Anatomy of Denonvilliers' Fascia and Its Relationship with Pelvic Autonomic Nerves

Xiangpeng Gu
Digestive Medicine Center, the Seventh Affiliated Hospital, Sun Yat-sen University, Shenzhen, Guangdong, China

Abstract: Objective: This study investigated the anatomy of Denonvilliers' fascia and its relationship with pelvic autonomic nerves. Methods: Eight pelvic specimens (three male and five female specimens) provided by the Department of Anatomy of Guangdong Pharmaceutical University and Sun Yat-sen University were dissected to observe the morphological structure, craniocaudal attachments, and lateral extension of Denonvilliers' fascia, as well as its associations with pelvic autonomic nerves and perirectal fascia. The histological staining was performed to analyze the tissue composition of Denonvilliers' fascia. Additionally, 102 laparoscopic surgical videos of mid-low rectal cancer from the Department of Gastrointestinal Surgery, the Third Affiliated Hospital of Sun Yat-sen University were retrospectively reviewed to verify the anatomical findings. Results: Denonvilliers' fascia was identified in all specimens. In males, it located between the prostate, seminal vesicles, and rectal proper fascia, which located between the posterior vaginal wall and rectal proper fascia in females. It was single-layer membranous structure originating cranially from the lowest peritoneal reflection and terminating caudally at the perineal body. At the anterolateral pelvic wall (approximately 2 o'clock and 10 o'clock positions), it connects with the pelvic fascia to form a complete cylindrical structure. Neurovascular bundles of pelvic autonomic nerves passed through Denonvilliers' fascia and ran in the anterior space, innervating genitourinary functions. Histologically, Denonvilliers' fascia is primarily composed of elastic fibers, collagen fibers, and abundant neurovascular tissues. Conclusion: Denonvilliers' fascia located between the prostate, seminal vesicles or posterior vaginal wall and rectal proper fascia, with cranial attachment to the lowest peritoneal reflection, caudal termination at the perineal body, and laterally attached the pelvic fascia. Neurovascular bundles pass through its anterolateral aspect. Preserving Denonvilliers' fascia during radical rectal cancer surgery is conducive to protecting neurovascular bundles.

***Keywords*:** Denonvilliers' fascia; Pelvic autonomic nerve; Neurovascular bundle; Rectal cancer

1. Introduction

In 1836, the French anatomist Denonvilliers [1] firstly described fascial structure between the seminal vesicles, prostate, and rectum in twelve male cadavers, terming it the "aponeurosis between the prostate and rectum". This structure was later named "Denonvilliers' fascia" in his honor. However, the controversies persisted regarding its anatomical details and relationships with adjacent tissues [2]. Since Heald proposed the total mesorectal excision (TME) concept for mid-low rectal cancer in 1982 [3], TME has become the gold standard due to reducing recurrence and improving long-term survival. Nevertheless, 18%–27% of patients develop urinary dysfunction and 11%–55% experience sexual dysfunction postoperatively [4], which are linked to pelvic autonomic nerve injury. This study aims to clarify the anatomical characteristics of Denonvilliers' fascia and its relationship with pelvic autonomic nerves through cadaveric dissection and surgical video verification, providing a theoretical basis for clinical practice.

2. Materials and Methods

2.1 Materials

Eight pelvic specimens (three male and five female specimens) were obtained from the Department of Anatomy of Guangdong Pharmaceutical University and Sun Yat-sen University, including three whole pelvic specimens and five hemi-pelvic specimens. All specimens were preserved in formalin and free from obvious pathological changes.

Retrospective analysis was conducted on 102 laparoscopic surgical videos of mid-low rectal cancer from the Department of Gastrointestinal Surgery, the Third Affiliated Hospital of Sun Yat-sen University, including 42 male and 60 female patients. All the materials in this study were in line with ethical requirements.

2.2 Methods

Anatomical dissection: Pelvic specimens were dissected to observe the location, shape, craniocaudal boundaries, and lateral extensions of Denonvilliers' fascia. The spatial relationships between Denonvilliers' fascia and pelvic autonomic

nerves, as well as perirectal fascia were recorded.

Histological examination: Tissues of Denonvilliers' fascia were stained observe cellular components and fiber distribution.

Surgical video analysis: The surgical videos were reviewed to confirm the anatomical features of Denonvilliers' fascia and its relationship with neurovascular bundles during operation.

3. Results

3.1 Anatomical Features of Denonvilliers' Fascia

In males, Denonvilliers' fascia was situated between the posterior surface of the prostate, seminal vesicles and the anterior surface of the rectal proper fascia, which located between the posterior vaginal wall and rectal proper fascia. It presented as thin, translucent monolayer membrane in the center. Cranially, it originated from the lowest point of the peritoneal reflection. Caudally, male Denonvilliers' fascia gradually fused with the prostatic capsule, while female Denonvilliers' fascia merged with the posterior vaginal wall, both terminating at the perineal body. At the anterolateral pelvis (approximately 2 o'clock and 10 o'clock positions relative to the rectum), Denonvilliers' fascia merged with the parietal pelvic fascia, forming a continuous cylindrical structure that enclosed the rectum and adjacent structures. There was loose areolar space between Denonvilliers' fascia and the rectal proper fascia, which was anterior rectal space.

Figure 1. Anatomy of Denonvilliers' fascia. Denonvilliers' fascia located between prostate, seminal vesicles or posterior vaginal wall and rectal proper fascia, originating from the lowest point of the peritoneal reflection, terminating at the perineal body. Denonvilliers' fascia merged with the parietal pelvic fascia laterally.

3.2 Anatomy of pelvic autonomic nerves and relationship with denonvilliers fascia

Pelvic autonomic nerves mainly consist of the superior hypogastric plexus, inferior hypogastric plexus, pelvic splanchnic nerves, and neurovascular bundles. The superior hypogastric plexus located below the aortic bifurcation, which divided into left and right hypogastric nerves running parallel to the ureters within the parietal pelvic fascia, The pelvic splanchnic nerves were composed of parasympathetic nerves from S2-S4. In the level of S3, the hypogastric nerves combined with ipsilateral pelvic splanchnic nerves and postganglionic fibers from the sacral ganglia forming the left and right inferior hypogastric plexuses which were also known as pelvic plexuses, locating both sides of the rectum and genitourinary organs such as seminal vesicles, prostate or cervix and vaginal fornix. The nerve fibers of pelvic plexuses divided into bladder plexus, prostatic plexus, uterovaginal plexus, and rectal plexus, regulating urinary and sexual functions.

Neurovascular bundles, formed by pelvic plexus branches and genitourinary vessels, were observed passing through the anterolateral aspect of Denonvilliers' fascia at the level below the seminal vesicles (males) or posterior vaginal fornix (females). After traversing Denonvilliers' fascia, these bundles traveled in the anterior space and distributed to the prostate, seminal vesicles, or posterior vaginal wall. Dissection of the anterior space of Denonvilliers' fascia revealed numerous fine nerve branches within this region.

Figure 2. Anatomy of pelvic autonomic nerves and relationship with denonvilliers fascia. superior hypogastric plexus divided into left and right hypogastric nerves traveling within the parietal pelvic fascia. Inferior hypogastric plexus was formed by the branches of hypogastric nerve and pelvic splanchnic nerve. Neurovascular bundle located anterolateral of Denonvilliers' fascia and passed through it.

3.3 Histological Characteristics

Histological staining showed that Denonvilliers' fascia was composed of collagen fibers and elastic fibers with scattered blood vessels and nerve fibers, supporting the anatomical observation of neurovascular bundle passage.

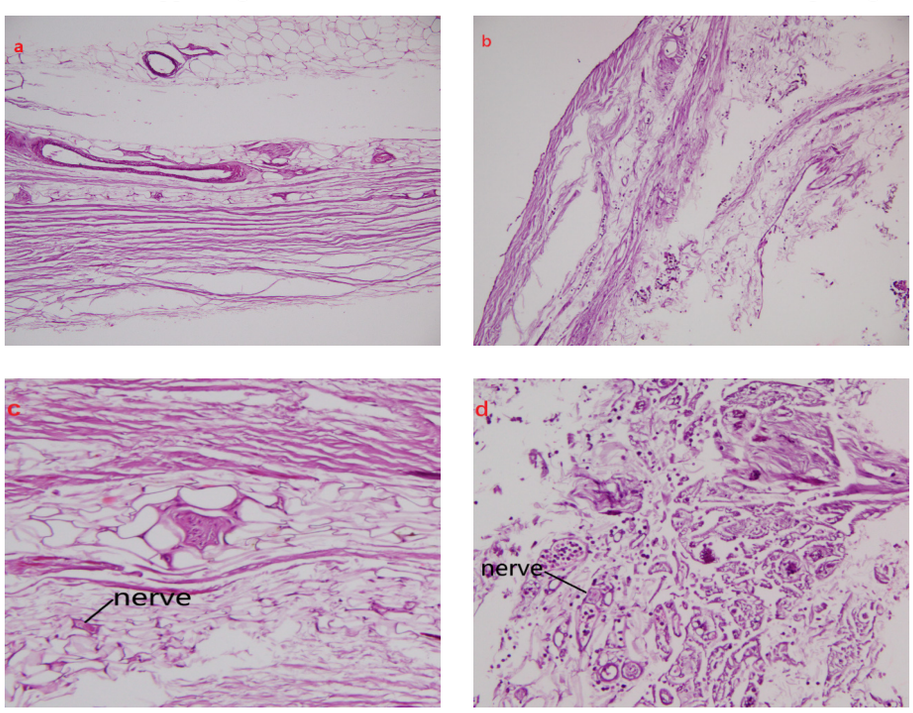

Figure 3. Histological staining of Denonvilliers' fascia. There were nerve fibers in the tissue of Denonvilliers' fascia.

3.4 Surgical Verification

Intraoperative findings were consistent with cadaveric dissection: Denonvilliers' fascia was visualized as a distinct membranous structure continuous with the parietal pelvic fascia, and neurovascular bundles were clearly identified passing through its anterolateral aspect. Preservation of Denonvilliers' fascia during dissection was associated with reduced iatrogenic injury to these neurovascular structures.

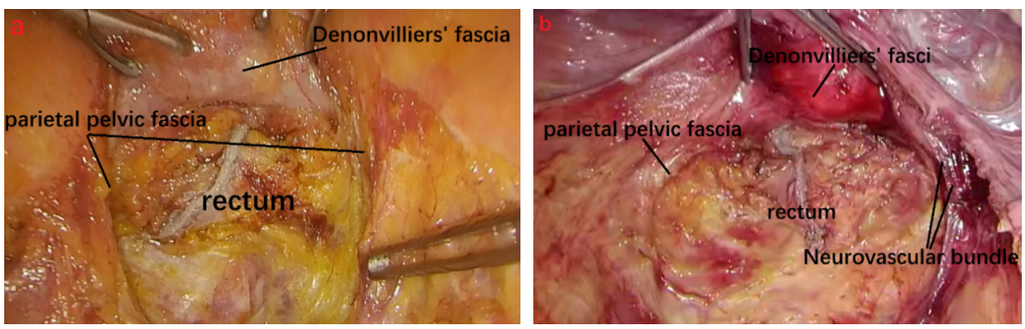

Figure 4. Denonvilliers' fascia in the surgery and the relationship with neurovascular bundle.

4. Discussion

Denonvilliers' fascia located between the seminal vesicles, prostate or posterior vaginal wall and the proper fascia of the rectum, presenting as single-layer membranous structure in the center. Controversies has existed among researchers regarding whether Denonvilliers' fascia is monolayer or multilayer structure. Some scholars considered it was double-layer structure. The anterior layer adhered to the seminal vesicles and prostate, followed the prostatic capsule, and eventually fused with it, while the posterior layer merges with the proper fascia of the rectum [5]. Smith [6] and Wesson [7] proposed that Denonvilliers' fascia included two layers. Tobin and Benjamin [8] suggested that the posterior layer of Denonvilliers' fascia was actually the proper fascia of the rectum. In contrast, Kourambas et al. [9] considered Denonvilliers' fascia as single-layer membranous structure through cadaveric dissection. Lindsey et al. [10] also supported the single-layer view based on embryological studies, believing that Denonvilliers' fascia was formed by peritoneal fusion. Similarly, Ludwikowski et al. [11] concluded that Denonvilliers' fascia was monolayer originating from the peritoneal reflection and terminating at the perineal body through embryological research. Some scholars argued that the structural characteristics of Denonvilliers' fascia could not be simply categorized as single-layer or multi-layer. Instead, it was monolayer in the center and double or triple-layered on both sides [12], with neurovascular bundles wrapped in the lateral parts. Therefore, some scholars suggested that Denonvilliers' fascia presented Y-shaped structure on both sides in the coronal plane [13], where it splited into two layers, allowing neurovascular bundles to pass through.

Denonvilliers' fascia originated cranially from the lowest part of the peritoneal reflection and terminates caudally at the perineal body, with controversies remaining regarding its lateral course and attachment points. Through anatomical studies of pelvic specimens, we found that Denonvilliers' fascia was continuous with the parietal pelvic fascia in the anterolateral pelvis, forming a cylindrical structure. There was loose space between Denonvilliers' fascia and the proper fascia of the rectum including the anterior rectal space and posterior rectal space. Kinugasa et al. [14] identified membranous structure between the retroperitoneal fascia and the proper fascia of the rectum through cadaveric dissection, naming it the prehypogastric nerve fascia. Anatomical studies have shown that the hypogastric plexus, left and right hypogastric nerves, and pelvic plexus were distributed within the prehypogastric nerve fascia [15]. A loose space existed between the proper fascia of the rectum and the prehypogastric nerve fascia, and dissection within this space during TME was crucial to ensure surgical radicality while protecting pelvic autonomic nerves [16].

Walsh et al. [17] firstly proposed the concept of genitourinary neurovascular bundles in 1983. The branches of the pelvic plexus and blood vessels lateral to the prostate, seminal vesicles, or vagina formed the neurovascular bundles. Zhai et al. [18] found through dissection of female pelvic specimens that genitourinary neurovascular bundles travel in the anterolateral aspect of the proper fascia of the rectum and posterolateral aspect of the vaginal fascia, passing through Denonvilliers' fascia toward the posterior vaginal wall. Bertrand et al. [19] observed in male pelvic specimens that genitourinary neurovascular bundles at the prostatic level traveled in the anterolateral aspect of the proper fascia of the rectum and posterolateral aspect of the prostatic fascia, passing through Denonvilliers' fascia toward the prostate. Cong et al. [20] divided neurovascular bundles into three parts based on anatomical location: the first part was the superolateral aspect of the seminal vesicles (original part), where nerves and blood vessels form a reticular network; the second part was the main trunk, traveling posterolaterally to

the prostate with the typical bundled form; the third part was the cavernous part, presenting as radiating peripheral nerves that directly controlled erectile function. Observed from the coronal plane of the pelvis, genitourinary neurovascular bundles were radially distributed on both sides of the anterior rectal space. Through anatomical studies of pelvic specimens and comparison with rectal cancer surgical videos, neurovascular bundles distributed in the anterolateral aspect of Denonvilliers' fascia, traveling in bundles and passing through Denonvilliers' fascia toward the prostate, seminal vesicles, or posterior vaginal wall. We found that numerous branches of neurovascular bundles in the anterior space of Denonvilliers' fascia after dissecting of pelvic specimens.

The surgery of total mesorectal excision significantly reduced postoperative recurrence and improved long-term survival in patients with middle and low rectal cancer. However, high proportion of patients still experienced sexual and urinary dysfunction postoperatively, which was closely related to intraoperative injury to pelvic autonomic nerves. Through the dissection of pelvic specimens, we found that neurovascular bundles located in the anterolateral aspect of Denonvilliers' fascia and pass through it, which provided anatomical basis for protecting these bundles during rectal cancer surgery. Wei et al. [21] confirmed the feasibility of dissection posterior to Denonvilliers' fascia, and multi-center clinical studies showed that patients undergoing dissection posterior to Denonvilliers' fascia had significantly lower incidence of postoperative sexual and urinary dysfunction without differences in oncological indicators.

5. Conclusion

Denonvilliers' fascia is monolayer in the center, locating between the genitourinary organs such as prostate, seminal vesicles or posterior vaginal wall and the rectal proper fascia, with cranial attachment to the lowest peritoneal reflection, caudal termination at the perineal body, and lateral continuity with the pelvic fascia. Neurovascular bundles pass through its anterolateral aspect, playing a critical role in genitourinary function. Preserving Denonvilliers' fascia during radical rectal cancer surgery is an effective strategy to protect these neurovascular structures, reducing postoperative complications.

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