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ORIGINAL ARTICLE

Reappraisal of the lateral rectal ligament: an anatomical study of total mesorectal excision with autonomic nerve preservation

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Abstract

Purpose The term "lateral rectal ligament" in surgery for rectal cancer has caused confusion regarding its true existence and contents. In previous studies, investigators claimed the existence of the ligament and described its topographical features as neurovascular structures and their surrounding connective tissues located at the anterolateral aspect of the distal rectum or the posterolateral aspect of the middle rectum. The purpose of this study is to evaluate the structure of the so-called "lateral rectal ligament" in cadaver dissections.

Methods Dissection was performed in nine cadavers (eight males and one female, aged 73 to 94 years) in accordance with typical total mesorectal excision techniques. During dissection, structures related to "the ligament" were examined and images recorded.

Results At the anterolateral aspect of the distal rectum, the middle rectal artery was noted to be crossing the fusion of Denonvilliers' fascia and the proper rectal fascia. At the posterolateral aspect of the middle rectum, there was a structure which consisted of the rectal nerves running through the fusion of the pelvic fasciae. Although called "ligaments," neither structure contained discrete strong connective tissue fixing the rectum to the pelvic wall.

Conclusions The proper rectal fascia and surrounding pelvic fasciae fuse firmly anterolaterally and posterolaterally where neurovascular structures course toward the rectum. During a total mesorectal excision, the surgical dissection plane coincides with the fused part of the fasciae, which had long been considered the "lateral rectal ligament."

Keywords Lateral rectal ligament · Total mesorectal excision · Autonomic nerve preservation · Pelvic anatomy

Introduction

Total mesorectal excision (TME) with autonomic nerve preservation is standard in the surgical management of rectal cancer [1–3]. It is based on the concept to achieve both cure of the cancer and preservation of the genitourinary function. Understanding pelvic anatomy is of vital importance because precise dissections along the proper rectal fascia are required to avoid injuries to the pelvic autonomic nerves.

There is controversy regarding the anatomy of the pelvic fasciae and the perirectal structures. The "lateral rectal ligament," in particular, is a contentious issue [4–8]. From the time when Miles first used this term in his description of the abdominoperineal resection, the "lateral rectal ligament" has been considered a discrete structure. Since TME was introduced in the late 1980s as the standard surgical technique for rectal cancer, some colorectal surgeons have insisted that the "lateral rectal ligament" is a surgical artifact caused by digital blunt dissection without direct visualization [7, 8]. With advances in technology, rectal cancer has been treated laparoscopically with precise dissection under magnified views [9, 10]. Other surgeons, however, still emphasize that dividing the "lateral rectal ligament" is the most critical step in laparoscopic TME with autonomic nerve preservation [11, 12]. Therefore the "lateral rectal ligament" remains the source of anatomical confusion.

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In the past two decades, several investigators have studied the anatomy of the pelvis and claimed the existence of the "lateral rectal ligament" by cadaveric studies or clinical observations [5, 6, 13–19]. However, there are some differences in its anatomical localization and composition. There are two pivotal studies which allegedly show the existence of the "lateral rectal ligament." One study conducted by Takahashi et al. was based on surgical findings [6]. In their study, the "lateral rectal ligament" which consisted of the middle rectal artery and its surrounding connective tissue was situated at the anterolateral aspect of the distal rectum. On medial traction of the rectum, this structure appeared to be an elongated connection between the pelvic side wall and the mesorectum. The other study, performed on cadavers by Nano et al. showed that the "lateral rectal ligament" was a trapezoidal structure at the posterolateral aspect of the middle rectum anchoring the mesorectum to the pelvic side wall and that it contained small nerve branches covered by connective tissue [5].

The aim of this study is to evaluate the structure of the so-called "lateral rectal ligament" using cadaver dissection with respect to (1) its composition and (2) its anatomical relations to the pelvic fasciae and the autonomic nerves.

Methods

Dissections were performed on nine cadavers (eight males and one female, aged 73 to 94 years) in the Department of Anatomy at Jichi Medical University. This study was approved by the Jichi Medical University Institutional Review Board (No. 13-23). All cadavers were preserved by the injection of 10% formalin in the femoral artery.

In all cadavers, the rectum was mobilized in accordance with routine TME techniques in a craniocaudal direction. During the mobilization of the rectum, neurovascular and fascial structures related to the "lateral rectal ligament" were examined. To better visualize each step of the dissections, all specimens were initially hemisected in the midsagittal plane. In three out of nine cadavers, either the right or left hemipelvis was not examined, because the specimen was not appropriate for this study due to lateral deviation of the rectum. For precise observation, an illuminated magnifier (Otsuka Optics Co. SKKL 2x) was used.

At each stage of dissection, the view of the pelvic structures was recorded with a digital camera (Pentax WG-1) and a video camera (Panasonic AG-MDC10G). Observations of the right hemipelvis on male cadavers are shown in Figs. 1, 2, 3, 4, and 5 and Videos 1 and 2.

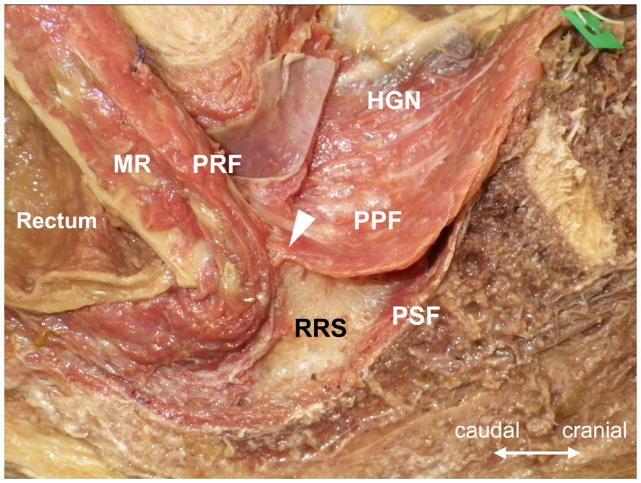

Fig. 1 Pelvic fasciae posterior to the mesorectum in the midsagittal plane. MR mesorectum, PRF proper rectal fascia, PPF parietal pelvic fascia, PSF presacral fascia, RRS retrorectal space, and HGN hypogastric nerve. White arrowhead indicates the fusion of PRF and PPF

Results

Pelvic fasciae and spaces related to the "lateral rectal ligament" (Video 1)

Posterior to the rectum

In the midsagittal plane, posterior to the rectum, the following three fasciae were identified from the inside to the outside: the proper rectal fascia enveloping the mesorectum, the parietal pelvic fascia covering the autonomic pelvic nerves (the hypogastric nerves), and the presacral fascia covering the middle sacral and internal iliac vessels. The parietal pelvic fascia is continuous with the retroperitoneal fascia at the brim of the pelvis.

Dissection posterior to the rectum was carried out as shown (blue dotted line) in Fig. 5a, b. The parietal pelvic fascia was easily separated from the proper rectal fascia at the level of the promontory of the sacrum. This fascia fused with the proper rectal fascia below the level of the second sacral vertebra (S2) (Fig. 1, white arrowhead). Anterior traction of the mesorectum developed a loose avascular space posterior to the parietal pelvic fascia, the retrorectal space (Fig. 1). To enter the retrorectal space, the parietal pelvic fascia was divided at the level of S2. The retrorectal space was anteriorly covered with parietal pelvic fascia, and posteriorly with presacral fascia. Approaching the level of the sacrococcygeal joint, the presacral fascia on the anterior surface of the sacrum ran ventrally and was fused with the parietal pelvic fascia. This fascial fusion was situated below the level of S4 or at the sacrococcygeal joint, and this level varied among the cadavers.

Below the level of the sacrococcygeal joint, another loose avascular space exists dorsal to the presacral fascia, the

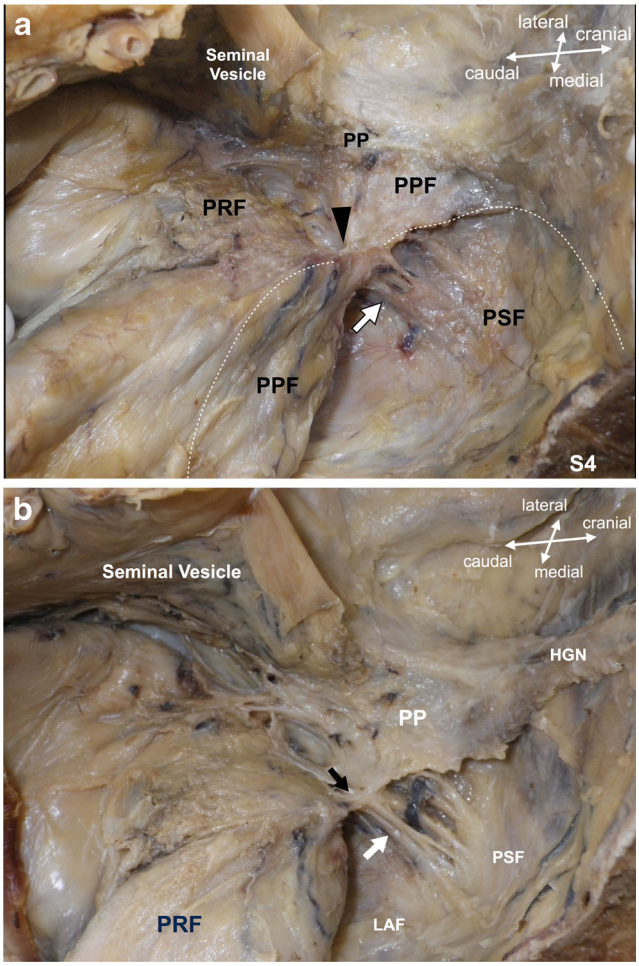

Fig. 2 **a** Posterolateral aspect of the pelvis after dissection posterior and lateral to the rectum. **b** The anterior portion of the "lateral rectal ligament" as described by Nano [5], which is located at the posterolateral aspect of the middle rectum. PRF proper rectal fascia, PPF parietal pelvic fascia, PSF presacral fascia, LAF levator ani fascia, HGN hypogastric nerve, and PP pelvic plexus. White and black arrows indicate the caudal pelvic splanchnic nerves and the rectal nerves respectively, while black arrowhead shows the "lateral rectal ligament" that Nano described [5]

supralevator space. To enter the supralevator space, the presacral fascia was divided at the level of the sacrococcygeal joint. As dissection through the retrorectal and the supralevator spaces advances laterally, the root of the caudal pelvic splanchnic nerves covered by the presacral fascia was seen 3 cm lateral to the midline at the level of the sacrococcygeal joint (Fig. 2a, white arrow). These nerves were well visualized through the presacral fascia, which was thin and sometimes transparent.

Lateral to the rectum

Following the posterior dissection, the lateral dissection was begun by dividing the peritoneum where the mesorectum was attached to the pelvic side wall then advanced anteriorly and posteriorly (Fig. 5b, green dotted

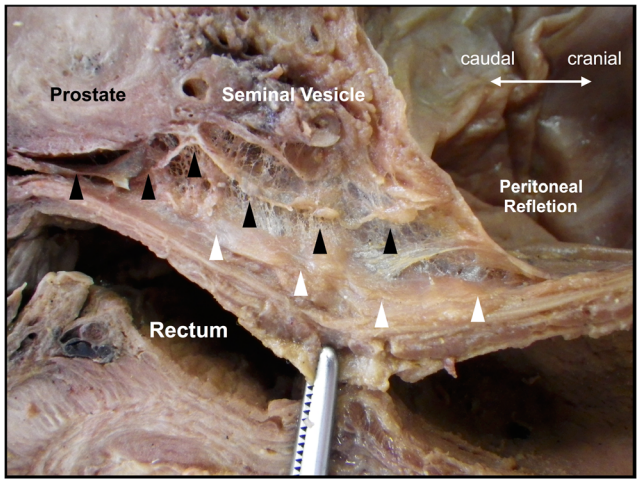

Fig. 3 Pelvic fasciae anterior to the mesorectum in the midsagittal plane. Black arrowheads indicate Denonvilliers' fascia, while white arrowheads indicate the proper rectal fascia (PRF)

line). On the pelvic side wall below the peritoneal reflection, there was a surgical plane between the proper rectal fascia and the parietal pelvic fascia covering the pelvic plexus, and those two fasciae were easily separated. As this dissection advanced posteriorly, this plane came to an end at the posterolateral aspect of the middle rectum. At the posterior border of this plane, the proper rectal fascia fused firmly with the parietal pelvic fascia and the presacral fascia. Seen from the cranial side, a trapezoid-shaped structure anchored the mesorectum to the pelvic side wall. This trapezoidal structure was the "lateral rectal ligament" described by Nano [5] (Fig. 2a, black arrowhead).

Anterior to the rectum

Anterior to the rectum, the space between the mesorectum and the posterior wall of the pelvic organs is separated into two spaces by Denonvilliers' fascia, which is continuous with the parietal pelvic fascia (Fig. 3, black arrowhead). Both spaces were avascular and loose in the midline. However, the space posterior to Denonvilliers' fascia was closed at the anterolateral aspect of the distal rectum where Denonvilliers' fascia fused with the proper rectal fascia (Fig. 5b, red dotted line). Applying medial traction to the rectum, this fused area formed a screen-shaped structure, which was the "lateral rectal ligament" described by Takahashi [6] (Fig. 4a, black dotted circle). This structure extends from the level of the seminal vesicle in a male, or the cervix of the uterus in a female, down to the area of the upper border of the anal canal along the lateral border of the prostate or vagina.

The space anterior to Denonvilliers' fascia was defined by the neurovascular structure at the lateral border of the prostate or the vagina which has been referred to as the neurovascular bundle by Walsh [20] (Fig. 5b, red dashed line).

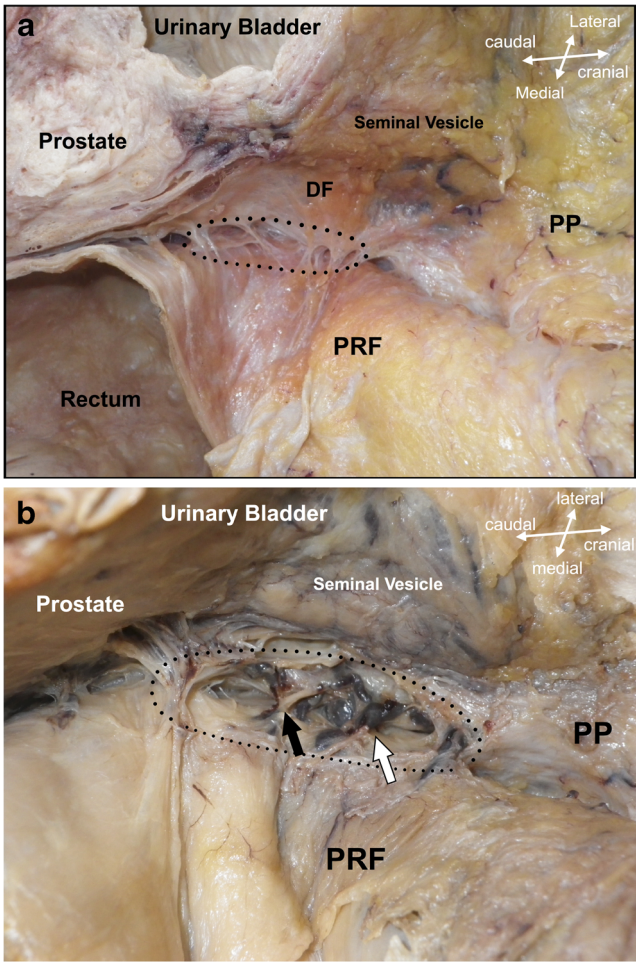

Fig. 4 **a** Anterolateral aspect of the pelvis after dissecting the space posterior to Denonvilliers' fascia. **b** Anterolateral aspect of the pelvis after dissecting the fusion of Denonvilliers and the proper rectal fasciae from the state shown in **a**. PRF proper rectal fascia, DF Denonvilliers' fascia, and PP pelvic plexus. Black dotted circle shows the area of the "lateral rectal ligament" that Takahashi described [6]. Black and white arrows indicate the middle rectal artery and vein, respectively

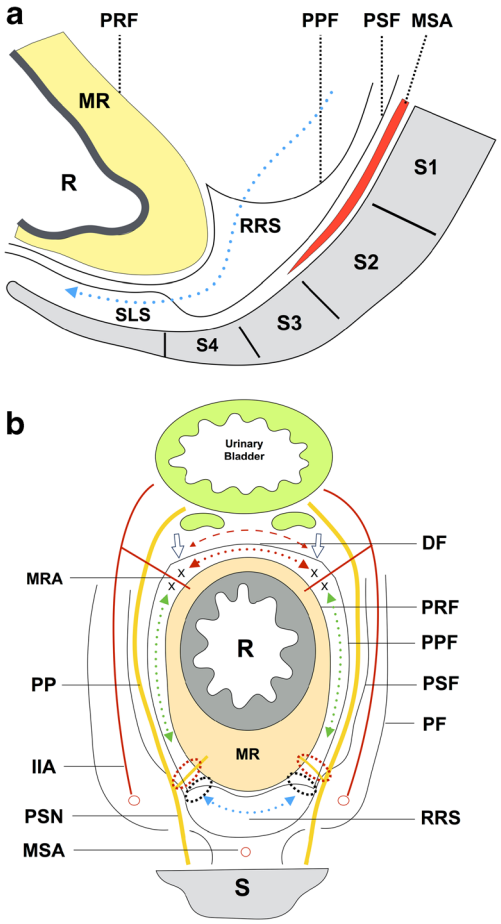

Fig. 5 Schematic representation of the perirectal fasciae and spaces. **a** Midsagittal section. **b** Axial section at the level between the third and the fourth sacral vertebrae. DF Denonvilliers' fascia, PRF proper rectal fascia, PPF parietal pelvic fascia, PSF presacral fascia, PF piriformis fascia, RRS retrorectal space, R rectum, S sacrum, MR mesorectum, MRA middle rectal artery, PP pelvic plexus, IIA internal iliac artery, PSN pelvic splanchnic nerve, and MSA median sacral artery. Red and black dashed circles indicate the anterior and posterior portions of the "lateral rectal ligament" described by Nano [5]. White arrows indicate the "lateral rectal ligaments" described by Takahashi [6]. Red dashed line indicates the anterior dissection plane in Takahashi's study [6], while blue, green, and red dotted lines indicate the posterior, lateral, and anterior dissection planes in the current study, respectively. X marks indicate the fusions of Denonvilliers' fascia and the proper rectal fascia

Identifying the "lateral rectal ligament" (Video 2)

At the anterolateral aspect of the distal rectum, the structure that Takahashi et al. identified as the "lateral rectal ligament" was examined [6] (Fig. 4a, black dotted circle). Dissection of the fusion of Denonvilliers' fascia and the proper rectal fascia revealed the middle rectal artery and veins (Fig. 4b, white and black arrows, respectively) which coursed toward the rectum and crossed the caudal branches of the pelvic plexus. An artery or two within this "ligament" was found in all nine cadavers (15/15 hemipelves). Among six cadavers in which a bilateral comparison was performed, one cadaver had two arteries bilaterally, another had two arteries unilaterally, and remaining four cadavers had one artery bilaterally. The three cadavers which were examined unilaterally (either right or left side) had one artery. Neither a dense connective tissue nor a solid ligamentous structure was noted around the artery. Just lateral to this fused area, the caudal branches of the pelvic plexus coursed along the lateral border of the prostate or vagina. Approaching the distal part of the prostate or the vagina, these nerves ran very closely to the mesorectum.

At the posterolateral aspect of the middle rectum, the trapezoidal structure which was referred to as the "lateral rectal ligament" by Nano et al. was examined [5] (Fig. 2a, black arrowhead). The base of the trapezoidal structure was situated 2 cm distally from the root of the caudal pelvic splanchnic nerves. The posterior portion of the structure described by Nano [5] as the ligament consisted of parietal pelvic fascia

that took on a trapezoidal shape (Fig. 5b, black dotted circle). After dissecting the parietal pelvic fascia at the base of the trapezoidal structure, small nerve branches running toward the rectum were identified at the anterior portion of the ligament described by Nano [5] in all nine cadavers examined (15 hemipelves) (Fig. 2b, black arrow), while an artery was found within this "ligament" unilaterally in two cadavers. These rectal nerves pierced the presacral fascia, the parietal pelvic, and the proper rectal fasciae, and here, these pelvic fasciae were fused firmly. Just lateral to the base of the trapezoidal structure, the caudal pelvic splanchnic nerves converged and joined the dorsocaudal corner of the pelvic plexus (Fig. 2b, white arrow). The pelvic splanchnic nerves branched off the rectal nerves where they joined the pelvic plexus.

Discussion

In this cadaver study, we investigated the structures that were referred to as the "lateral rectal ligament" in previous literature. This study shows that the previously described structures were not substantial ligamentous structures, but rather areas of fascial fusion. At the anterolateral aspect of the distal rectum, the fusion of Denonvilliers and the proper rectal fascia, with the middle rectal artery passing through, was identified. At the posterolateral aspect of the middle rectum, the fusion of the three pelvic fasciae through which the rectal nerves pierced was identified. There was no dense connective tissue around these two structures.

Several studies described that the "lateral rectal ligament" was located at the anterolateral aspect of the distal rectum and was the condensation of connective tissue around the middle rectal artery [6, 11, 12, 21]. In their descriptions, however, the dissection was carried out in a space anterior to Denonvilliers' fascia (Fig. 5b, red dashed line). As a consequence of the dissection plane used, the middle rectal artery was covered by Denonvilliers' fascia (Fig. 5b, white arrow). They must have recognized the middle rectal artery covered by Denonvilliers' fascia as the "lateral rectal ligament." It is not a ligament in the true sense but rather a surgical artifact produced by the dissection outside of Denonvilliers' fascia.

Other studies described that the "lateral rectal ligament" was situated at the posterolateral aspect of the middle rectum [5, 13–19] (Fig. 5b, red and black dashed circle). The dissection in Nano's study [5] was performed through the retrorectal space which was the same dissection plane as ours because the caudal pelvic splanchnic nerves were visible during mobilization of the rectum (Fig. 5b, blue dotted line). These nerves were visualized well only when the dissection was performed through the retrorectal space, as shown in this study. The structure that included the rectal nerves and the parietal pelvic fascia was considered to be the "lateral rectal ligament" by Nano and others [5, 13–19]. Although they described that the "lateral rectal ligament" was an extension of the mesorectum [5, 13, 19], we found that the structure was composed of the rectal nerves backed by the parietal pelvic fascia, which fused posteriorly with the proper rectal fascia enveloping the mesorectum.

It is conceivable that Nano et al. did not recognize the fusion of the proper rectal fascia and the parietal pelvic fascia below S2 which had been overlooked in previous anatomical studies regarding the pelvic fasciae [17, 22–25]. In previous studies, the proper rectal fascia and the parietal pelvic fascia were perceived as a single fascial layer, so that this fascial fusion was overlooked [18, 22, 26]. However, the parietal pelvic fascia is a different fascia from the proper rectal fascia, because it is a continuation of the retroperitoneal fascia [4, 16, 27]. We speculate that, in the retrorectal space, the dissection plane they perceived as "along the proper rectal fascia" is in fact "just outside of the parietal pelvic fascia." This could explain why they took the parietal pelvic fascia at the posterolateral aspect of the rectum as the "lateral rectal ligament" or an extension of the mesorectum (Fig. 5b, black dotted circle).

Conventional surgical literature has emphasized the importance of the dissection through the loose avascular space posterior and anterior to the rectum [11, 19]. After dissecting in this manner, the remaining structures which contain the autonomic nerve supply to the rectum and the artery, if present, are referred to as the "ligament." Some investigators still recommend clamping the "ligament" and dividing the connection to the pelvic side wall when mobilizing the rectum [11–13, 15]. However, the mesorectum is connected to the pelvic side wall with a fascial attachment or fusion instead of a ligamentous structure. Clausen et al. microscopically analyzed the "lateral rectal ligament" and showed that the "ligament" contained the autonomic ganglia in the outer third close to the pelvic side wall [13]. The autonomic ganglia do not exist in the rectal nerve, but in the pelvic plexus [28]; therefore, clamping and dividing the fascial attachment as the "ligament" will cause inadvertent lateral deviation of the surgical plane that results in the injury of the autonomic pelvic nerve system.

For a safe dissection of the fascial attachment at the anterolateral or the posterolateral aspect of the rectum, the following surgical steps are important. When dissecting the retrorectal space, it is important to dissect close to the parietal pelvic fascia posterior to the rectum. When dissecting the space anterior to Denonvilliers' fascia, it is important to stay on Denonvilliers' fascia anterior to the rectum (Fig. 5b blue dotted line and red dashed line). Lateral deviation in these spaces will damage vessels of the pelvic side wall or the autonomic pelvic nerves, in particular the third or fourth pelvic splanchnic nerve. Next to the anterior and the posterior dissection, the dissection lateral to the rectum should be carried out (Fig. 5b green dotted line). At the anterolateral or the posterolateral aspect of the rectum, there is no loose plane, so the fascial attachments have to be dissected sharply without

clamping. When dividing these attachments, it is prudent to make certain that the direction of the dissection and the traction are appropriate. When dissecting the fascial attachment at the posterolateral aspect of the rectum, a concept "T-junction" may be helpful for the dissection [29, 30]. At this attachment, the pelvic plexus and its nerve branch to the rectum form "T-shape," and dividing the attachment at the "junction" is an appropriate manner for the nerve preservation and the oncological resection.

Dividing the "lateral rectal ligament" without recognizing it as fascial fusion may cause the injury to the nerves, which results in postoperative sexual dysfunction. This study shows that the caudal pelvic splanchnic nerves and the caudal branches of the pelvic plexus are located very close to the "lateral rectal ligament." Many urological studies have revealed that the cavernous nerves which control erectile function originate from the caudal pelvic splanchnic nerves and course along the pelvic plexus and terminate at the penis in a male [31–37]. The pelvic autonomic nerves which control erectile function may easily be damaged by dividing the "lateral rectal ligament."

There are several limitations to this study. First, only a limited number of cadavers were investigated in this study. In particular, we investigated only one female cadaver in this study. Anatomical findings regarding bilateral differences of the "ligament" are not conclusive, because six out of nine cadavers were examined bilaterally. The cadavers' age was 73 years or older. Our study subjects were all Japanese and were not free from the bias in terms of its generational composition. Additional studies need to be performed using specimens from younger age groups.

In conclusion, the proper rectal fascia and the surrounding pelvic fascia fuse anterolaterally in the distal rectum and posterolaterally in the middle rectum where neurovascular structures course toward the rectum. During TME, the surgical dissection plane coincides with the fused part of the fasciae, which had long been considered the "lateral rectal ligament." Conventional surgical dissection of the rectum was performed outside the parietal pelvic, or Denonvilliers, fascia. As a result, these pelvic fasciae that envelope the neurovascular structures were perceived as the "lateral rectal ligament." In fact, it is not a substantial ligamentous structure, but rather a by-product of the mobilization of the rectum without recognizing fascial fusion. It is of vital importance to understand that the mesorectum is attached to the pelvic side wall by fascial fusion rather than a cord-like ligament, which is located very close to the pelvic autonomic nerves responsible for sexual function.

Authors' contributions MI made substantial contributions to conception and design, acquisition, and analysis and interpretation of data. AS contributed to analysis and interpretation of data and assisted in the preparation of the manuscript. All other authors have contributed to data interpretation and critically reviewed the manuscript. All authors gave final approval of the version to be submitted.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the Jichi Medical University Institutional Review Board and with the 1964 Helsinki declaration and its later amendments.

Informed consent Informed consent for cadaver donation was obtained from every family of the cadaver.

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