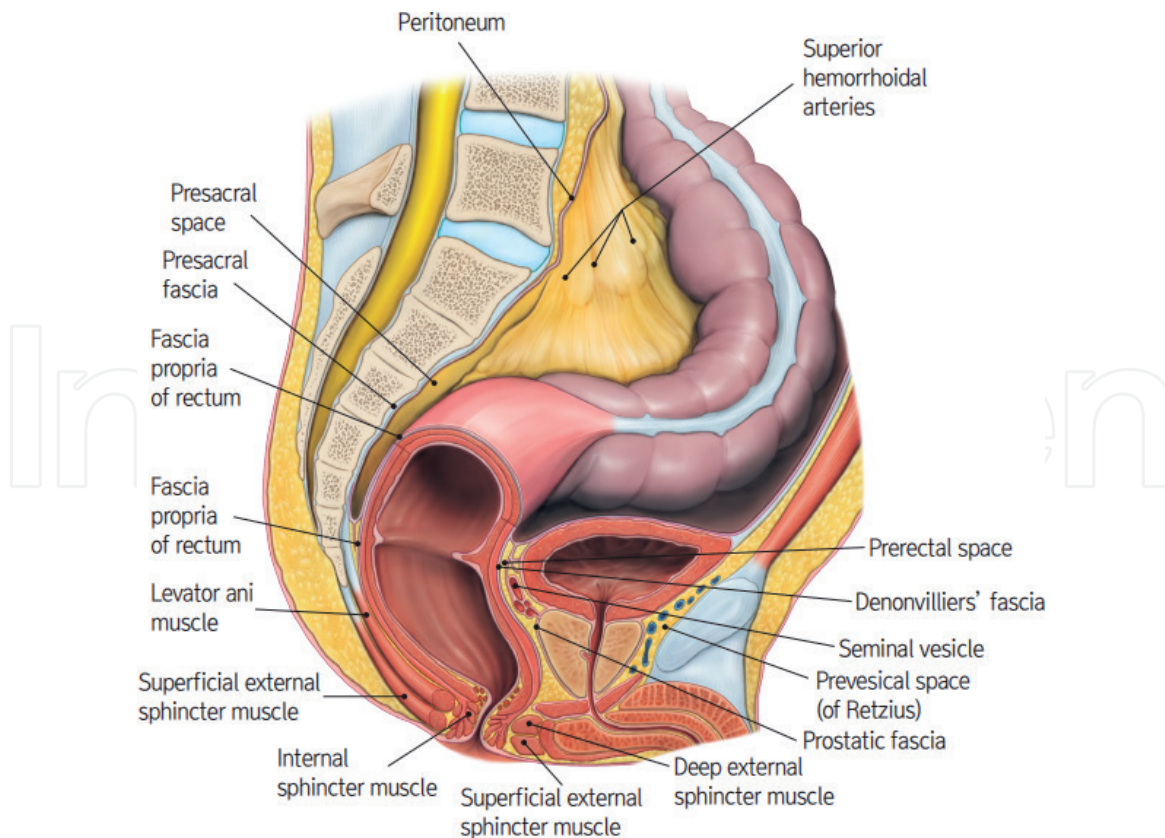
Figure 2.
Anatomy of fascia around the rectum. The fascia propria of the rectum covers the rectum and mesorectum. The presacral fascia covers the anterior surface of the sacrum. It combines with the fascia propria of the rectum at the S4 level (recto-sacral fascia = Waldeyer's fascia). Denonvilliers' fascia is a dense membrane between the rectum and seminal vesicles.

2.2.1 Fascia propria of the rectum and presacral fascia

The rectum and mesorectum are enveloped by the fascia propria of the rectum, also called as mesorectal fascia. The mesorectal fascia corresponds to the visceral fascia of the rectum. Caudally, it ends at the internal sphincter and laterally ends at the internal iliac artery, and is connected to the parietal pelvic fascia [7]. A magnetic resonance image scan (MRI) can clearly show the boundaries of these mesorectum and mesorectal fascia (**Figure 3**). During total mesorectal excision, it is important to completely excise this mesorectal fascia without damage to obtain optimal oncologic outcome [6, 8, 9].

The presacral fascia, also called as parietal pelvic fascia, covers the anterior surface of the sacrum and encloses the sacral vessels and nerves. It combines with the mesorectal fascia at the S4 level and became part of the anococcygeal ligament at the level of anorectal junction. The presacral venous plexus is formed by the two lateral sacral veins, the middle sacral vein, and the communicating veins, and it runs underneath the presacral fascia. If the dissection plane is too deep to damage the presacral fascia during the posterior dissection, life-threatening massive bleeding can occur and it often is difficult to control. Therefore, dissection should be done along with the space between the mesorectal fascia and the presacral fascia until the recto-sacral fascia is encountered [10, 11].

2.2.2 Recto-sacral fascia (Waldeyer's fascia)

Recto-sacral fascia, also known as Waldeyer's fascia, is a dense connective tissue linking the presacral fascia to the mesorectal fascia at the S4 level. As the
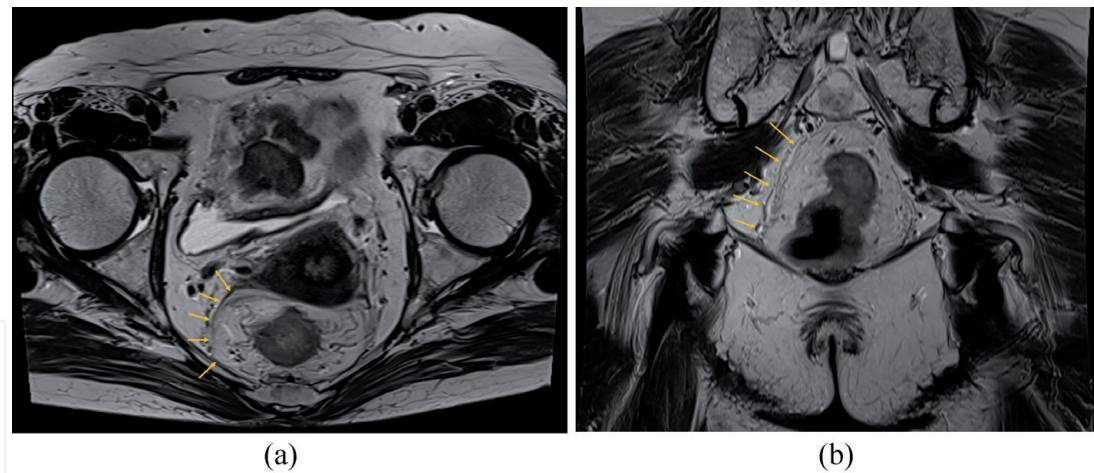
Figure 3.
Magnetic resonance image scan. Magnetic resonance image scan (MRI) can clearly show the boundaries of these mesorectum and mesorectal fascia. (a) T2 weighted image on MRI. Axial view. The rectum and mesorectum are enveloped by the fascia propria of the rectum (mesorectal fascia). (b) T2 weighted image on MRI. Coronal view. Mesorectum, mesorectal fascia, and puborectalis muscle.

posterior dissection proceeds down along the plane between the mesorectal fascia and the presacral fascia, a dense, tough recto-sacral fascia is identified. To enter the retro-rectal space and reach the pelvic floor, this fascia must be incised and dissected further caudally. This fascia has a different thickness from individuals, it is not visible when it is too thin. Because the presacral artery and venous plexus and autonomic nerves pass behind this fascia, it is important to perform sharp division to avoid excessive bleeding due to presacral vein injury (**Figure 4**) [8, 12].

2.2.3 Denonvilliers' fascia

During the anterior dissection of the rectum, a thin, dense connective tissue layer known as the Denonvilliers' fascia presents between the seminal vesicles and

Figure 4.
Recto-sacral fascia (Waldeyer's fascia). Recto-sacral fascia (Waldeyer's fascia) is a dense connective tissue linking the presacral fascia to the mesorectal fascia at the S4 level. It is important to perform sharp dissection [11].
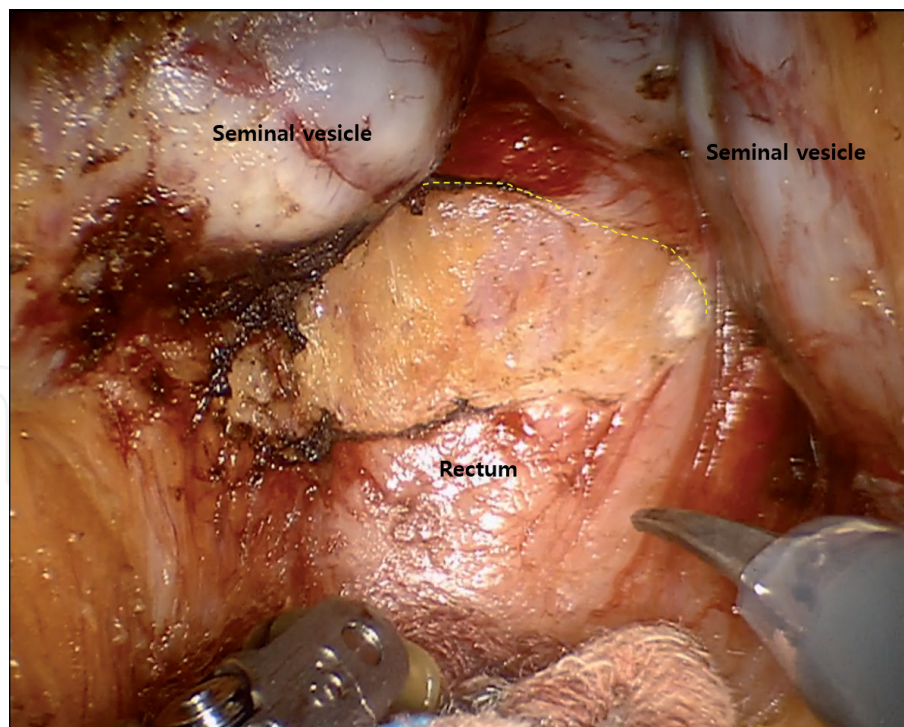
Figure 5.
Denonvilliers' fascia. During anterior dissection of the rectum. The dense connective tissue between rectum and seminal vesicles can be seen. The dissection should be performed below the Denonvilliers' fascia.

rectum [13]. The rectum can be separated from the seminal vesicles and prostate by opening this membrane at the level of anterior peritoneal reflection. After incising the fascia and entering the embryologic plane between the rectum and the seminal vesicles, the dissection should be performed below the Denonvilliers' fascia [14]. It is because there were neurovascular bundles running from the pelvic plexus to the ventral side of the Denonvilliers' fascia, especially in the directions of 10 and 2 o'clock, and these neurovascular bundles were related to urogenital function (**Figure 5**) [15]. However, if the deeply infiltrative tumor is located on the anterior wall of the rectum, the dissection should be performed in front of the Denonvilliers' fascia for curative resection. In females, there is a thin membranous structure that separates the rectum and vagina, which is called the rectovaginal septum. Although Denonvilliers reported that the Denonvilliers' fascia was not present in females, many researchers considered that the rectovaginal septum was consistent with the Denonvilliers' fascia in males (**Figure 6**) [16–19]. During the anterior dissection of the rectum in female, care must be taken not to perforate the vagina since this septum is very thin.

2.3 Anal canal

The rectum enters the pelvic floor and becomes the anus. The anal canal is defined as from the dentate line to the anal verge by anatomists, but most surgeons consider the anal canal from the anorectal ring to the anal verge [20]. The anorectal ring is where the rectum enters the pelvic floor and is angled by the puborectalis muscle. This ring can be palpated by a meticulous digital rectal exam. The dentate line, which divides the upper two-thirds and lower third of the anal canal, is an anatomically important landmark of the anal canal, and there are 6–14 longitudinal folds on the dentate line known as columns of Morgagni (**Figure 7**). The upper and lower part of the anal canal differs in venous and lymphatic drainage, innervation, and the epithelial surface based on the dentate line. Above the dentate line, the blood drains into the portal venous system, and lymphatics drains to the superior
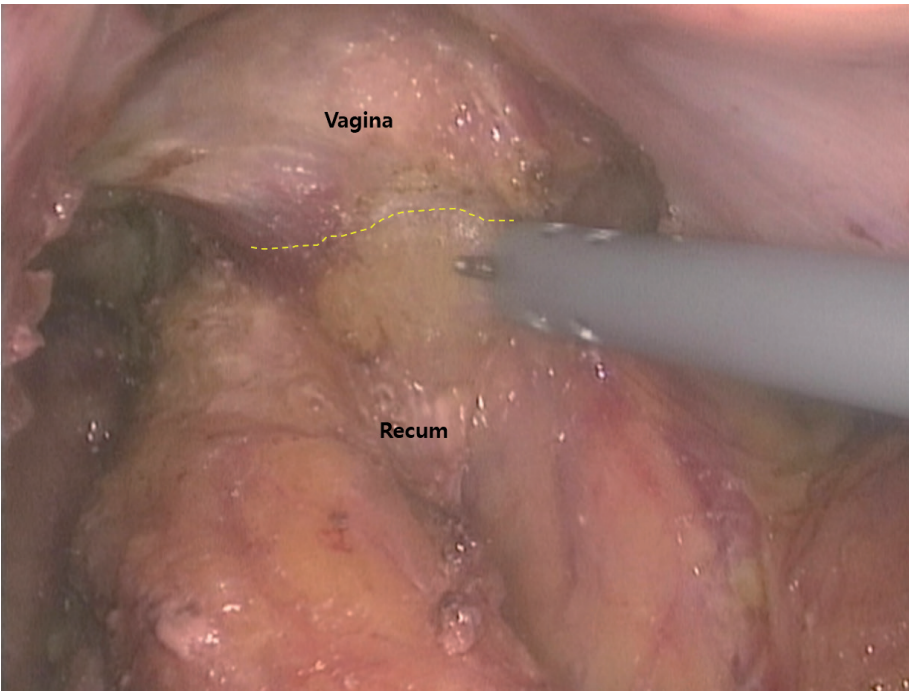
Figure 6.
Rectovaginal septum. In female, the rectovaginal septum was consistent with the denonvilliers' fascia in male.
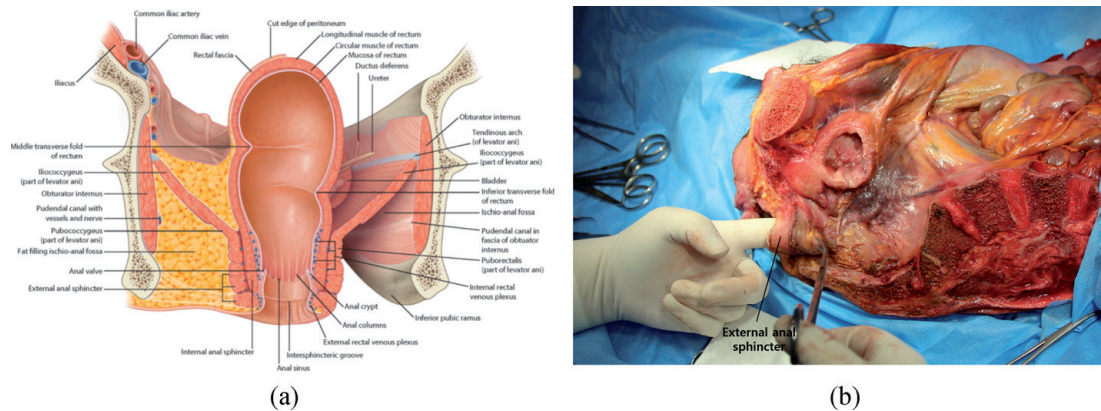

(a)   (b)

Figure 7.
Anal canal and anal sphincter complex. (a) The dentate line divides the upper two thirds and lower third of the anal canal, and there are longitudinal folds known as columns of Morgagni. The external sphincter consists of three separate parts: Subcutaneous, superficial, and deep part [21]. (b) External anal sphincter. Lt. Hemipelvis.

rectal and iliac lymphatic chains. Below the dentate line, the blood drains into the caval system, and lymphatics drain into the inguinal lymph nodes.

There are two sphincter muscles surrounding the anus, the internal sphincter and the external sphincter. The internal sphincter is connected from the inner circular smooth muscle of the rectum and descends to 1–1.5 cm below the dentate line. Its length is about 2.5–4 cm and the mean thickness is about 0.5 cm. It is an involuntary smooth muscle and plays an important role in the maintenance of fecal incontinence because it contributes a majority of the resting pressure of the anal canal. The outer longitudinal muscle of the rectum conjoins the fibers from the puborectalis muscle and is located between the external and internal sphincter. The external sphincter muscle is a striated muscle surrounding the internal sphincter in the shape of a cylinder, and it extends slightly below the internal sphincter. The external sphincter consists of three separate parts: subcutaneous, superficial, and deep part. The subcutaneous external sphincter attaches to the perianal skin encircling the anus. The external anal sphincter is innervated by the rectal branch
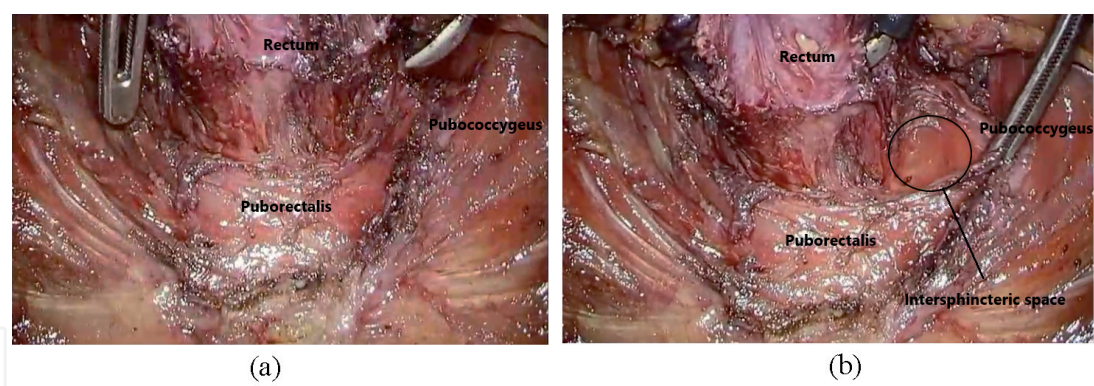
of the pudendal nerve and is under voluntary control [20, 22, 23]. The intersphincteric groove between the internal and external sphincter is an important landmark in surgery for patients with distal rectal cancer such as intersphincteric resection (ISR) [24].

2.4 Pelvic floor

The pelvic floor is a structure that forms the bottom of the pelvis, and plays an important role in supporting the pelvic organs. In the past, pelvic floor muscles could not be visualized clearly, however, the development of magnetic resonance imaging assessments and improvements in minimally invasive surgery techniques such as laparoscopy and robotic surgery can clearly show the anatomy of this region It is mainly composed of the levator ani muscle complex: pubococcygeus, iliococcygeus, and puborectalis muscle. The levator ani muscle received direct innervation from sacral nerve roots (S3-S5) and play an important role in cooperative action through coordinated contraction and relaxation during defecation [25]. The pubococcygeus is located in the most anterior portion of the levator ani muscles, and from both pubic bone to the coccyx. The iliococcygeus is the posterior part of the levator ani muscle and extends from the ischial spine to the anococcygeal raphe and coccyx. The puborectalis muscle, which is located below the pubococcygeus, forms a U-shaped ring around the rectum and makes an anorectal angle to prevent fecal incontinence. The coccygeus muscle, which is also a part of the pelvic floor, is located posterior portion of the levator ani muscle and reinforces the posterior pelvic floor (**Figure 8**) [20]. The pelvic floor has two hiatuses: the urogenital hiatus and the rectal hiatus. The rectal hiatus is located in the posterior of the pelvic floor through which the anal canal passes. The perineal body, a pyramidal fibromuscular mass, is located between the urogenital hiatus and the anal canal, strengthens the pelvic floor [26]. During distal rectal cancer surgery for sphincter preservation such as ISR, the intersphincteric space between the puborectalis muscle and the rectal wall should be identified, and the dissection continues down to the deep part of the anal canal through the intersphincteric space (**Figure 9**) [24]. On the other hand, during an abdominoperineal resection, the levator ani muscles must be cut [27].

2.4.1 Anococcygeal ligaments

The anococcygeal ligament is a fibrous membrane, which extends between the coccyx and the margin of the anal canal. In an anatomical study, the anococcygeal

(a)   (b)

Figure 8.
Anatomy of the pelvic floor. (a) Inferior view. The levator ani muscle consists of pubococcygeus, iliococcygeus, and puborectalis muscle [21]. (b) Pelvic floor muscles and anal sphincter complex [20].

Figure 9.
Levator ani muscles and intersphincteric space. (a) Puborectalis and pubococcygeus muscle. (b) Intersphincteric space between rectum and puborectalis muscle.

ligament was divided into two layers. The ventral layer of the ligament was loose and rich in small and fragile vessels and extended from the presacral fascia to the conjoint longitudinal muscle layer of the anal canal. The dorsal layer of the ligament was thin and dense and extended between the coccyx and external anal sphincter (**Figure 10**) [28]. To fully mobilize the rectum from the pelvic floor at the final stage of total mesorectal excision, the anococcygeal ligament must be divided. If the anococcygeal ligament cannot be seen in the final step, it can be visualized after the mesorectum is completely mobilized from the pelvic floor.

2.5 Surgical plane for very low-lying rectal cancer

In case of very low-lying rectal cancer, several surgical options can be considered (**Figure 11**). If the tumor did not invade the anal sphincter complex, the ultra-low anterior resection with coloanal anastomosis could be considered. If the tumors are located close to the dentate line, the intersphincteric resection (ISR) could be considered. The ISR is the partial or complete resection of the internal anal sphincter along the intersphincteric plane. However, if the tumor invades the external sphincter complex, the abdominoperineal resection (APR) should be performed. For invasive low rectal cancer which invades the levator ani muscle, extralevator APR (ELAPE) should be considered to achieve adequate resection margin. The ELAPE is the cylindrical anorectal excision and removes more tissue around the tumor including levator ani muscle (**Figure 12**). This procedure has the advantage of reducing the risk of tumor perforation during operation and acquiring sufficient
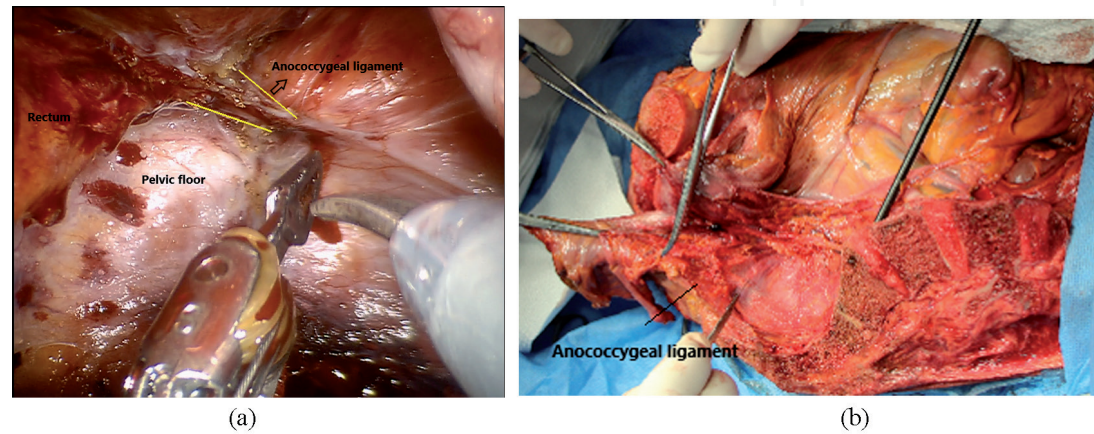

Figure 10.
Anococcygeal ligament. (a) Anococcygeal ligament and pelvic floor. During posterior dissection of the rectum. (b) Anococcygeal ligament during cadeveric dissection. Lt. hemipelvis.
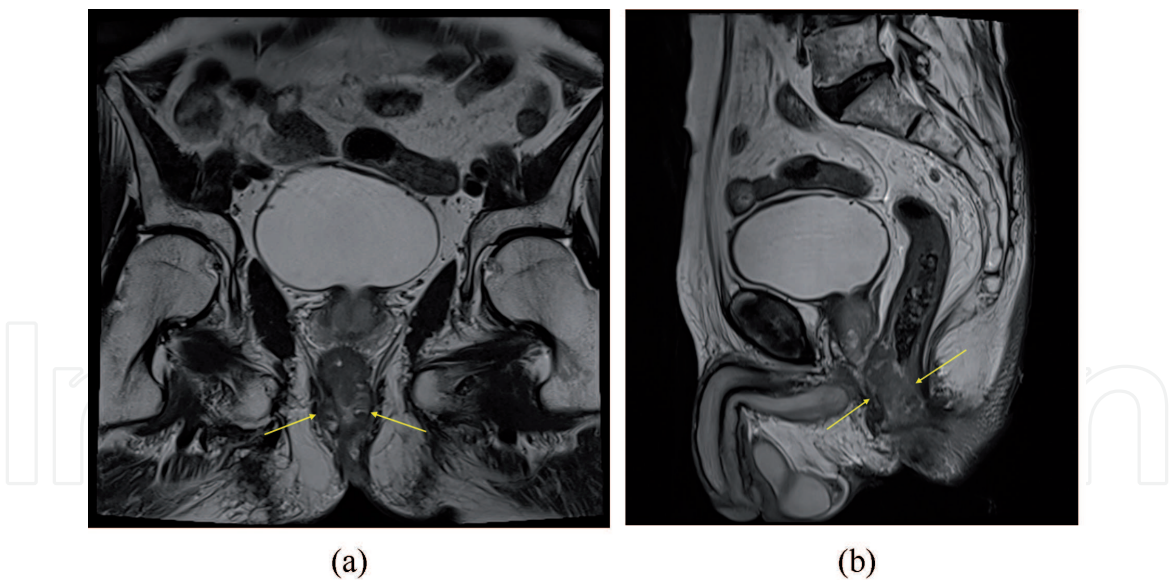
Figure 11.
Low-lying rectal cancer. (a) T2 weighted image on MRI. Coronal view. The low-lying rectal cancer invades internal anal sphincter. (b) T2 weighted image on MRI. Sagittal view.
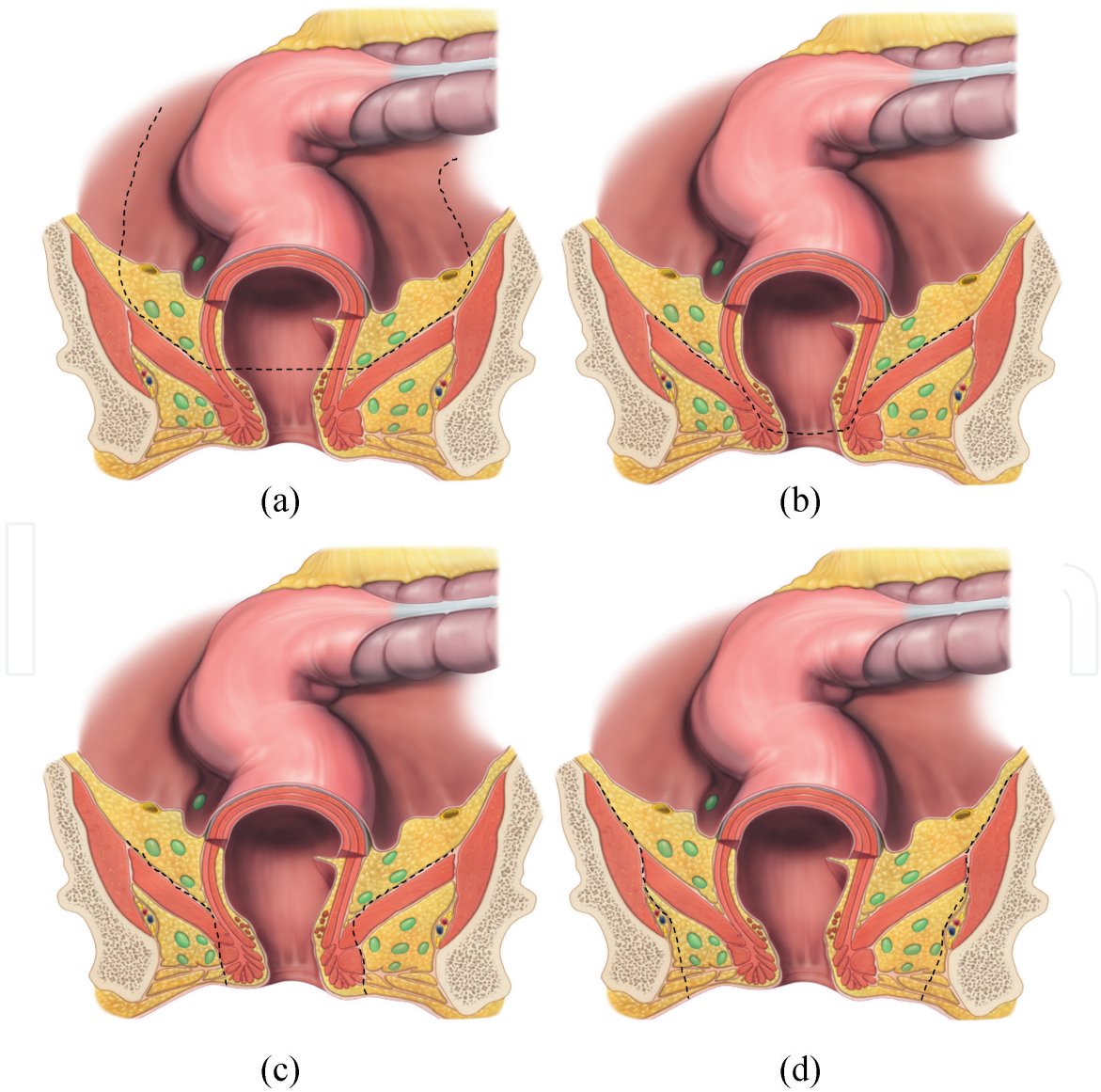

Figure 12.
Sugical plane for low-lying rectal cancer. (a) Low anterior resection (LAR). (b) Intersphincteric resection (ISR). (c) Abdominoperineal resection (APR). (d) Extralevator APR.

safety resection margin, but there is still controversy about the long-term oncologic outcome [29]. In addition, the postoperative complications can be increased due to the wide resection range.

2.6 Pelvic autonomic nerve system

In terms of quality of life, the importance of not only oncological outcomes but also functional outcomes such as urinary function, sexual function, and defecatory function after rectal cancer surgery have been emphasized. Urinary dysfunction after rectal surgery occurs in approximately 27%, and it includes difficulty emptying the bladder and incontinence [30, 31]. Sexual dysfunction for males consists of erectile dysfunction, absence of ejaculation, or retrograde ejaculation. For females, it causes sexual dysfunction such as impaired ability to achieve orgasm, decreased vaginal secretion, or dyspareunia [15]. The major cause of postoperative urogenital dysfunction is autonomic nerve damage that occurs during surgery. As minimally invasive surgery such as laparoscopy and robotic approach develops, meticulous nerve preserving surgery became possible with good visualization of the pelvic autonomic nerves [32–34]. To preserve the postoperative urogenital function, a thorough understanding of the anatomy of the pelvic autonomic nerve is crucial.

2.6.1 Superior hypogastric plexus and hypogastric nerves

The superior hypogastric plexus, which is a collection of sympathetic nerve bundles arising from T10-L3, forms a dense nerve plexus at the anterior area to the body of L5 and bifurcates into hypogastric nerves at the level of the sacral promontory (**Figure 13**). The superior hypogastric plexus runs around the inferior mesenteric artery. Therefore, this nerve can be damaged during dissection around the origin of the inferior mesenteric artery, and it results in retrograde ejaculation, urinary incontinence [35]. The hypogastric nerve crosses the left common iliac artery at the level of the first sacrum and descends to the pelvic cavity along the lateral pelvic wall.

2.6.2 Pelvic splanchnic nerves

The pelvic splanchnic nerves are considered to be parasympathetic nerves that arise from the second to fourth sacral spinal nerves. These nerves enter the pelvis through the sacral foramen, posterior to the parietal fascia that covers the piriformis
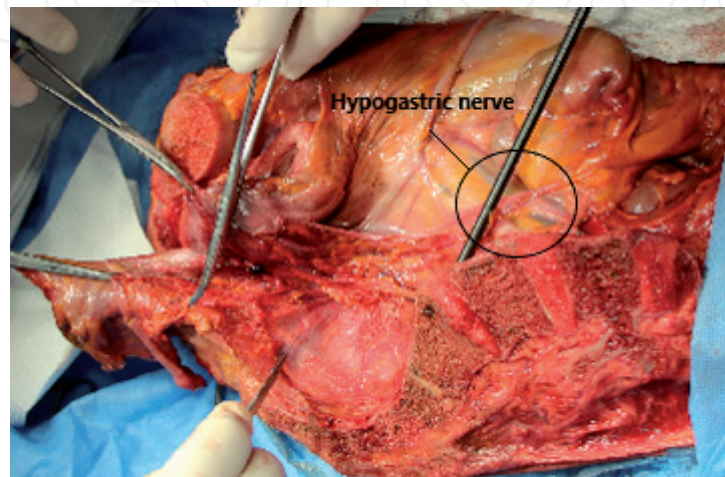

Figure 13.
Hypogastric nerves. The hypogastric nerves run from the superior hypogastric plexus and descend to the pelvic cavity and meet the pelvic splanchnic nerves.
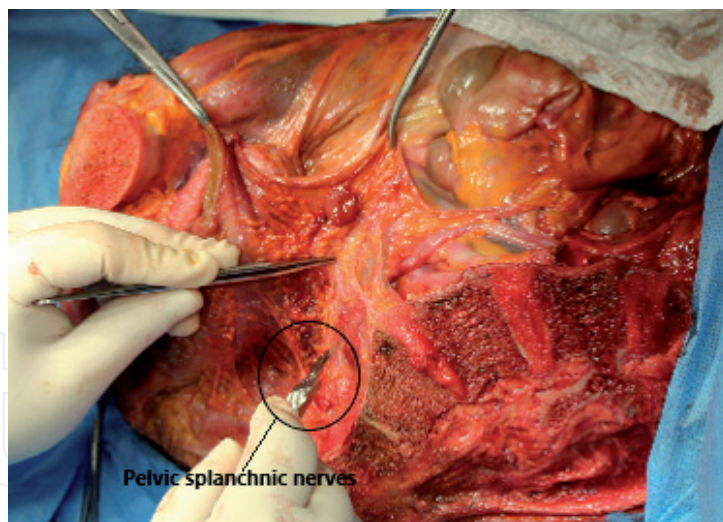
Figure 14.
Pelvic splanchnic nerves. The pelvic splanchnic nerves arise from the S2 to S4 spinal nerves. Small branches of the pelvic splanchnic nerves run medially and enter the mesorectum.

muscle and crosses the retrorectal space, to enter the visceral compartment through the visceral fascia about 4 cm from the midline. Small branches of the pelvic splanchnic nerves run medially and enter the mesorectum (**Figure 14**). These nerves regulate the emptying of the urinary bladder and influence erectile functions and motility of the rectum. Therefore, damage to these nerves causes erectile dysfunction and decreased blood flow to the vagina and vulva, which can reduce vaginal lubrication.

2.6.3 Inferior hypogastric (pelvic) plexus

The pelvic splanchnic nerves meet the hypogastric nerves and form the inferior hypogastric plexus at the lateral pelvic wall. It lies outside the fascia propria in the superficial layer of the parietal fascia. The inferior hypogastric plexus can be observed as a mesh-like structure at the posterolateral pelvic wall close to the prostate and seminal vesicles. Because the inferior hypogastric plexus consists of both sympathetic and parasympathetic efferent fibers, any damage to this plexus may cause severe disturbances in urogenital and sexual function including erection and ejaculation. It extends forward to form neurovascular bundles running down the seminal vesicle at 2 o'clock and 10 o'clock direction (**Figure 15**).
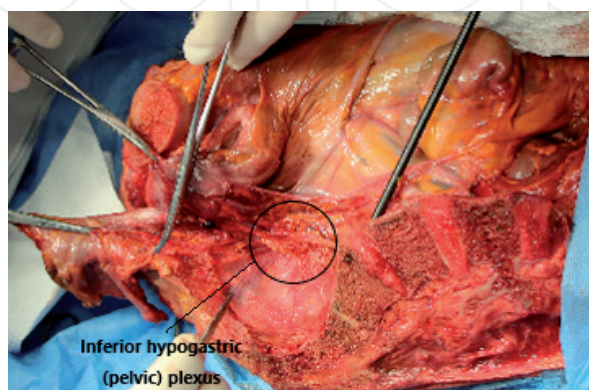

Figure 15.
Inferior hypogastric (pelvic) plexus. The inferior hypogastric (pelvic) plexus is a network of sympathetic and parasympathetic fibers arising from the hypogastric nerves and the pelvic splanchnic nerves. It can be observed as a mesh-like structure at the posterolateral pelvic wall. It extends forward to form neurovascular bundles running down the seminal vesicle on both sides.

These neurovascular bundles run through the posterolateral border of the prostate and continue to the periprostatic plexus, which supplies to the prostate, seminal vesicles, corpi cavernosi, and the vas deferens [15, 36]. Injury to the neurovascular bundles during anterior dissection may cause urinary and sexual dysfunction. Meticulous dissection is required because nerve damage may occur when surgery is performed along the wrong plane or excessive traction is performed.

3. Conclusion

The rectum is surrounded by a fatty tissue complex called the mesorectum, which contains abundant blood vessels, lymphatics, and lymph nodes. The rectum and mesorectum are enveloped by the mesorectal fascia. During total mesorectal excision, it is important to completely excise this mesorectal fascia without damage. The mesorectal fascia conjoins with the recto-sacral fascia, which extends forward from the presacral fascia at the level of S4, and descends to the pelvic floor. To enter the retro-rectal space and reach the pelvic floor, this fascia must be incised and sharp dissection should be performed to prevent severe bleeding due to injury to the presacral plexus. During the anterior dissection of the rectum, it is important to recognize Denonvillers' fascia located between the rectum and seminal vesicles, and dissection should be performed below the Denonvilliers' fascia. The pelvic floor is a structure that forms the bottom of the pelvis and is mainly composed of the levator ani muscle complex: pubococcygeus, iliococcygeus, and puborectalis muscle. The levator ani muscle received direct innervation from sacral nerve roots (S3-S5) and play an important role in cooperative action during defecation. To reach the deep part of the anal canal, the dissection should be performed between the puborectalis muscle and the rectal wall. During the whole process of TME, surgeons should take care to identify and preserve the autonomic nerve in order to avoid postoperative urogenital dysfunction. Care should be taken not to damage the superior hypogastric nerve during IMA ligation, and not to damage the pelvic plexus during posterolateral pelvic dissection. In addition, during anterior dissection of the rectum, it is important to perform meticulous dissection so as not to injure small numerous neurovascular bundles running in the 2 o'clock and 10 o'clock directions of the seminal vesicle. Based on a sufficient understanding of pelvic anatomy, precise surgical techniques using advanced surgical tools will give favorable oncologic and functional outcomes for rectal cancer patients.

Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

None.

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