Anatomical Basis of Rectal Cancer Surgery Focused on Pelvic Fascia

4

Jin-Tung Liang

Abstract

Fascial structures are the natural embryonic dissection plane for the precise surgery of rectal cancer. This chapter characterized the fascial structures implicated in the rectal cancer surgery, which include Toldt fascia, Denonvilliers' fascia, proper fascia of the rectum, endopelvic fascia (parietal layer of pelvic fascia), presacral fascia, rectosacral fascia, and Waldeyer's fascia. Toldt fascia is the extension of Gerota fascia and constitutes the natural dissection plane for the mobilization of left colon. The whole mesorectum was enclosed circumferentially by the thin layer of proper fascia of the rectum; the pelvic sacral bone was covered with the endopelvic fascia (parietal layer of pelvic fascia). Endopelvic fascia and proper fascia of the rectum fused at the level of sacral promontory, and the presacral space is entered after the fascial junction is incised.

Rectosacral fascia usually originated in the S4 level, and the retrorectal space is entered when this fascia is sharply incised. Waldeyer's fascia constitutes the fascia layer covering levator ani muscle. Denonvilliers' fascia is situated in front of proper fascia of the rectum. Usually, the anterior dissection for mobilization of the rectum is in front of Denonvilliers' fascia to ensure oncological efficacy; however, to enhance the preservation of sexual function, some surgeons suggest the dissection plane be back to the Denonvilliers' fascia. Full respect of the fascia structures is the basic principle for the precise implementation of total mesorectal excision for rectal cancer.

Keywords

Toldt fascia · Denonvilliers' fascia · Proper fascia of the rectum · Endopelvic fascia (parietal layer of pelvic fascia) · Presacral fascia · Rectosacral fascia · Waldeyer's fascia · Gerota fascia

4.1 Introduction

Total mesorectal excision (TME) has become the technical paradigm for the surgery of rectal cancer. The basic tenet of surgical oncology is to en bloc extirpate the cancer with its spreading lymphatic basin along the embryonic natural dissection plane. During the implementation of TME procedure, most colorectal surgeons adopted the following dissection sequences:

(1) Explore the duodeno-mesenteric fossa to find out the inferior mesenteric artery (IMV), and then ligate and transect IMV in the fashion of no-touch isolation technique.

J.-T. Liang
Department of Surgery, National Taiwan University Hospital, Taipei City, Taiwan
e-mail: jintung@ntu.edu.tw

N. K. Kim et al. (eds.), *Surgical Treatment of Colorectal Cancer*,
https://doi.org/10.1007/978-981-10-5143-2_4

(2) Medial-to lateral mobilization of the mesocolon belonging to the anatomic territory of descending-sigmoid colon along the Toldt fascial dissection plane.
(3) Isolate and transect the inferior mesenteric artery (IMA), in consideration of adequate lymph node clearance.
(4) Mobilize the rectosigmoid mesentery laterally and downward to the junction of endopelvic and proper fascial of the rectum.
(5) Enter the presacral space along the holy plane posterior to the mesorectum, sharply incise the rectosacral fascia, and continue the dissection downward to the Waldeyer's fascia.
(6) Incise the Douglas pouch and dissect the anterior mesorectum downward to the pelvic floor along the Denonvilliers' fascia, prostate capsule in male, and rectovaginal septum in female, in consideration of the preservation of autonomic nerve supplies to genitourinary organs.

In order to ensure the quality surgery of rectal cancer and enhance the dissection efficiency, the importance of the respect for the fascial planes implicated in the TME procedure cannot be overemphasized.

4.2 Anatomic Concepts of Toldt Fascia

Dissection along the Toldt fascia is involved in the mobilization of descending colon to take down the colonic splenic flexure, which is an important procedure to facilitate a tension-free colorectal anastomosis following total mesorectal excision for the treatment of rectal cancer. Based on the "rotation and fusion" theory, during the developmental process of the embryonic dorsal mesentery [1–4], the fascial layer, which anchors the ascending and descending colon to the retroperitoneum, should be sandwiched by two mesothelial layers belonging to the overlying mesocolon and the underlying retroperitoneum, respectively, as elegantly demonstrated by Culligan et al. [4]. It has been demonstrated that the dissection plane for the mobilization of the ascending, descending, and sigmoid colon is within the Toldt fascial layer. The upper part of Toldt fascial layer fused closely with the mesothelial layer of the overlying mesocolon; the low part of Toldt fascial layer fused closely with the mesothelial layer of the underlying retroperitoneum, and therefore, "mesofascial interface" and "retrofascial interface" were frequently utilized to label the transitions from the fascial layer to the mesothelial layer attached to the overlying mesocolon and the underlying retroperitoneum, respectively. In 1879, Carl Toldt identified a mesentery associated with the ascending and descending colon and showed that, although these structures were flattened against the posterior abdominal wall, they remained separate from it, i.e., between them, there exists a fascial dissection plane, which can be utilized to separate the mesocolon from the underlying retroperitoneum [1]. Given Toldt precise description, we proposed that Toldt fascia be an appropriate eponym for this fascial layer, within which a natural embryonic dissection plane can be precisely developed for the mobilization of the whole colorectum (Fig. 4.1).

Structurally, it has been found that the Toldt fascia was loose and even manifested as areolar tissues in texture. And, during the advancement of surgical dissection, we found minute vessels were present in this fascial plane and sometimes caused oozing of blood. Surfaces of the perirenal fat of bilateral kidneys are covered by the Gerota fascia, which consists of dense connective tissue fibers. On the anatomic territory of bilateral kidneys, the floor of Toldt fascia fused securely with Gerota fascia and to separate the two layers was technically unfeasible. Sometimes, deliberate separation of Toldt and Gerota fascia might perforate the Gerota fascia and overexpose the perirenal fat.

From the kidney area, the fused Toldt and Gerota fascia, or the so-called retrofascial interface, extended in all directions. Upward, the fused fascia advanced into the dorsal surface of the duodenum, liver, and pancreas. Downward, the fused Toldt and Gerota fascia became a thinner layer of membrane-like structures covering

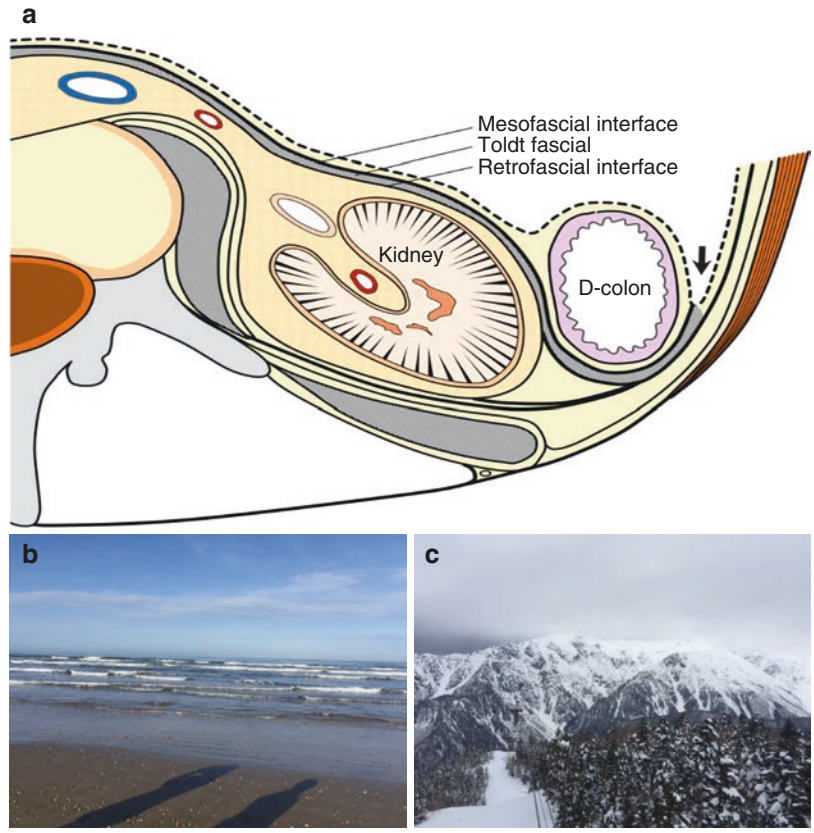

Fig. 4.1 (**a**) The correct dissection plane for the mobilization of descending-sigmoid mesocolon is within the Toldt fascia (gray area). (**b**) Recognition of the dissection plane along the Toldt fascia is just like identification of the junction between sky and blue sea, when you stand at the seven-miles' beach in Ishikawa Prefecture, Japan. Can you catch it? (**c**) Recognition of the dissection plane along the Toldt fascia is just like identification of the junction between gray sky and snowy peak, when you stand at the Hida Mountain in Hokuriku, Japan. Can you find it?

the gonadal vessels, bilateral ureters, and retroperitoneum structures. At this point we carefully preserved gonadal vessels and ureters and simultaneously kept the membrane intact. Any attempt to isolate the ureter might perforate this retrofascial interface and impair the continuity of the Toldt fascial plane.

Laterally, the Toldt fascia tapered at the area below the reflection of visceral and parietal peritoneum and then became sparse and continuous with the loose fibrous tissues surrounding the subperitoneal fatty tissues. Remarkably, Carl Toldt originally described the peritoneal reflection in the paracolic gutter, and later this structure is named as "white line of Toldt" in eponym. The white line of Toldt is formed due to the difference in the density of the connective tissues between the visceral and parietal peritoneum.

For patients with moderate body mass index (more than 24 kg/m^2), the Toldt fascia was looser and areolar in nature, and therefore the dissection plane was fairly easy to develop. In contrast, for slim patients, especially the body mass index less than 18 kg/m^2, the Toldt fascia was nearly absent or invisible, and in such patients we could see Gerota fascia manifest as a whitish membrane and adhere closely to the thin mesocolon, and the development of a dissection plane between the two layers was very difficult and vulnerable to perforate the mesentery.

During the surgical dissection and by scrutiny of the surgical specimens, it has been demonstrated and reproduced that Toldt fascia was a contiguous anatomic structure for anchoring the mesentery to the retroperitoneum from ileocecal junction to the upper rectum, where the endopelvic fascia and proper fascia of the rectum met, as described in the previous cadaveric studies [1–4].

It needs to be further addressed that the misleading term "fascia of fusion" used to describe the Toldt fascia was first coined by Goligher [3].

Actually, Toldt fascia is composed of loose or even areolar fibrous tissues and contains lymphatics and minute blood vessels inside and can be dissected within. If Toldt fascia is a fused fascial structures in nature, it cannot be dissected within, just as we cannot make any dissection within the Denonvilliers' fascia [5], which is an obvious fused fascia overlying the anterior mesorectum. The fascia is developed from mesenchymal cells, whereas the peritoneum is from mesothelial cells. Recently, Culligan et al. have made an in-depth histologic study of Toldt fascia, pointing out that Toldt fascia is sandwiched by upper mesothelium attached to overlying mesocolon and retroperitoneal mesothelium [4]; therefore, it is conceivable that the mechanisms for the formation of Toldt fascia is through the "condensation theory" rather than "fusion theory," i.e., the mesenchymal cells were deposited in between when the visceral and parietal peritoneum of the dorsal mesentery began to fuse together during the embryonic stage [5]. Some authors suggested that the mobilization of the mesocolon of ascending and descending colon could be made along either the mesofascial interface or retrofascial interface; we feel that it is impractical for clinical surgery, and, otherwise, the best way for the development of correct dissection plane should be dissection within the Toldt fascia.

4.3 Rectosacral and Waldeyer's Fascia Revisited

During the clinical practice of total mesorectal excision for the treatment of middle and low rectal cancer, posterior mobilization of the rectum is along the holy plane, which consists of loose areolar connective tissues [6]. With further posterior downward mobilization, a thick tough fascia will be encountered, generally known as rectosacral fascia, and failure to recognize and divide the rectosacral fascia can perforate the mesorectum or lead to severe presacral hemorrhage. Division of the rectosacral fascia allows mobilization of the rectum as far as the anorectal junction and exposes the Waldeyer's fascia, conceptually known as the endopelvic fascia covering the pelvic floor. However, there is significant confusion about what Waldeyer's fascia represents as the eponym has been used to describe the presacral fascia, the rectosacral fascia, or all fascia posterior to the rectum [7, 8]. This is because Wilhelm Waldeyer did not mention rectosacral fascia and just vaguely described the floor of retrorectal space as the fascia lying along the anococcygeal ligament [9, 10].

Based on the high-resolution images in robotic or laparoscopic surgery for patients with distal rectal cancer undergoing total mesorectal excision, the dissection of holy plane was vividly demonstrated and conceptualized. Briefly, the junction between proper rectal fascia and parietal layer of presacral fascia was incised, and the presacral space is easily entered and enlarged downward along the loose areolar tissue planes. At the level of the body of the fourth sacral vertebra (frequently) or the third sacral vertebra(less frequently), we might encounter the so-called rectosacral fascia, which varies in thickness from a thin transparent membrane to a thick, tough, opaque fascia, running from the periosteum overlying the vertebra body to insert into the proper fascia of the rectum about 3–5 cm above anorectal junction. However, rectosacral fascia was visualized in only 44% of patients undergoing laparoscopic surgery and 48% of patients undergoing robotic surgery. We think only a half minus of patients whose rectosacral fascia can be visualized is because the rectosacral fascia, most of the time, was too thin to be visualized under the strong sharp electrocautery during laparoscopic or robotic surgery or related to the quality of dissection, such as bleedings from bridging venules during dissection. After the rectosacral fascia is divided, a small space is entered inferior to the rectosacral fascia and the rectum, containing the rectococcygeus muscle and lying on the posterior attachment of levator ani to the coccyx and sacrum; this space maybe described as the infrarectal space, also known as the retrorectal space, since it is below the almost horizontal part of the rectum, in the upright position. The floor of retrorectal space consists of an extension of the parietal layer of presacral fascia enveloping the rectococcygeus muscle or its fibrous remnant,

which blends with the medial edge of levator ani to form the upper part of the strong anococcygeal ligament. Based on the present study and with reference to the original description of Wilhelm Waldeyer [9–11], we strongly suggest that the fascia covering the floor of retrorectal space should mean Waldeyer's fascia. Remarkably, both rectosacral fascia and Waldeyer's fascia are more obvious in patients after concurrent chemoradiation therapy.

In summary, rectosacral fascia and Waldeyer's fascia are two distinct anatomical structures: The former traverses and separates the presacral space into superior compartment and inferior retrorectal space; the latter forms the floor of retrorectal space (Fig. 4.2). Further clarification of the rectosacral and Waldeyer's fascia would facilitate the precise and quality surgery for patients with distal rectal cancer. Sharp division of the condensed and thicker rectosacral fascia is preferred over blunt dissection in order to avoid inadvertent tearing of posterior mesorectal fascia and bleeding from presacral veins.

4.4 Dissection of Denonvilliers' Fascia Implicated in Total Mesorectal Excision

Ample imaging and surgical practices have suggested that the key to a successful anterior dissection in TME is based on the full appreciation of the Denonvilliers' fascia and its relationship to the anterior mesorectum [12–15]. The Denonvilliers'

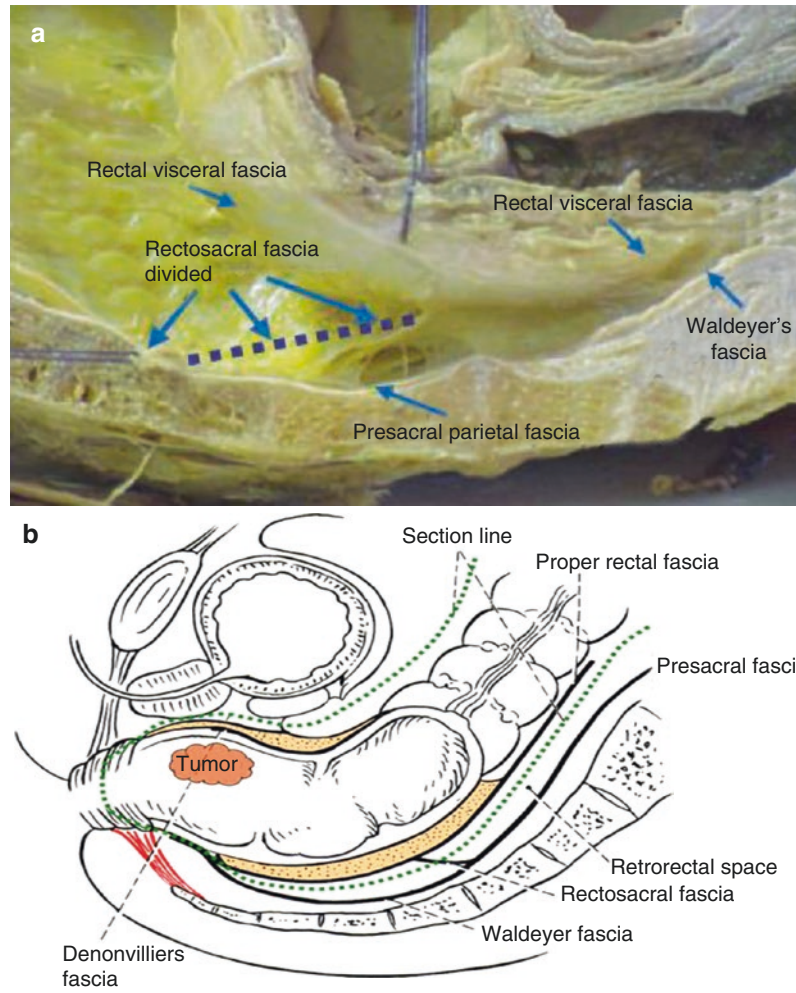

Fig. 4.2 (**a**) Retrorectal space after division of the rectosacral fascia (necessary to mobilize the rectum completely). Waldeyer's fascia denotes the thick endopelvic fascia covering the levator ani muscle. At the lower end (floor) of the retrorectal space, we can see presacral parietal fascia (endopelvic fascia) fuse with proper fascial of the rectum at the level of the anorectal junction. (**b**) Rectosacral fascia frequently originated from endopelvic fascia at S4 sacral level and less frequently from S3 level; Waldeyer's fascia is the endopelvic fascia covering the levator ani muscle. The green line is suggested dissection plane for a TME

fascia is generally considered macroscopically to be a one-layer fascia arising from the fusion of the two walls of the embryonic peritoneal cul-de-sac, and thus it histologically actually consists of two-layer fibromuscular tissues and extends from the peritoneal reflection cranially to the perineal body caudally [13]. Heald et al. advocated that there is usually no surgical plane behind the Denonvilliers' fascia and insisted that optimal TME for rectal cancer should be by dissection "in front of" this fascia [16, 17]. However, Lindsey et al., based on the histologic and embryologic evidences, pointed out that the fascia propria of the rectum and the Denonvilliers' fascia would be separable, and thus the correct natural dissection plane of TME should be "anterior" to the fascia propria of the rectum and "posterior" to the Denonvilliers' fascia [13, 14]. Moreover, Kinugasa et al. found that at the level of seminal vesicles, incision in front of the Denonvilliers' fascia was likely to injure superior parts of the pelvic nerve plexus and the left/right communication; and therefore to preserve all autonomic nerves for a normal genitourinary function, optimal TME for rectal cancer, in their opinion, required a dissection behind the Denonvilliers' fascia [15–18]. On the other hand, the concepts of Denonvilliers' fascia in female patients remain unclear for most colorectal surgeons. Actually, Denonvilliers' original description gave no account of the presence of such a fascia in the female, but gynecologists generally believe that the rectovaginal septum is the female counterpart and is a normal, constant structure [19, 20]. Heald et al. stated that the fascia is less obvious in women, but, importantly for the conduct of rectal dissection, it provides mobility for the rectum on the posterior vaginal wall [16].

For nearly all male patients (91%), the boundaries of Denonvilliers' fascia could be clearly recognized in laparoscopy [5]. Immediately after the peritoneum over the rectovesical pouch was incised, the bluish bubble-shaped seminal vesicles were exposed nakedly with little purposely dissection. Medially, the surface of seminal vesicles was generally covered with sparse areolar fibrous tissues, whereas, laterally, it was contiguous with some dense fibrous structures, which were postulated to contain the communicating nerve fibers from the nearby neurovascular bundle of Walsh.

Posterior to the seminal vesicles, we could see the Denonvilliers' fascia, varying in nature from a fragile translucent fibrous layer to a tough leathery membrane, manifesting itself as a trapezoidal "apron" covering the glistening fatty tissues of the anterior mesorectum (Fig. 4.3a). Although Lindsey et al. showed that the Denonvilliers' fascia and the anterior part of the fascia propria of the rectum proper rectal fascia were two separable layers in histology [12–14], it has been found that there was no natural dissection plane between the two layers in practice, because any attempt to dissect along this postulated surgical plane would have nearly resulted in the perforation of this fascial layer (Fig. 4.3b). This finding gave us the impression that the upper part of the Denonvilliers' fascia was more adherent to, or even fused with, the anterior part of the fascia propria of the rectum than to the seminal vesicles. Moreover, in laparoscopy, the Denonvilliers' fascia usually has clear left and right edges, which are fenced by the insertion of lateral ligaments at the anterolateral (2 and 10 o'clock) direction of the rectum. Remarkably, the Denonvilliers' fascia was even more prominent in male patients after preoperative concurrent chemoradiation therapy.

Technically, by pushing the seminal vesicles ventrally along the areolar tissue plane "in front of" the Denonvilliers' fascia, the anterior dissection in TME can be efficiently continued downward until the prostate is reached, where the Denonvilliers' fascia fuses with the prostate capsule and the natural surgical plane halts (Fig. 4.3c). Therefore, in order to continue the dissection, we had to incise the Denonvilliers' fascia at this site and shift the dissection plane to "behind" this fascia (Fig. 4.3d), and thereafter, by gentle pushing the very thin fatty tissues of the anterior mesorectum dorsally, the rectum could be completely separated from the prostate and mobilized to the pelvic floor. However, for tumors located at the anterior rectal wall with suspected invasion into the prostate capsule, we deliberately kept the dissection plane in front of the Denonvilliers' fascia and even into the pros-

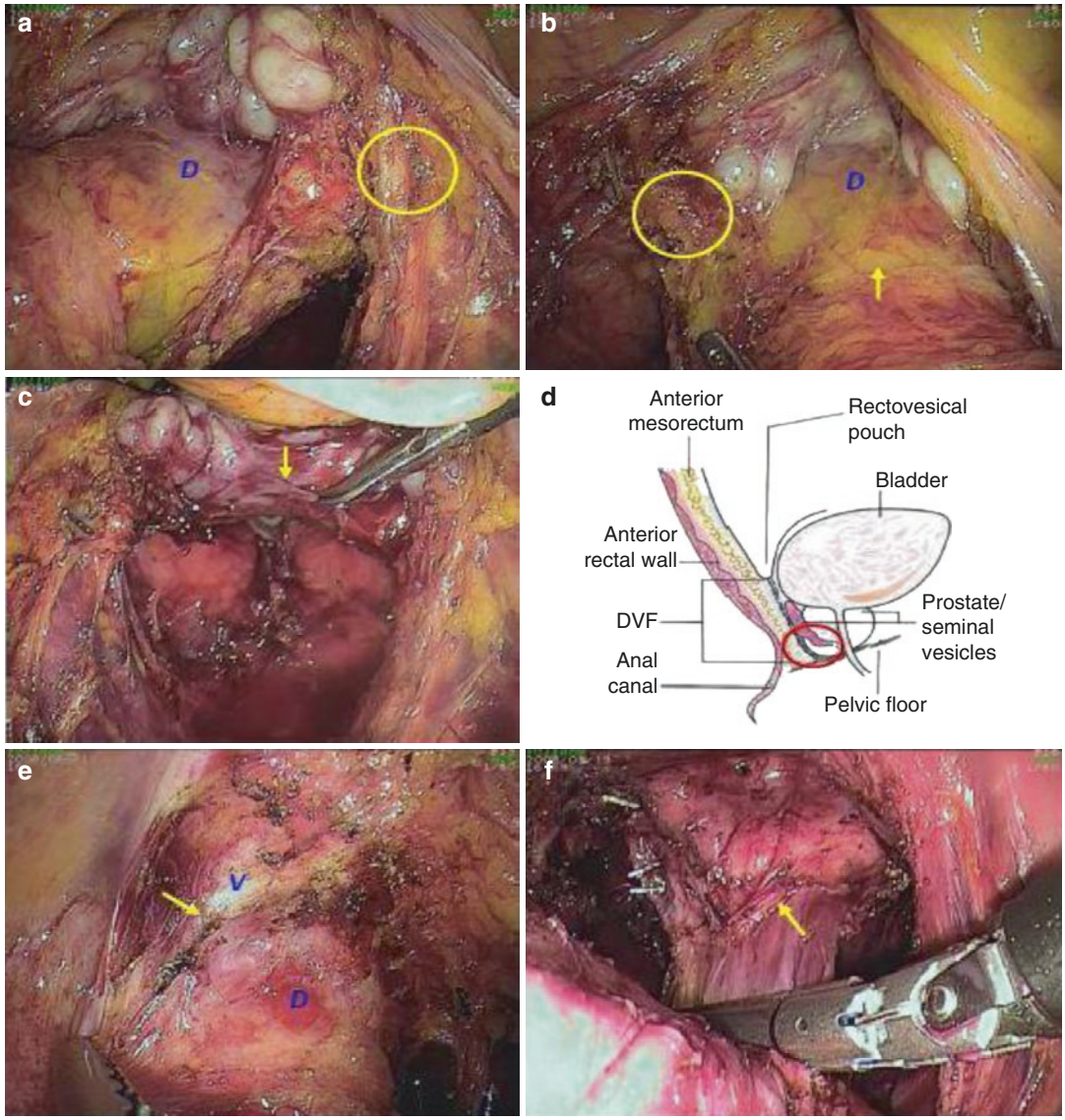

Fig. 4.3 (**a**) The Denonvilliers' fascia (*D*) is a fibrous layer in between seminal vesicles anteriorly and fatty mesorectum posteriorly. The left edge of Denonvilliers' fascia is at the insertion of the left lateral ligament. The left side of seminal vesicles is close to the neurovascular bundle of Walsh (yellow circle). (**b**) Attempt to dissect between the Denonvilliers' fascia and the fascia propria of the rectum resulted in perforation of this layer (arrow). (**c**) The tented structure (arrow) was the cutting end of the Denonvilliers' fascia, which was incised at the level of prostate so that the dissection could be continued downward. (**d**) The band of dotted lines indicates the Denonvilliers' fascia, whose lower part fuses with the posterior capsule of the prostate and could not be separated (red circle), modified from Lindsey et al. Br J Surg 2000;87:1288. (**e**) In some adipose females, there is still a scanty layer of fibrous tissue, which may be equivalent to Denonvilliers' fascia (*D*), covering the anterior mesorectum. In between the posterior vaginal wall (*V*) and anterior mesorectum, the rectovaginal septum is composed of intertwined fibrous tissues (arrow). (**f**) A laparoscopic view of the lower part of the rectovaginal septum (arrow), in which no distinct layer of the Denonvilliers' fascia could be found

tate parenchyma to ensure an adequate anterior resection margin for cancer. However, such dissection always resulted in more bleeding as well as postoperative sexual dysfunction, which was due to the unavoidable injury of the peri-prostate autonomic nerve plexus.

In contrast, the female Denonvilliers' fascia was found to be much less obvious as a distinct fibrous layer than in the male counterpart. Generally, the vagina and rectum are separated by a sheet of strong fibrous tissues, which have long been recognized by gynecologists as "rectovaginal septum." Under laparoscopy, after the peritoneum over cul-de-sac was excised, we could clearly identify the intertwined fibrous tissues in between the vaginal vault and the rectum. In more adipose women (body mass index ≧ 27 kg/m^2), posterior to this area of irregular fibrous tissues, we could still identify the shiny fatty tissues of the mesorectum, which tapered caudally (Fig. 4.3e). However, in thinner females, the anterior mesorectum is very scanty or actually not present, and therefore in this condition, it seems that the intervening fibrous tissue plate acts as the linking substances to anchor the posterior vaginal wall to the anterior rectal wall all the way from the level of cul-de-sac down to the perineal body [21].

Based on the observation in our previous study [5], we feel that there is no natural surgical plane between the rectum and vagina, and therefore, during surgical practice, we usually first clearly identify the whitish posterior vaginal wall and then push it ventrally and caudally against the backward-pulled rectum (Fig. 4.3f). By this sliding action, the vaginal wall can then be separated from the rectum, and simultaneously the anterior surface of the rectum can be kept attached by some fibrous tissues of the rectovaginal septum to ensure that the anterior resection margin was adequate during the whole dissection process. On the other hand, it has also been noted that in females after preoperative concurrent chemoradiation therapy, the so-called female Denonvilliers' fascia became more dense, unclear, and irregular and therefore more difficult to dissect.

4.5 In Conclusion

In assisting a resident in an operation, I frequently cited the ancient Chinese article entitled "Chinese Gastronomy," which was written by Chuangtse in the fourth century BC and emphasized the use of the cleaver (Fig. 4.4).

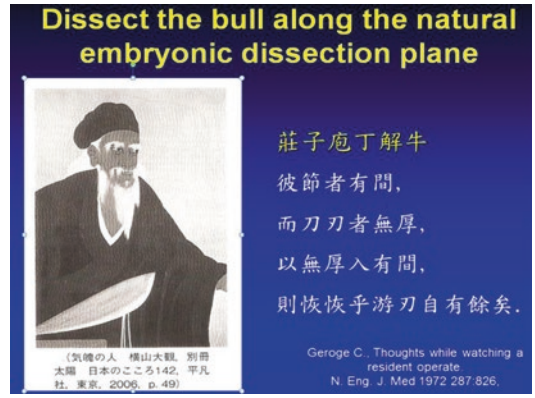

Fig. 4.4 The ancient Chinese Taoist Chungtse advocated if the dissection was performed along the natural dissection plane, the surgeons will meet the least resistance and greatly enhance the work efficiency, which is the core philosophy of the Chinese Taoism

Much of its wording seems applicable to our daily practice of colorectal cancer surgery, particularly the concept of working "with the mind, not the eye":

> Prince Huei's cook was cutting up a bullock. Every blow of his hand, every heave of his shoulders, every trend of his foot, every thrust of his knee, every whshh of rent flesh, every chhk of the chopper, was in perfect rhythm-like the dancer of the Mulberry Grove, like the harmonious chords of Ching Shou.
> "Well done!" cried the Prince. "Yours is skill indeed!"
> "Sire," replied the cook laying down his chopper," I have always devoted myself to Tao, which is higher than mere skill. When I first began to cut up bullocks, I saw before me whole bullocks. After three years' practice, I no longer saw whole animals. And now I work with my mind and not with my eye. My mind works without control of the senses. Falling back on eternal principles, I glide through such great joints or cavities as there may be, according to the natural constitution of the animal. I do not even touch the convolution of muscle and tendon, still less attempt to cut through large bones.
> "A good cook changes his chopper once a year because he cuts. An ordinary cook once a month because he hacks. But I have had this chopper for nineteen years, and although I have cut up many thousand bullocks, its edge is as if fresh from the whetstone. For at the joints there are always interstices, and the edge of chopper being without thickness, it remains only to insert that which is without thickness into such an interstice. Indeed there is plenty of room for the blade to move about. It is thus that I have kept my chopper for nineteen years as though fresh from the whetstone.

> Nevertheless, where I come upon a knotty part which is difficult to tackle, I am all caution. Fixing my eye on it, I stay my hand, and gently apply my blade, until with a hivah the part yields like earth crumbling to the ground. Then I take out my chopper, stand up, and look around with an air of triumph.
> "Bravo!" cried the Prince. "From the words of this cook I have learnt how to take care of my life." [22]

This quotation from the ancient manuscript is so self-explanatory that no comment is needed. It is stranger, however, that in books on surgical technique, much space is spent on advice on the gentle handling of tissues and the benefits of sharp dissection but little or none on how to find the natural tissue planes and separate them by a gentle traction and a minimum of dissection. Fully respecting the Toldt, Gerota, rectosacral, Waldeyer, Denonvilliers fascia, and its relation to the neighboring proper fascia of the rectum, endopelvic fascia, and rectal lateral ligament would ensure the quality surgery of rectal cancer, which can extrapolate to optimal oncological efficacy, even without the proof from randomized prospective clinical trials.

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