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REVIEW ARTICLE

The Toldt fascia: A historic review and surgical implications in complete mesocolic excision for colon cancer

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Summary To clarify the anatomic concept of Toldt fascia, based on the literature review and the surgical anatomic dissection using laparoscopic or robotic approach. We undertook review of the historic literature and surgical videos from 250 patients with colorectal cancer operated on laparoscopically or robotically to discuss the surgical implications of Toldt fascia in complete mesocolic excision for colon cancer. Toldt fascia, sandwiched by the overlying mesothelial layer of the mesocolon and underlying mesothelial layer of the retroperitoneum, comprised loose fibrous tissues with minute vessels inside, and was contiguous from the ileocecal mesentery radix to the upper rectum. Surgical dissection plane is readily developed within the Toldt fascia; however, any attempt to dissect along the interface between Toldt fascia and the overlying mesocolon or underlying retroperitoneum failed. Within the anatomic territory of kidney, Toldt fascia fused with Gerota fascia, and then extended in all directions: upward to the dosal surface of the duodenum, liver and pancreas; medially to fuse with the adventitia layer of the abdominal aorta; laterally, it tapered at the area below the reflection of visceral and parietal peritoneum; and downward, it became a thin membranous structure covering the gonadal vessels, ureters and retroperitoneal structures and ended at the upper rectum, where it met the junction of endopelvic fascia and proper fascia of the rectum. The present study demonstrated that Toldt fascia is a natural embryonic dissection plane for the precise conduction of complete mesocolic excision for colon cancer.

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1. Introduction

Complete mesocolic excision, which means adequate resection of tumor-bearing bowel segment with en bloc removal of mesocolon along the embryonic fascial plane, has become a new surgical paradigm for the treatment of colon cancer.[1] The recent studies from Coffey et al have provided the anatomic basis for the clinical practice of complete mesocolic excision.[2–4] They suggested that the correct dissection plane for the mobilization of ascending, descending, and sigmoid colon, should be along the Toldt fascia, in the context of complete mesocolic excision for the surgery of colon cancer. However, there have been controversies regarding the appropriate terms for the fascial structures underlying the ascending and descending mesocolon, and numerous synonyms including 'fascia of fusion', 'embryological fascial planes', 'parietal fascia ', 'white line of Toldt', 'Gerota fascia', 'prerenal fascia', 'anterior pararenal fascia', and 'deep subperitoneal fascia' have been used to label this dissection plane.[5–8]

Recently, more and more patients with colorectal cancer were operated on with laparoscopic or robotic approach. It has been generally accepted that the quality of dissection is greatly enhanced under the magnified view of 2-D or 3-D laparoscopy. In this study, we revisited the Toldt fascia and its neighboring fascial structures through laparoscopic or robotic dissection. Further clarification of such anatomic concepts based on live surgery, would help find out the correct dissection plane, standardize the nomenclature of surgical approach[8–10] and thus ensure the quality colorectal surgery.

2. Methods

2.1. Historic review of Toldt fascia

The literature of Toldt fascia were extensively searched under the key words of "Toldt fascia", "white line of Toldt", complete mesocolic excision, and total mesorectal excision and the surgical implications were scrutinized and discussed.

2.2. Surgical dissection of Toldt fascia

We selectively retrieved surgical videos from patients who successfully underwent laparoscopic complete mesocolic excision for ascending colon cancer (n = 50) and descending-sigmoid colon cancer (n = 100), and robotic total mesorectal excision for rectal cancer (n = 100) in our Colorectal Surgical Department from 2008 to 2017. The extent, texture, and anatomical features of Toldt fascia, and their relationship to mesocolon and contiguous fascial structures related to the complete mesocolic excision of colon cancer, especially the Gerota fascia, were scrutinized and appraised its implications in surgical practice. Moreover, the surgical specimens were examined, focusing on the intactness of the fascial linings of the resected mesocolon, to define the extent of Toldt fascia and evaluate the quality of complete mesocolic excision.

For the mobilization of the mesocolon of descending colon, we first explored the duodeno-mesenteric fossa, identified the inferior mesenteric vein in the low border of pancreas, and then incised the visceral peritoneum just medial to the inferior mesenteric vein. With the tenting of the mesentery containing the inferior mesenteric vein, a retroperitoneal tunnel could be readily created along the retroperitoneal fascial plane upward to the low border of the dorsal side of pancreas, and laterally to the reflection of visceral and parietal peritoneum just below the low border of spleen.

During the mobilization of the sigmoid mesocolon, after the inferior mesenteric artery with the associated mesentery was transected at the ventral surface of abdominal aorta, with the tenting of the mesocolon of the descending-sigmoid colon, a retroperitoneal tunnel again could be easily created along the retroperitoneal fascial plane extending medially to laterally from the lateral side of the adventitia layer of abdominal aorta to the reflection of the visceral and parietal peritoneum in the left colonic gutter.

With the continuous tenting and traction of the mesenteric vascular pedicle, the fascial dissection plane could be continued downward to the junction of proper fascia of the rectum and the endopelvic fascia. When the junction of proper fascia of the rectum and the endopelvic fascia was incised, the presacral space was entered and loose areolar fascial tissues of the presacral space could be seen.

Likewise, for the mobilization of ascending colon, a retroperitoneal tunnel could be developed between the mesocolon and retroperitoneum along the fascial plane in all directions. The anterior, posterior, medial, lateral, cranial, and caudal boundaries of the right retroperitoneal tunnel; i.e., the retrocolic space, are the ascending mesocolon, the prerenal fascia, the superior mensenteric vein, the right paracolic sulcus (the reflection of visceral and parietal peritoneum), the subhepatic peritoneal margin, and the inferior ileocolic mesentery radix, respectively.

For the mobilization of the right (ascending colon) and left colon (descending and sigmoid colon), the final procedure is the incision of the reflection of visceral and parietal peritoneum along paracolic gutter from the sigmoid-descending colonic junction upward to the low border of spleen for left colon; and, from the cecum to colonic hepatic flexure for right colon.

3. Results

3.1. Historic aspects of Toldt fascia

Carl Toldt was an Austrian anatomist who was professor of anatomy in Prague and Vienna. In Toldt's Germany book,[11] he described a white line at the lateral reflection of posterior parietal peritoneum of abdomen over the mesentery of the ascending and descending colon, which has been widely cited in the contemporary textbook of colorectal surgery as "white line of Toldt" in eponym. In 1879, Carl Toldt published his account pertaining to the structure and development of human mesentery.[12] He proposed that the human mesentery is a continuous anatomic structure from the duodenuo-jejunal flexure to the mesorectum.[4,9,10] And, he emphasized the presence of a mesentery (or the mesocolon) 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.[13] This distinct fascial plane between the mesocolon and the underlying retroperitoneum might be formed by the fusion and resorption of the visceral peritoneum of the mesocolon with the parietal peritoneum of the retroperitoneum.[14–18] Based on the "rotation and fusion" theory, during the developmental process of the embryonic dorsal mesentery[14–18] (Fig. 1A, B), 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 Calligan et al.[17] Given Toldt's precise cogent description, we proposed that Toldt's 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.

3.2. Surgical implications of Toldt fascia

The present study demonstrated that the dissection plane for the mobilization of the ascending, descending and sigmoid colon is within the fascial layer, i.e., the Toldt fascia. The upper part of this fascial layer fused closely with the mesothelial layer of the overlying mesocolon; the low part of this fascial layer fused closely with the mesothelial layer of the underlying retroperitoneum, and therefore, we utilized "mesofascial interface" and "retrofascial interface" to label the transitions from the fascial layer to the mesothelial layer attached to the overlying mesocolon and the underlying retroperitoneum (Fig. 2A), respectively.

Structurally, we found that the Toldt's fascia was loose and even manifested as areolar tissues in texture. And, during the advancement of surgical dissection, we found minute vessels, especially the venules, were present in this fascial plane and sometimes caused oozing of blood (Fig. 2B). 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 dosal surface of the duodenum, liver, and pancreas (Fig. 2C). Downward, the fused Toldt and Gerota fascia became a thinner layer of membrane-like structures covering the gonodal vessels, bilateral ureters, and retroperitoneum structures. At this point we can carefully preserved gonodal vessels and ureters, and simultaneously kept the membrane intact (Fig. 2D). Any attempt to isolate the ureter might perforate this retrofascial interface and impair the continuity of the Toldt fascial plane.

Laterally, the Toldt's 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 (Fig. 2E).

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

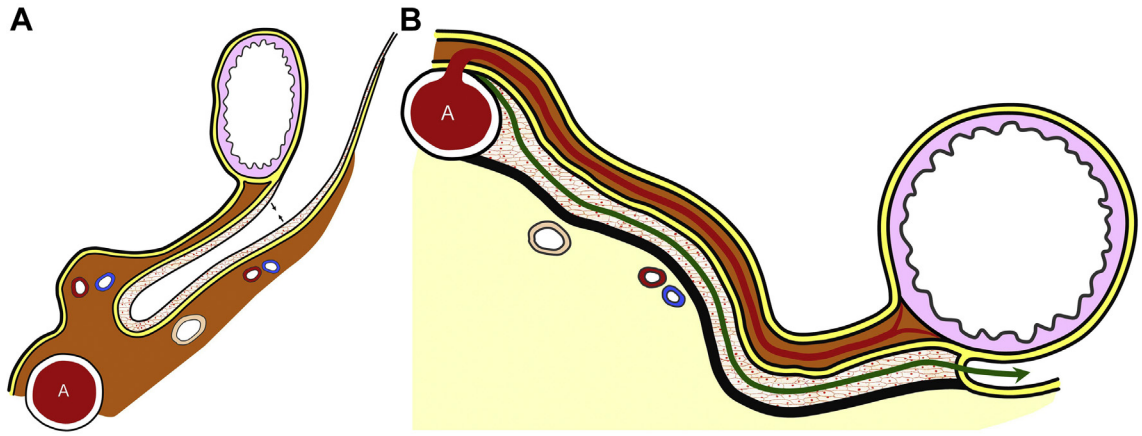

Figure 1 A. Fusion theory of the embryonic dorsal mesentery. The parietal and visceral peritoneum (yellow) of the embryonic dosal mesentery rotated and fused together with the inlets of mesenchymal cells to develop into the Toldt fascia. The Toldt fascia was sandwiched by the two layers of mesothelium, which derived from the mesothelial cells in the primitive visceral and parietal peritoneum. B. The dissection plane was within the Toldt fascia (green line), developing from the adventitious layer of the abdominal aorta (A) to the lateral peritoneal reflection. During the whole course of the surgical dissection within the Toldt fascia, no fusion of fascia was seen.

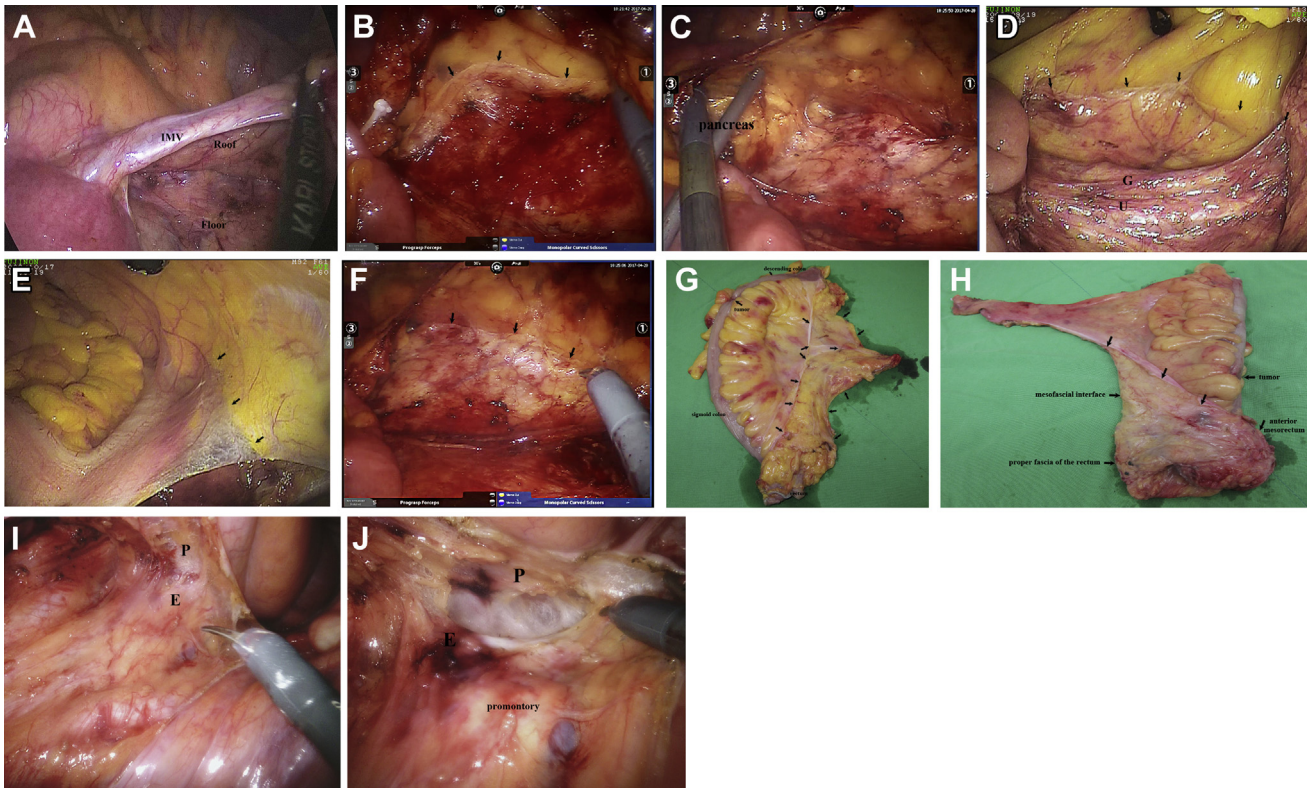

Figure 2 A. With the tenting of the mesentery containing inferior mesenteric vein (IMV), we readily created a retroperitoneal tunnel, of which the floor consisted of the fused Toldt and Gerota fascia (retrofascial interface), and the roof is he fusion of Toldt fascia with the mesothelial layer belonging to the overlying mesocolon (the mesofascial interface). B. We swept down the whitish Gerota fascia (arrow) to separate it from the mesocolon to develop a dissection plane within the Toldt fascia. The Toldt fascia was composed of loose fibrous tissues containing minute venules, which caused blood oozing during this surgical dissection. C. Upward, the dissection plane along the Toldt fascia could be developed into the dosal surface of pancreas. D. Downward, the fused Toldt and Gerota fascia became a membranous structure (arrow) covering the gonadal vessels (G) and ureter (U). E. Laterally, the dissection plane was developed to the white line of Toldt. At this site, the Toldt fascia tapered and became sparse and contiguous with the fibrils surrounding subperitoneal fatty tissues. F. For slim patients, the Toldt fascia sticks to the mesocolon closely and the dissection plane is relatively difficult to develop and sometimes prone to perforate the mesocolon. G. Scrutiny of the posterior surface of the mesentery of resected sigmoid-descending colon showed the extent of the contiguous mesofascial interface (arrow), which was the fusion of Toldt fascia with the overlying mesothelium from mesocolon. H. Scrutiny of the dorsal surface of the resected rectosigmoid colon demonstrated that the mesofascial interface (arrow) was contiguous with the proper fascia of the rectum. I. At the level of the sacral promontory, the fused Toldt and Gerota fascia (retrofascial interface) ended and joined the junction of proper fascia of the rectum (P) and the endopelvic fascia (E). J. When the junction of the endopelvic fascia (E) and proper fascia of the rectum (P) was incised, we entered the presacral space comprising loose areolar tissues.

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 (Fig. 2F).

During the surgical dissection and by scrutiny of the surgical specimens (Fig. 2G, H), we demonstrated and reproduced that Toldt's 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[13,16,17](Fig. 2I, J).

4. Discussion

The present study characterized the correct dissection plane, the Toldt fascia, for the mobilization of ascending, descending, and sigmoid mesocolon through high-magnification and high-definition intraoperative imaging during laparoscopic or robotic surgery. The Toldt fascia varied in structure in different anatomic locations and patients with different body-mass index. It needs to be further addressed that the misleading term "fascia of fusion" used to describe the Toldt fascia was first coined by Goligher.[16] 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,[18] 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[17]; and 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.[18] 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,[7,9] 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.

The present study delineated the extent of Toldt fascia; however, our upward dissection halted in the subhepatic area of the right side of abdomen and the low border of pancreas and spleen of the left abdominal side. Actually, the Toldt fascia is a contiguous structure and this dissection plane can be advanced up to the bare area of the liver in the right abdominal side and the diagram in the left side.[6] Theoretically, if we dissect along Toldt fascial plane, the whole abdominal organs except bilateral kidneys can be eviscerated.

In conclusion, the present study confirmed that the correct dissection plane for the mobilization of the mesocolon of ascending, descending, and sigmoid colon is within the Toldt fascia. Carl Toldt deserves this anatomic eponym in the field of colorectal surgery. Minimally invasive surgery, either the laparoscopic or robotic surgery, fulfilling the basic tenet for the surgery of colon cancer, that is, en bloc resection of the tumor-bearing bowel segment along the natural tissue planes with gentle traction and a minimum of dissection,[19] will become a trend for the precision surgery of colorectal cancer.

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Conflict of interest

All authors of this article have nothing to declare.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent

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References

1. Liang JT, Huang J, Sun CT. Long-term oncologic results of laparoscopic D3 lymphadenectomy with complete mesocolic excision for right-sided colon cancer with clinically positive lymph nodes. *Surg Endosc*. 2015;29:2394—2401.
2. Sehgal R, Coffey JC. The development of consensus for complete mesocolic excision (CME) should commence with standardisation of anatomy and related terminology. *Int J Colorectal Dis*. 2014;29:763—764.
3. Sehgal R, Coffey JC. Standardization of the nomenclature based on contemporary mesocolic anatomy is paramount prior to performing a complete mesocolic excision. *Int J Colorectal Dis*. 2014;29:543—544.
4. Coffey JC. Surgical anatomy and anatomic surgery—clinical and scientific mutualism. *Surgeon*. 2013;11:177—182.
5. Chesbrough RM, Burkhard TK, Martinez AJ, Burks DD. Gerota versus Zuckerkandl: the renal fascia revisited. *Radiology*. 1989;173:845—846.
6. Dodds WJ, Darweesh RM, Lawson TL, et al. The retroperitoneal spaces revisited. *Am J Roentgenol*. 1986;147:1155—1161.
7. Mike M, Kano N. Laparoscopic-assisted low anterior resection of the rectum — a review article of the fascia composition in the pelvic space. *Int J Colorectal Dis*. 2011;26:405—414.
8. Oliphant M, Berne AS. Computed tomography of the subperitoneal space: demonstration of direct spread of intra-abdominal disease. *J Comput Assist Tomogr*. 1982;6:1127—1137.
9. Culligan K, Remzi FH, Soop M, Coffey JC. Review of nomenclature in colonic surgery—proposal of a standardised nomenclature based on mesocolic anatomy. *Surgeon*. 2013;11:1—5.
10. Coffey JC, Sehgal R, Culligan K, et al. Terminology and nomenclature in colonic surgery: universal application of a rule-based approach derived from updates on mesenteric anatomy. *Tech Coloproctol*. 2014;18:789—794.
11. von Langer Carl, Langer Karl, Langer C. *Ritter von Edenberg Karl Langer, Carl Toldt, Felix Sieglbauer. Lehrbuch der systematischen und topographischen Anatomie*. Book from the collections of Harvard University; 1902.
12. Toldt C. Splanchology — general considerations. In: Toldt C, Della Rossa A, eds. *An Atlas of Human Anatomy for Students and Physicians*. New York: Rebman Company; 1919:408.
13. Coffey JC, O'Leary DP. The mesentery: structure, function, and role in disease. *Lancet Gastroenterol Hepatol*. 2016;1:238—247.
14. Congdon ED, Blumberg R, Henry W. Fasciae of fusion and elements of the fused enteric mesenteries in the human adult. *Am J Anat*. 1942;70:251—279.
15. Coffey JC, Dillon M, Sehgal R, et al. Mesenteric-based surgery exploits gastrointestinal, peritoneal, mesenteric and fascial continuity from duodenojejunal flexure to the anorectal junction—a review. *Dig Surg*. 2015;32:291—300.
16. Culligan K, Coffey JC, Kiran RP, et al. The mesocolon: a prospective observational study. *Colorectal Dis*. 2012;14:421—428.
17. Culligan K, Walsh S, Dunne C, et al. The mesocolon: a histological and electron microscopic characterization of the mesenteric attachment of the colon prior to and after surgical mobilization. *Ann Surg*. 2014;260:1048—1056.
18. Liang JT, Cheng KW. Laparoscopic dissection of Denonvilliers' Fascia implicated for total mesorectal excision for treatment of rectal cancer. *Surg Endosc*. 2011;25:935—940.
19. Geroge C. Thoughts while watching a resident operate. *N Engl J Med*. 1972;287:826.