

# Laparoscopic surgery for colon cancer: a review of the fascial composition of the abdominal cavity

Makio Mike · Nobuyasu Kano

Received: 18 June 2013 / Accepted: 16 December 2013 / Published online: 11 February 2014  
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**Abstract** Laparoscopic surgery has generally been performed for digestive diseases. Many patients with colon cancer undergo laparoscopic procedures. The outcomes of laparoscopic colectomy and open colectomy are the same in terms of the long-time survival. It is important to dissect the embryological plane to harvest the lymph nodes and to avoid bleeding during colon cancer surgery. To date, descriptions of the anatomy of the fascial composition have mainly involved observations unrelated to fundamental embryological concepts, causing confusion regarding the explanations of the surgical procedures, with various vocabularies used without definitions. We therefore examined the fascia of the abdominal space using a fascia concept based on clinical anatomy and embryology. Mobilization of the bilateral sides of the colon involves dissection between the fusion fascia of Toldt and the deep subperitoneal fascia. It is important to understand that the right fusion fascia of Toldt is divided into the posterior pancreatic fascia of Treitz dorsally and the anterior pancreatic fascia ventrally at the second portion of the duodenum. A comprehensive understanding of fascia composition between the stomach and transverse colon is necessary for dissecting the splenic flexure of the colon. As a result

of these considerations of the fascia, more accurate surgical procedures can be performed for the excision of colon cancer.

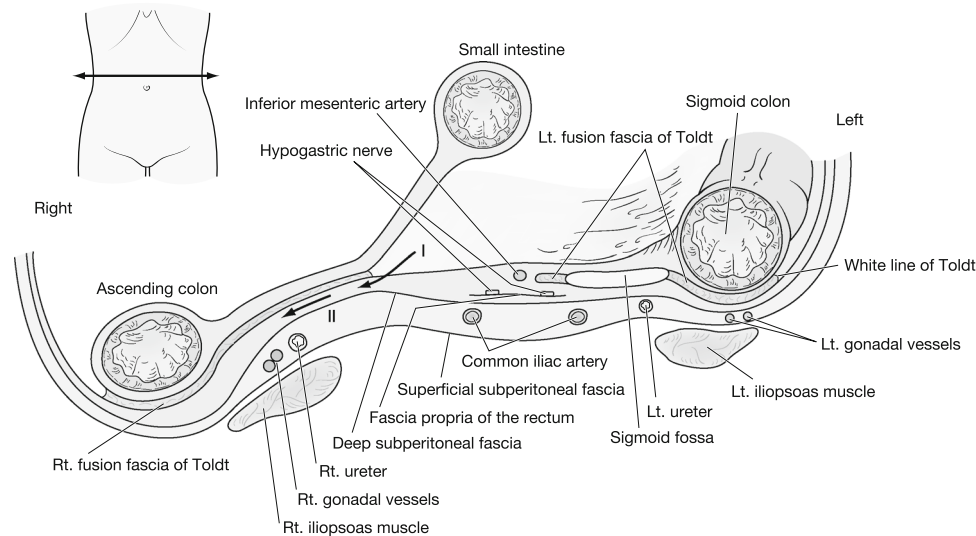
**Keywords** Colon cancer surgery · Fascial composition · Fusion fascia · Subperitoneal fasciae

## Introduction

Laparoscopic surgery has generally been performed for digestive diseases, and many patients with colon cancer undergo laparoscopic procedures. The outcomes of laparoscopic colectomy and open colectomy are the same with regard to the long-time survival [1–7]. During colon cancer surgery, it is important to dissect the embryological plane to harvest the lymph nodes and avoid bleeding [8]. To date, the fascial composition of the abdominal cavity has been considered based on the clinical anatomy and histological examination of specimens [9–19]. However, descriptions of the anatomy in terms of the fascial composition have also mainly involved observations unrelated to fundamental embryological concepts, causing confusion regarding explanations of the surgical procedures, with various vocabularies used without definitions.

We therefore examined the fascia of the abdominal space using a fascial concept based on the clinical anatomy and embryology. A better understanding of the fascial composition is useful not only for the laparoscopic approach, but also for open surgery. Focusing on laparoscopic sigmoidectomy, right colectomy, and resection of the splenic flexure, the fascial configuration in the laparoscopic view was considered. As a result, more accurate surgical procedures can be performed.

M. Mike (✉) · N. Kano  
Department of Surgery, Kameda Medical Center,  
929 Higashicho, Kamogawa, Chiba 298-8602, Japan  
e-mail: mmike@ace.ocn.ne.jp



**Fig. 1** The fascial composition of the sigmoid colon and the ascending colon. The posterior sigmoid mesocolon fuses with the parietal retroperitoneum to become the right fusion fascia of Toldt. The mobilization of the ascending colon involves dissection between the right fusion fascia of Toldt and the deep subperitoneal fascia [32, with permission]

The posterior ascending mesocolon fuses with the parietal retroperitoneum to become the right fusion fascia of Toldt. The mobilization of the ascending colon involves dissection between the right fusion fascia of Toldt and the deep subperitoneal fascia [32, with permission]

We believe that this is the best concept for the excision of colon cancer.

### The peritoneal configuration, body wall and intestinal rotation in foetal life

Adhesion and fusion are common terms used in digestive surgery, and the difference between them in clinical anatomy must be understood precisely. Resection of the gastrointestinal tract is made possible if the dorsal or ventral side of the fusion fascia is dissected in accordance with the embryonic fascial anatomy.

The concept of a fusion fascia is thus indispensable when considering the relationship between the peritoneum and the mesentery at the end of intestinal rotation. In the case of a fusion fascia, the adjacent serosa lose mobility and eventually fuse into a single sheet of connective tissue [20–22]. By definition, the inside of fusion fascia cannot be dissected.

For a basic understanding of the fascial composition of the body circumference, interpretations have been provided by Tobin et al. [23] and Satoh [24]. According to these interpretations, the structure of the body below the diaphragm can be simplified as a straight intestine within a cylindrical body. The basis of the body composition can then be divided into the composition of the peritoneal cavity (composition within the cylinder) and the composition of the body wall (composition of the cylinder wall). In the former, the cranial abdomen includes the dorsal and

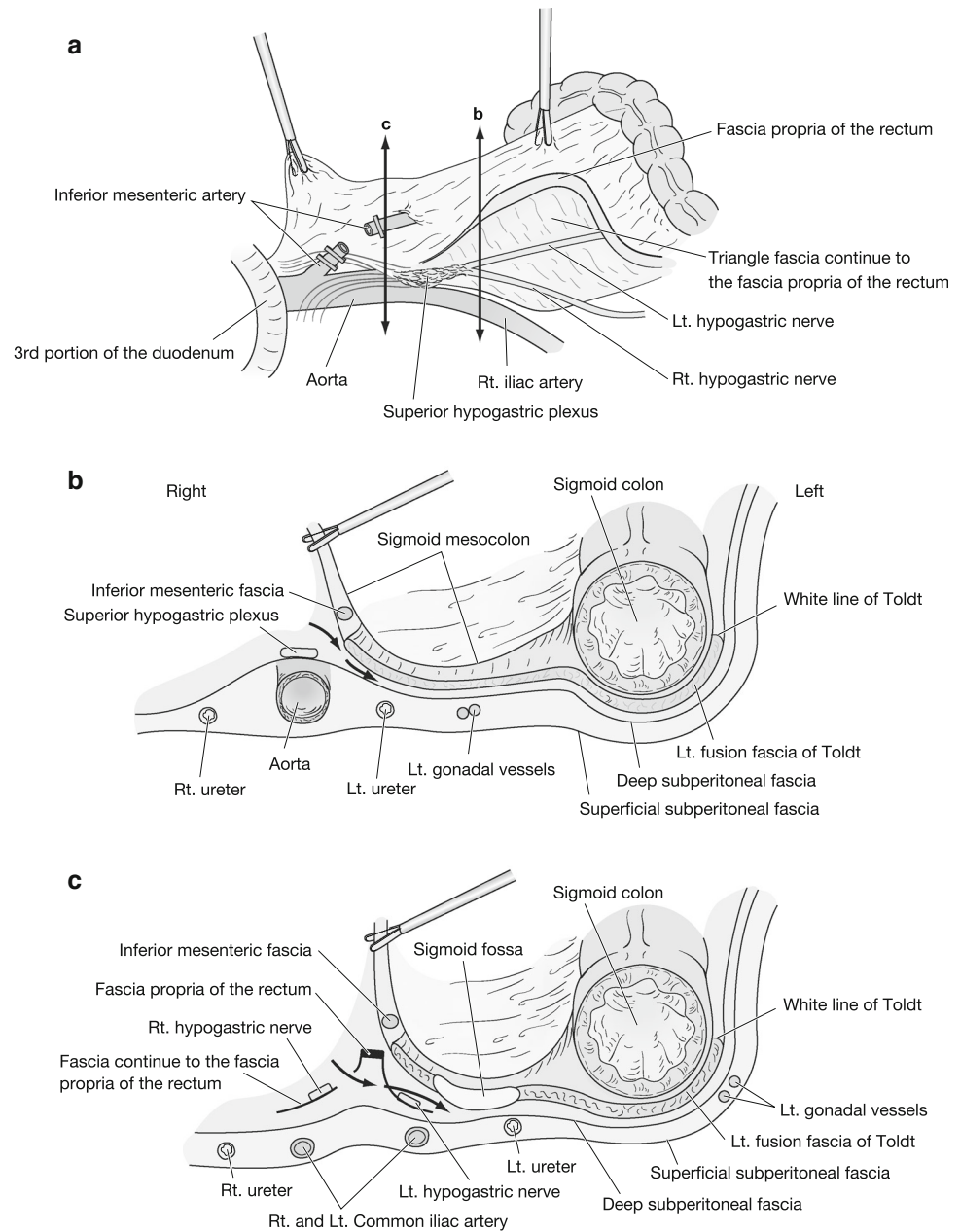
ventral mesentery, and the caudal abdomen includes only the dorsal mesentery involving the intestine. The latter has a ringed composition, and the body walls are symmetrical in relation to the central position of the muscle layer. The trunk has typically been regarded as an onion-like, multi-layered structure [25].

Corresponding to the subcutaneous superficial fascia and subcutaneous deep fascia, deep subperitoneal fascia and superficial subperitoneal fascia exist circumferentially around the abdominal wall. The fascial structure present in the body wall is embryologically represented by the terms ‘superficial’ or ‘deep’, defined in relation to the superficial skin surface. The terms ‘anterior’ and ‘posterior’ are not used because of their arbitrariness [26].

As mentioned above, the visceral peritoneum (fascia) and the parietal peritoneum (fascia) are fused in foetal life and become the fusion fascia [20–22]. The terms ‘visceral fascia’ and ‘parietal fascia’ used in recent papers about colon surgery have not been defined [9–19]. Thus, these terms must not be used to describe surgical manoeuvres.

When we dissect the plane between the fusion fascia of the colon and the deep subperitoneal fascia, we often see another fascia, for example, in the ascending colon or sigmoid colon surgery. The deep subperitoneal fascia has been extended to the colon wall through the dorsal mesentery [24]. Thus, the mesentery is composed of four fasciae. However, it has been said that the important thing is not the number of fasciae, but that the fascia is used to indicate the right plane to dissect [26].

**Fig. 2** The dissection plane of the medial–lateral approach for laparoscopic sigmoidectomy (a). On the cranial side (b): the sigmoid colon can be mobilized with dissection between the left fusion fascia of Toldt and the deep subperitoneal fascia. On the caudal side (c): the triangle fascia that continues to the fascia propria is dissected as ventrally as possible, and the dissection can be continued to the dorsal side of the left fusion fascia of Toldt or the dorsal side of the sigmoid fossa [32, with permission]

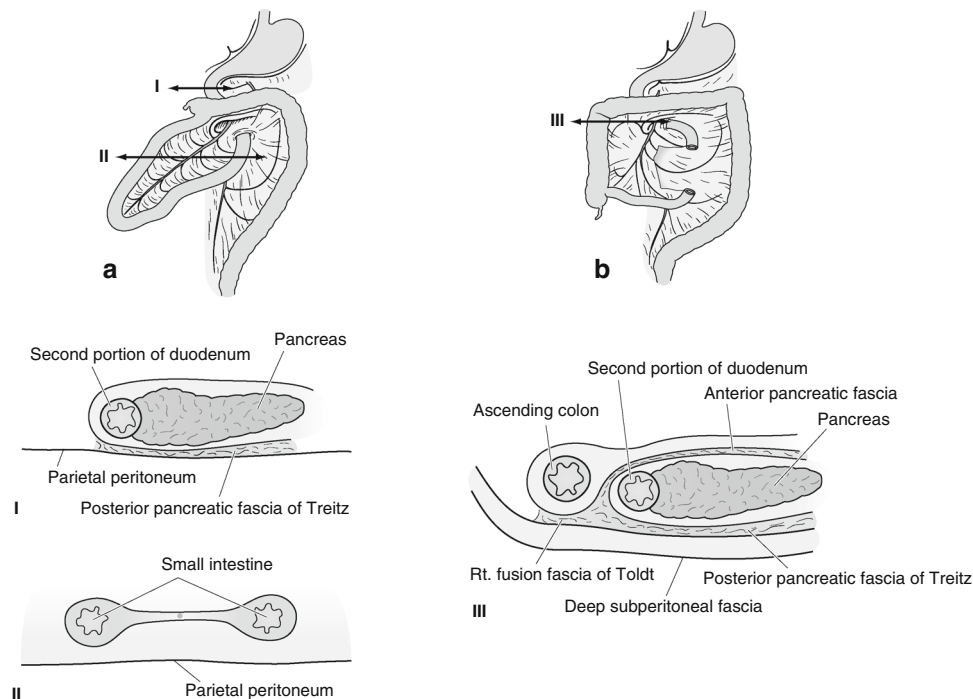


### Fascial composition and fusion fascia of the sigmoid colon

The descending colon and the sigmoid colon are embryologically connected with an abdominal wall through the dorsal mesentery, where the vessels and nerves run and show mobility at that time. The mobility of the descending colon disappears after the formation of the left fusion fascia of Toldt due to the fusion of the left lobe of the descending mesocolon with the parietal retroperitoneum at the end of intestinal rotation. In contrast, the adjacent relationship of the sigmoid colon shows many variations depending on the length and flexion. Due to incomplete fusion of the dorsal

mesentery and retroperitoneum, a fan-shaped sigmoid fossa is typically formed behind the sigmoid mesocolon during this process [26].

The dissection and mobilization of the sigmoid mesocolon involves dissecting between the left fusion fascia of Toldt and the deep subperitoneal fascia (Fig. 1). In a sectional view of the caudal part of the sigmoid colon (Fig. 1), the sigmoid fossa is added, and the new fascia is added on the ventral (deeper) side of the deep subperitoneal fascia. This new fascia seems to fuse to the deep subperitoneal fascia at the most cranial part. In the rectum, this fascia is called the fascia propria of the rectum [26, 27, 28, pp. 221–227, 475–480, 1039–1044].



**Fig. 3** The relationship between the ascending colon and the pancreatoduodenal region in foetal life. The second portion of the duodenum is accompanied by a dorsal mesentery that will fall to the right to form the posterior pancreatic fascia of Treitz between the parietal peritoneum and the pancreatoduodenal region (**a I**). Then, the ascending colon that covers the head of the pancreatoduodenal

region at the time of intestinal rotation has been completed, and it forms the right fusion fascia of Toldt and the anterior pancreatic fascia (**b III**). In other words, the right fusion fascia of Toldt is divided into the posterior pancreatic fascia of Treitz dorsally, and the anterior pancreatic fascia ventrally, at the margin of the second portion of the duodenum [34, with permission]

Sigmoidectomy is performed using either a lateral or a medial approach. The lateral approach is necessary for the resection during left colectomy and of the splenic flexure of the colon. Here, the manoeuvres of the medial approach are presented.

First, in the medial approach, it is necessary to identify the fascia propria of the rectum. Maintaining the fascia propria, procedures proceed cranially, dividing the vessels and nerves at the right side of the fascia propria of the rectum (Fig. 2a).

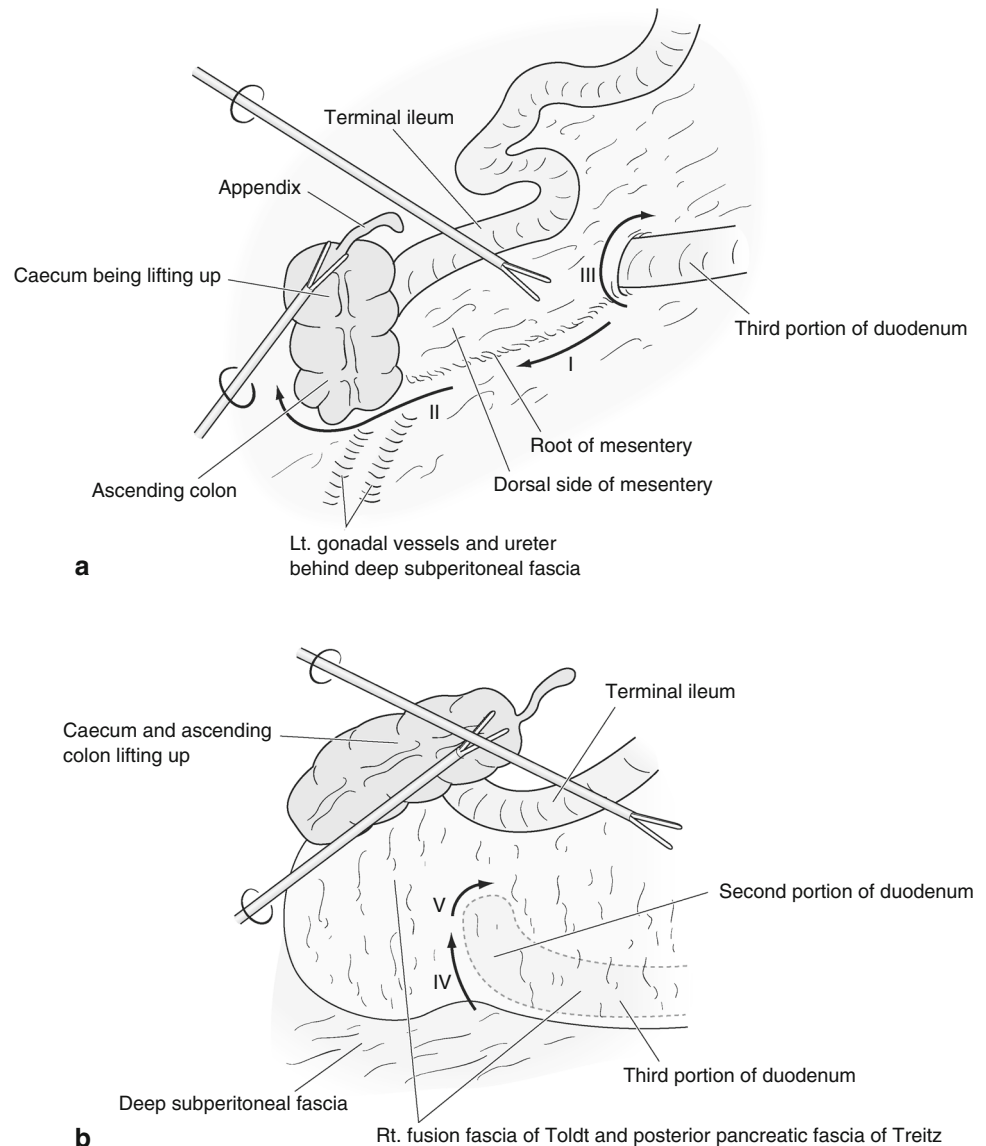
The medial approach is easy to explain with two cross-sections, cranial and caudal. At the cranial section, the sigmoid colon can be mobilized if the dissection is done between the left fascia of Toldt and the deep subperitoneal fascia (Fig. 2b). In the caudal section, if the triangle that continues to the fascia propria of the rectum (Fig. 2a) is dissected as ventrally as possible, the dissection can be continued to the dorsal side of the left fusion fascia of Toldt or the dorsal side of the sigmoid fossa, and the dissection is continued to mobilize the sigmoid colon (Fig. 2c). As a consequence, the left ureter is confirmed on the dorsal side of the deep subperitoneal fascia.

After freeing the inferior mesenteric artery (IMA) from the surrounding nerve plexus, the IMA is divided at the root or just distal to the left colonic artery (Fig. 2a). However, most patients with colon cancer have little nodal involvement around the IMA root [29, 30]. Thus, to preserve the left colic artery for blood flow to the stump of the colon, a less-invasive low ligation should be considered, with CT-based lymph node detection [30]. Hence, the recommendations of the NCC [31] regarding this area become less meaningful.

The lateral dissection of the sigmoid colon is easy to perform if the medial dissection is performed sufficiently lateral. After confirmation of the sigmoid fossa, the white line of Toldt is cut, beginning at the lateral side of the iliopsoas muscle.

After exposing the ventral side of the deep subperitoneal fascial, the descending colon is freed from the deep subperitoneal fascia cranially. After dissecting the descending colon sufficiently to the cranial side, the dissection of the sigmoid colon is performed sufficiently to the caudal side. During this process, a tunnel is made between the medial and lateral sides.

**Fig. 4** Incision and dissection of the base of the mesentery. The operation is begun by incising the peritoneum at the base of the mesentery of the small intestine. Lifting the caecum and the terminal ileum, the dissection is performed just dorsal of the right fusion fascia of Toldt sufficiently to the cranial side (**a I, II**). The dissection is continued medially to the second portion of the duodenum with blunt dissection (**a III**). The ureter and gonadal vessels are dorsal to the deep subperitoneal fascia. In the plane of continuity from the right fusion fascia of Toldt to the posterior pancreatic fascia of Treitz, the duodenum can be dissected medially if the fusion fascia is divided at the lateral side of the duodenum (**b IV, V**) [34, with permission]



The sigmoid colon is divided, and the anastomosis is continued [32].

### The fascial composition of the right side colon

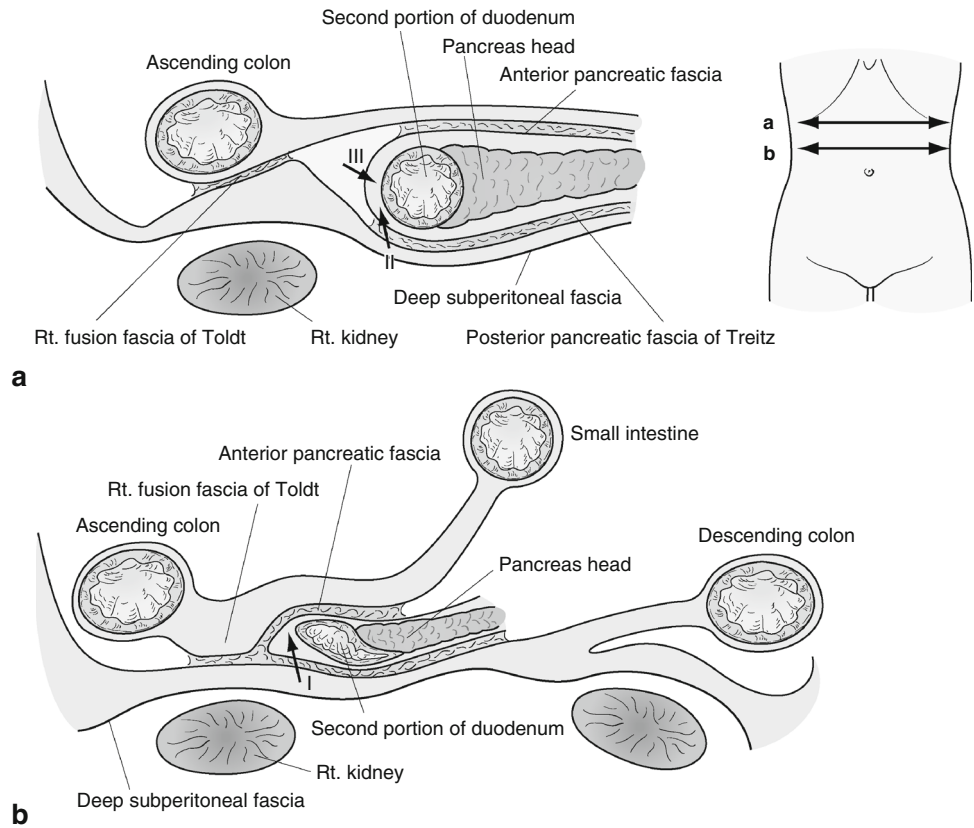
When examining the configuration of the right colon, one can consider it as divided into a simple fusion fascia between the colon and retroperitoneum at the caudal side (Fig. 1), and a relatively complex fusion fascia at the cranial pancreatoduodenal portion (Fig. 3III). In the former, the right colon and retroperitoneum fused to become the right fusion fascia of Toldt, and the ascending colon was buried in the retroperitoneum (Fig. 1). In the latter, it is easy to understand the fascial composition if the embryological processes are divided

into two stages (Fig. 3a, b). That is, the second portion of the duodenum that was accompanied by a dorsal mesentery falls to the right, forming the posterior pancreatic fascia of Treitz between the parietal peritoneum and the pancreatoduodenal region (Fig. 3I). Next, the ascending colon covers the head of the pancreatoduodenal region at the time that intestinal rotation is completed, and forms the right fusion fascia of Toldt and the anterior pancreatic fascia (Fig. 3III). In other words, the right fusion fascia of Toldt is divided into the posterior pancreatic fascia of Treitz dorsally and the anterior pancreatic fascia ventrally at the margin of the second portion of the duodenum (Fig. 3III).

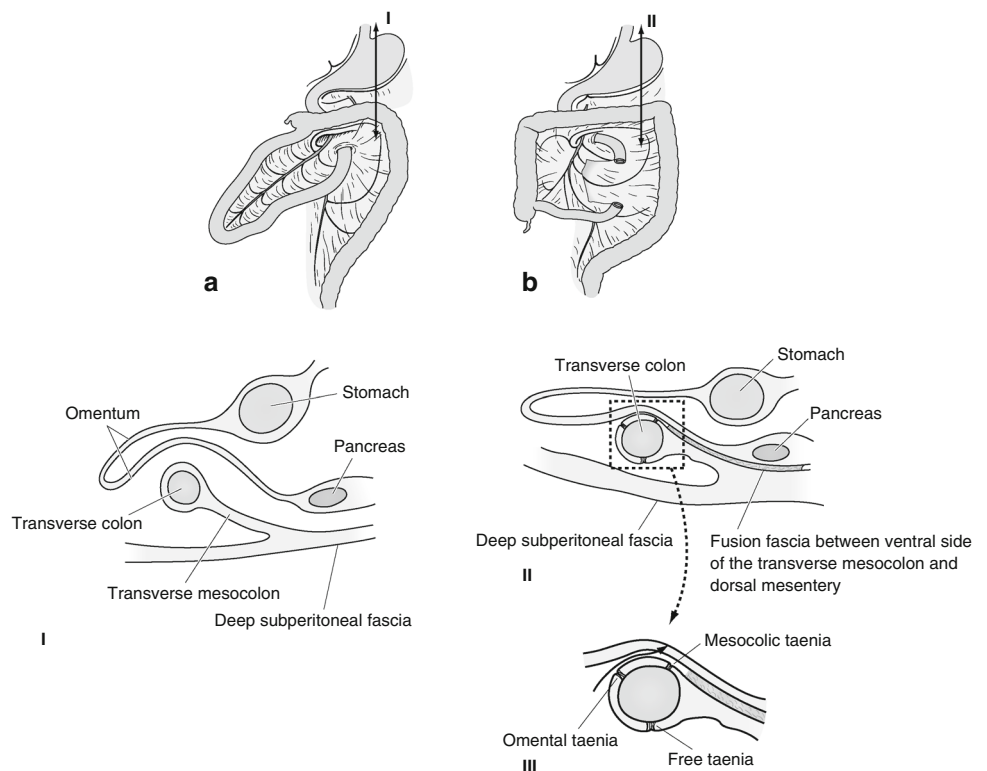
The operation is then begun to incise the peritoneum at the base of the mesentery of the small intestine. Lifting the caecum and the terminal ileum, the dissection is performed

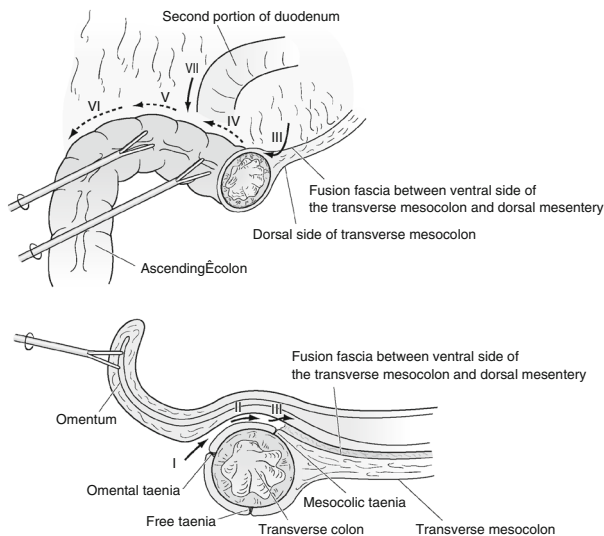


**Fig. 5** Dissection of the fascia at the second portion of the duodenum. The duodenum can be dissected medially where the fusion fascia is divided at the lateral side of the duodenum. The dissection is continued as cranially as possible along the ventral and medial sides of the second portion of the duodenum (**b I, a II**) [34, with permission]



**Fig. 6** The relationship between the transverse colon and the omentum. The relationship between the transverse colon and the omentum is easy to consider if the relationship is divided into two stages based on the course of intestinal rotation. In the vertical cross-sectional view (*I*), the omentum and mesocolon are irrelevant. But in view *II*, the fusion fascia is formed [39, with permission]





**Fig. 7** Dissection of the hepatic flexure of the colon. The ventral side of the anterior pancreatic fascia can be entered by dissection of the omentum from the taenia coli of the transverse colon at the medial side of the second portion of the duodenum (I–IV). Continuing the dissection of the omentum to the lateral-cranial side, it arrives at the hepatic flexure of the colon. At last, dividing the peritoneum at the hepatic flexure, the mobilization of the hepatic flexure is finished (V, VI). Sequentially, dissecting the ventral–lateral side of the duodenum caudally, in other words, dividing the ventral fascia (the anterior pancreatic fascia) caudally, the dissected retroperitoneal space is connected by the manoeuvre (VII) [34, with permission]

just dorsal to the right fusion fascia of Toldt, but to the cranial side (Fig. 4a I, II).

The dissection is continued medially to the second portion of the duodenum with blunt dissection (Fig. 4a III). The ureter and gonadal vessels are dorsal to the deep subperitoneal fascia.

In the plane of continuity from the right fusion fascia of Toldt to the posterior pancreatic fascia of Treitz, the duodenum can be dissected medially where the fusion fascia is divided at the lateral side of the duodenum (Figs. 4b IV, V, 5b I). The dissection is continued as cranially as possible along the ventral and medial sides of the second portion of the duodenum (Fig. 5a II, b I). In addition, the dissection arrives at the pancreas head after the tissue is dissected ventrally and medially along the duodenum.

Originally, the two sheets of dorsal mesentery became four sheets, and then formed the omentum between the stomach and transverse colon. The third sheet of the dorsal mesentery is the posterior wall of the omental bursa, and the fourth sheet of the dorsal mesentery fused with the ventral side of the transverse mesocolon in foetal life (Fig. 6). To understand these concepts, it is easy to consider the relationship between the omentum and the transverse mesocolon if the relationships are divided into two stages in the course of intestinal rotation. In the

vertical cross-sectional view (Fig. 6I), the omentum and mesocolon are irrelevant. But in the view shown in Fig. 6II, the fusion fascia is formed.

Here, the hepatic flexure of the colon is dissected and divided within the field of vision of the transverse colon. The ventral side of the anterior pancreatic fascia can be entered by dissection of the omentum from the taenia coli of the transverse colon at the medial side of the second portion of the duodenum (Fig. 7I–IV). Continuing the dissection of the omentum to the lateral-cranial side, it arrives at the hepatic flexure of the colon. At last, dividing the peritoneum at the hepatic flexure, the mobilization of the hepatic flexure is finished (Fig. 7V, VI). Sequentially dissecting the ventral–lateral side of the duodenum caudally, in other words, dividing the ventral fascia (the anterior pancreatic fascia) caudally, the dissected retroperitoneal space is connected by the manoeuvre (Figs. 5III, 7VII).

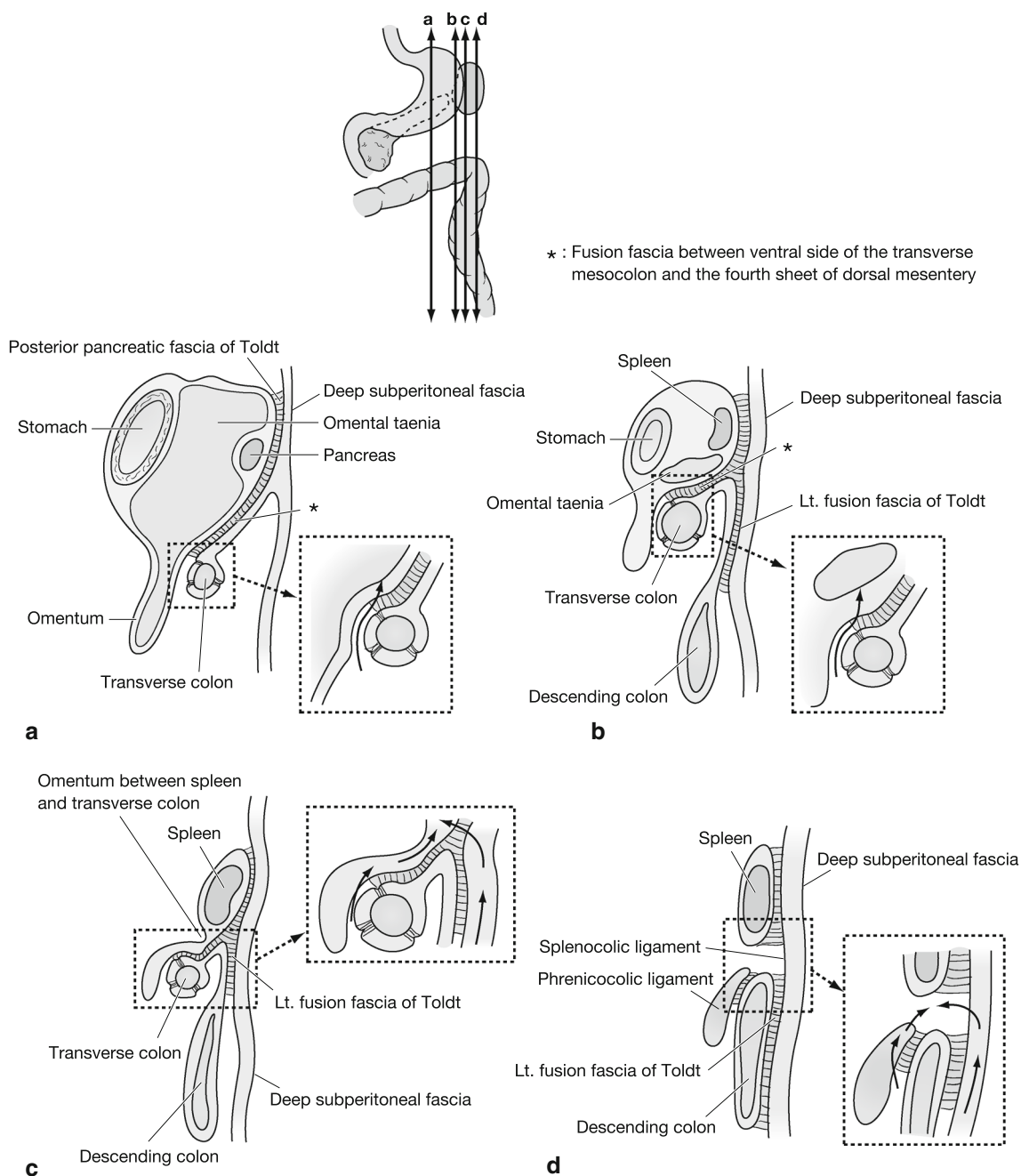
With regard to the clinical aspects of right colectomy, the lymphatic flow is not to the superior mesenteric artery, but to the ventral and lateral sides of the superior mesenteric vein, where it is called the surgical trunk [33]. Given this, lymph node dissection of the central of the feeding artery does not have meaning during right colectomy [34].

### The fascial composition of the left side colon and the splenic flexure

The mobilization of the sigmoid and the descending colon is performed with the dissection between the left fusion fascia of Toldt and the deep subperitoneal fascia cranially (Fig. 1). On the cranial side, confirming the boundary between the adipose tissue wrapped by the left fusion fascia of Toldt and the deep subperitoneal fascia, the dissection exposes the ventral side of the deep subperitoneal fascia and reaches the splenic flexure of the colon.

There are two fixing ligaments at the splenic flexure of the colon. One is the left colo-phrenic ligament, which connects the splenic flexure of the colon and the diaphragm. The left colo-phrenic ligament is considered to be the left protrusion of the bursa omentalis, which is similar to a ligament in terms of its characteristics and function. Another is the colo-splenic ligament. It is a secondary vertical ligament formed by the parietal peritoneum between the splenic flexure of the colon and the spleen or the leftmost part of the transverse mesocolon.

The splenic flexure of the colon is defined as the area from one-third of the anal side of the transverse colon to the first portion of the descending colon [35], and it is the transition between the transverse colon, with a degree of



**Fig. 8** The fascial composition of the transverse colon, descending colon and splenic flexure of the colon. The dissection of the omentum is begun by entering between the three sheets of the dorsal mesentery and the fusion fascia of the transverse mesocolon at the taenia of the colon (a, b). This layer can continue to the dissecting layer on the

ventral side of the deep subperitoneal fascia if the left fusion fascia of Toldt is cut at the splenic flexure of the colon (c). In this way, the hanging band, left colo-phrenic ligament and colo-splenic ligament can be easily cut (d) [39, with permission]

freedom, and the descending colon is fixed to the retroperitoneum with fusion.

The dissection of the omentum is begun by entering between the third sheet of the dorsal mesentery and the fusion fascia of the transverse mesocolon at the taenia coli (Fig. 8a, b). This layer can continue to

the dissecting on the ventral side of the deep subperitoneal fascia if the left fusion fascia of Toldt is cut at the splenic flexure of the colon (Fig. 8c). In this way, the hanging band, the left colo-phrenic ligament, and the colo-splenic ligament can be easily cut (Fig. 8d).



When performing the procedure via the omental bursa, it is necessary to re-enter the dorsal side of the third sheet of the dorsal mesentery at the leftmost portion and to cut the left fusion fascia of Toldt.

Segmentectomy is sufficient for paracolic lymph node dissection for the left colon [36–38], and the lymph node metastases are mostly present in the paracolic area and around the left colic artery [39].

## Discussion

Terminology based on embryology must be used to more accurately define the procedures used during surgery. The most important term in colon surgery is the fusion fascia [20–22], and it is important to understand the fascial composition of the body trunk based on the intestinal rotation that occurs in foetal life. However, recent descriptions of colon cancer surgery have caused confusion due to their use of words such as the ‘visceral fascia’ and the ‘parietal fascia’, because these terms are not defined. In addition, the clinical anatomy of the colon cannot be expressed using defined terminologies.

In the seventh week of foetal life, the colon is a midline structure supported by the medial mesocolon, covered on both sides by peritoneum. The colon and its mesentery rotate during the subsequent. The dorsal surfaces of the ascending and descending mesocolon are then fused to the parietal peritoneum and become the fusion fascia of Toldt at both sides of the colon [40]. If the fusion fascia of Toldt is called the visceral fascia, what is the parietal fascia? It must be the deep subperitoneal fascia that stays on the dorsal side of the fusion fascia of Toldt. In other words, the terms visceral fascia and parietal fascia are replaced by the fusion fascia of Toldt and the deep subperitoneal fascia.

Furthermore, as an example of the confusion arising due to the terminology, the fusion fascia of the colon is mentioned to be related to the fascial composition of the rectum in total mesorectal excision (TME). In 1988, Heald [41] published his famous studies on the “holy plane” of rectal surgery, whereby he standardized TME, which led to a lower recurrence rate and improved 5-year survival [42, 43]. However, the surgical manoeuvres were explained by unifying various terminologies. For example, the concept of TME is based upon sharp dissection of the visceral fascia (‘mesorectum’, ‘fascia pelvis visceralis’) from the parietal plane (‘fascia endopelvina’, ‘parietal fascia’, ‘somatic fascia’ ‘Waldeyer’s plane’, ‘Denonvilliers’ fascia’) [10]. However, these fasciae are not defined and are not continued to the sigmoid and descending colon. It is necessary to reconsider these terms and to understand the differences in the fascial composition between the colon and the rectum. Takahashi [27, 28, pp. 221–227, 475–480,

1039–1044] corrected the confusion regarding the fascial composition of the rectum. The fusion fascia of Toldt is not directly related to the fascia of the rectum.

Given the fine vision available with the development of laparoscopically assisted surgery, an improved understanding of the fascial composition is required. Reviews of the fascial composition of the colon circumference are thus sporadically required.

The fascial composition of the colon is comparatively simple if intestinal rotation and the term fusion fascia are understood. However, the composition of fascia originally observed intraoperatively cannot be anatomically and histologically identified [26], and only the clinical anatomy seems to be capable of allowing for examination and understanding. Moreover, the fascial composition according to histological examinations is considered with accompanying vessels, nerves and fatty tissue as indicators. The use of only histological and anatomical examinations is not feasible [44].

When the fascial composition is considered, the interpretations of Tobin et al. [23] and Satoh [24] offer a shortcut for understanding the development of the human body, especially the basic fascial composition around the body circumference [26]. In this interpretation, the fascial composition of the sigmoid colon shows the continuity of the entire colon. This continuity should always be kept in mind during general abdominal surgery. The sigmoid fossa is then formed by the multiplicity of the fusion fascia between the left (dorsal) lobe and the retroperitoneum, and dissection of the sigmoid colon from the retroperitoneum is made difficult by this structure during sigmoidectomy [26].

In laparoscopic right colectomy, it is necessary to understand the embryological construction of the right colon, and in the real field of vision, the relationships between the right fusion fascia of Toldt and the anterior pancreatic fascia and the posterior pancreatic fascia of Treitz should be noted. In the medial approach, after lifting the ileocolic vessels and isolation of the vessels, the dissection is continued to the back of the vessels. Using this method, the dissection enters between two sheets of the mesocolon of the ascending colon, and as a result, the dissection is continued by dissecting the ventral plane of the fusion fascia of Toldt to the second portion of the duodenum. Thus, this is not an en bloc operation that wraps the lymph nodes with the mesocolon.

In the medial–retroperitoneal approach, the dissection is performed along the ventral side of the deep subperitoneal fascia and the surface of the duodenum, so that the manoeuvre for dissection is en bloc, and in conformity with principles of lymph node dissection. In other words, it is important to understand that the right fusion fascia of Toldt is divided into two sheets in the second and third portions of the duodenum. In addition, unless it is understood that

the fusion fascia between the omentum and the transverse mesocolon in the cranial approach is at the hepatic flexure of the colon, the clinical anatomy of this portion cannot be understood.

Mobilization of the splenic flexure of the colon is performed using an approach with mobilization of the sigmoid and descending colon, and using the approach from the omental side. The fascial composition between the stomach and the transverse colon is complex. In this area, the omentum consists of the dorsal mesentery, and the fourth sheet of the dorsal mesentery forms the fusion fascia with the ventral mesocolon of the transverse colon during foetal life. It is therefore necessary to understand the fascial relationships between the transverse colon, diaphragm and spleen.

The fascial dissection in the transverse colon is performed using the third sheet of the dorsal mesentery as a landmark, namely, the posterior wall of the bursa omentalis [34].

It is important to remember that colon cancer treatment is now multimodal, and the improvement in patients' survival in the last decades is surely linked with the improvements in chemotherapy and the advances in the agents used. However, optimal surgery remains an important element for a good oncological outcome, as the experience with rectal cancer treatment has demonstrated [19].

Accurate, comprehensive and clinically relevant data collection is central to evidence-based practice [45]. In surgery, standardizing the clinical terminology and measurements is essential. However, there are problems with the surgical manoeuvres, namely, that the methodology for the operative statistics colon cancer is lacking [46]. Statistics about which procedure results in the best outcomes cannot be collected unless sound operations are performed using standard methodology [47]. Clarification of the clinical anatomy of the colon enables the standardization of the manoeuvres used for surgical treatment [48]. Therefore, knowledge of the fascial composition between the mesocolon and the retroperitoneum is indispensable, and this can be understood using the embryonic construction of the colon.

**Conflict of interest** The authors declare that they have no conflicts of interest in association with this study.

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