



Surgical outcomes of various surgical approaches for transverse colon cancer

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The transverse colon has anatomical peculiarities in the middle position between the foregut and the midgut. Because the transverse colon harbors a flexure at both ends, mobilization of the transverse colon can be especially challenging compared with other colons. Although transverse colon cancer is relatively uncommon, an optimal surgical management for transverse colon cancer must be established. In transverse colon cancer, proximity to the pancreas and variation in arterial and venous anatomy make radical resection more difficult. Dissection of lymph nodes around the middle colic vessels is a critical step in transverse colon cancer resection. The proximity of the middle colic vessels to the superior mesenteric vessels contributes to the complexity of this step, making it challenging for less-trained surgeons. For these reasons, patients with transverse colon cancer were not included in most landmark studies that compared laparoscopic surgery with open surgery. More radical operations, such as subtotal colectomy or extended right or left hemicolectomy, can be performed for transverse colon cancer to secure an adequate lymphadenectomy. Such cancers have also been treated with limited segmental colectomies, such as right, transverse, or left colectomy. Currently, there is still a lack of standardized definitions and procedures. Therefore, it is time to discuss and establish optimal surgical treatments for transverse colon cancer.

Keywords: Transverse colon, Colonic neoplasms, Colectomy, Colon

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INTRODUCTION

Transverse colon cancer is relatively rare. It consists of about 10% of all colon cancers [1,2]. Transverse colon cancer is usually detected late; therefore, it can be advanced when diagnosed. Additionally, the transverse colon lies near adjacent organs, such as the liver, pancreas, stomach, and spleen. Due to these anatomical features of the transverse colon, patients with transverse colon cancer have a higher chance of invasion into adjacent organs. Therefore, resection of transverse colon malignancies is considered a challenging surgical procedure.

Surgery for transverse colon cancer has several characteristics different from other colon cancers. First, the type of surgical pro-

cedure and the extent of routine lymph node dissection differed according to the location of the tumor. Second, the laparoscopic approach to resection of transverse colon malignancy requires outstanding surgical skills due to the anatomic variations of the middle colic vessels and the technical difficulties of lymphadenectomy around the middle colic vessels. Due to these difficulties in laparoscopic surgery, transverse colon cancer was excluded from landmark randomized trials that compared laparoscopic resection with open surgery [3–5].

EMBRYOLOGY AND VESSEL ANATOMY OF TRANSVERSE COLON CANCER

Embryology and lymphatic drainage of transverse colon cancer

Embryologically, transverse colon is derived from both the midgut and hindgut. The proximal two-thirds of transverse colon is derived from the midgut, while the distal one-third is the hindgut in origin. And these two segments are supplied by the middle colic and left colic arteries [6]. Therefore, lymphatic drainage of transverse colon cancer occurs in different directions, depending on the location. The lymphatic drainage route of the colon generally mirrors that of the arterial circulation, in contrast to most of the anatomy, where lymphatic drainage mirrors the venous circulation. The lymphatic vessels of the proximal transverse colon drain into the lymph nodes associated with the superior mesenteric artery and the middle and right colic arteries, while the vessels of the distal transverse colon drain into the nodes associated with the inferior mesenteric and left colic arteries.

Anatomy of the middle colic vessels

When lymph node dissection is performed around the middle colic vessels, surgeons must be aware of the anatomy of the middle colic vessels. There are variations in the arterial and venous anatomy of the middle colic vessels. Due to these variations, dissection around the middle colic vessels is technically challenging. A poor understanding of these anatomies makes surgery difficult. In particular, understanding the anatomy of the middle colic vein is more critical than understanding that of the middle colic artery. Injury to the middle colic and superior mesenteric veins is associated with difficult bleeding control. The middle colic vein was located more cranially than the middle colic artery on the ventral side of the transverse mesocolon. During caudal to cranial dissection of the transverse mesocolon, the middle colic artery and middle colic vein are ligated. The right and left middle colic veins drain into different veins. The right middle colic vein drains into the gastrocolic trunk. The left middle colic vein predominantly drains into the superior mesenteric vein. The right and left middle colic veins can be one or several [7].

GENERAL CONSIDERATION OF SURGERY FOR TRANSVERSE COLON CANCER

Depending on the location, there are several surgical approaches for transverse colon cancer, unlike right and left colon cancers. These approaches include subtotal colectomy, extended right or left hemicolectomy, right or left hemicolectomy, and segmental resection, such as transverse colectomy and splenic flexure colec-

tomy. Two main issues are associated with the surgical approach for transverse colon cancer. One is the extent of resection, and the other is the minimally invasive approach.

Extended versus segmental resection for transverse colon tumors

Extended transverse colon surgery, such as extended right or left hemicolectomy, or segmental resection, such as transverse colectomy, can be performed in transverse colon cancer. A meta-analysis using seven comparative series compared the outcomes of extended and segmental resection [8]. Segmental resection had better outcomes about operating time and postoperative ileus. However, extended resection showed better outcomes about anastomotic leakage and retrieved nodes. Hospital stay, disease recurrence, and overall survival were similar between the two procedures. A study using the National Cancer Database of the United States reported different results [9]. Extended surgery results in poor survival. Remarkably, the long-term outcomes of extended surgery were worse in the mid-transverse colon. This study concluded that performing an extended colectomy does not provide an advantage of survival outcomes over segmental resection. These results contradict the previous belief regarding better long-term outcomes of extended operation.

Open versus minimally invasive surgery for transverse colon tumors

Recent studies have reported that laparoscopic transverse colectomy is feasible and safe [10–12]. The operative time for open resection is shorter. However, the blood loss and postoperative complications of laparoscopic surgery were lower. The length of hospital stay and the time to first flatus for laparoscopic surgery were shorter. Overall survival and disease recurrence were similar between open and laparoscopic approaches [13]. Recently, a randomized clinical trial showed similar outcomes in terms of postoperative complications, hospital stay, and survival between open and laparoscopic surgeries. The health-related quality of life of laparoscopic colectomy is better than that of open colectomy at 1 and 6 months after surgery [14].

Recently, robotic surgery has been introduced for the resection of transverse colon cancer. Ozben et al. [15] compared laparoscopic noncomplete mesocolic excision with robotic complete mesocolic excision. Their study showed that the rate of intra-corporeal anastomosis and the number of lymph nodes harvested were higher in robotic resection.

SURGICAL OUTCOMES AND APPROACHES ACCORDING TO TUMOR LOCATION

Proximal transverse colon cancer

The standard surgical treatment for the proximal transverse colon is extended right hemicolectomy [16]. In a Korean study, the authors investigated the pattern of lymph node metastasis in the transverse and right colon [17]. In hepatic flexure colon cancer, lymph node metastasis was observed in the middle, right colic, and ileocolic arteries. Extended right hemicolectomy is an appropriate surgical option to treat this cancer.

Mid-transverse colon cancer

In mid-transverse colon cancer, extended right or left hemicolectomy and transverse colectomy can be performed. However, transverse colectomy is generally perceived as a difficult procedure due to mobilization of both flexures and dissection around the middle colic root.

Lymphatic metastasis and dissection of the mid-transverse colon

In mid-transverse colon cancer, the middle colic lymph nodes are the most commonly involved nodes. Approximately 7% to 10% of patients with mid-transverse colon cancer had metastases to the right colic nodes. Because there are no metastases in the lymph nodes along the ileocolic artery, it seems reasonable to perform operation that preserves the ileocecal valve in transverse colon cancer [17]. For the dissection of the area of the middle colic artery, the lymph nodes at the root of the middle colic vessels must be removed.

Extended versus segmental resection for mid-transverse colon tumors

A nationwide retrospective cohort study from Italy compared 388 segmental resections and 1,141 extended resections for mid-transverse colon cancer [18]. This study demonstrated that segmental resection had worse outcomes about postoperative complications and disease-free survival. These results conflicted with those of the National Cancer Database from the United States [9]. Currently, the benefits of extended resection have not yet been confirmed. Another propensity score matching analysis showed similar long-term and short-term outcomes between extended and segmental resection [19,20].

Open versus laparoscopic resection for mid-transverse colon tumors

A nationwide retrospective cohort study from Denmark showed that long-term survival was similar between open and laparo-

sopic surgery for mid-transverse colon cancer [21]. However, laparoscopic surgery is associated with a higher rate of non-mesocolic surgical planes. Therefore, recently, a laparoscopic transverse colectomy using an articulating laparoscopic instrument has been reported for complete mesocolic excision [22].

Distal transverse colon cancer

Distal transverse colon cancer can be treated almost like splenic flexure colon cancer. Splenic flexure colon cancer is rare (approximately 2%–5% of all colon cancers) and has a high probability of obstruction. A recent international study showed that colon cancer with splenic flexure had more stenosis, infiltrating serosa, mucinous histology, and recurrence of peritoneal carcinomatosis. However, splenic flexure colon cancer does not have a worse long-term prognosis than other malignancies [23,24].

When resection of the distal transverse colon is performed, surgeons must be aware of the blood supply to the splenic flexure colon. There are several types of blood supply to the splenic flexure colon. The left colic artery mainly supplies the splenic flexure colon. The accessory left colic artery seems to be an important source of arterial supply and lymphatic drainage of the splenic flexure colon [25]. In addition to the Riolan's arch, which connects the superior and inferior mesenteric arteries, the accessory middle colic artery is an important source of arterial supply to the splenic flexure colon. Furthermore, dissection of the middle colic artery and left colic artery, the accessory middle colic artery should be dissected, ligated centrally, and cut to ensure maximum regional lymph node harvest [26,27].

Lymphatic flow in the distal transverse colon

Two studies investigated lymphatic drainage in the distal transverse colon. A Japanese study using indocyanine green fluorescence imaging found no cases of lymphatic drainage in the left colic artery and the left branch of the middle colic artery areas. Most of the patients (61.3%) had lymphatic drainage directed to the area of the root of the inferior mesenteric vein [28]. Another study used radioactive scintigraphy mapping. This study found that the lymphatic flow of the general splenic flexure is preferentially directed toward the left colic in most cases [29]. Retrieving these nodes should be prioritized for the resection of splenic flexure cancer, with an important secondary emphasis on the left middle colic nodes. In these studies, the pedicle of the inferior mesenteric vein and left colic artery appeared to be important in splenic flexure cancer surgery. Based on this point of view, the researchers claimed that ligation of the left colic artery and inferior mesenteric vein of the mesenteric root was adequate and that these procedures could avoid unnecessary resection of the middle colic artery or inferior mesenteric artery.

Table 1. Operation name for transverse colon cancer according to ligation of arteries

Operation name	Ligation of arteries
Subtotal colectomy	ICA, RCA, MCA, and IMA
Extended right hemicolectomy	ICA, RCA, MCA with or without LCA
Extended left hemicolectomy	MCA, IMA
Left hemicolectomy	Left branch of MCA, IMA
Splenic flexure colectomy (segmental resection)	Left branch of MCA, LCA

ICA, ileocolic artery; RCA, right colic artery; MCA, middle colic artery; IMA, inferior mesenteric artery; LCA, left colic artery.

Definition of surgery for distal transverse colon cancer

Several surgical options are available for the treatment of distal transverse colon cancer. These are segmental splenic flexure colectomy, left hemicolectomy, extended left hemicolectomy, extended right hemicolectomy, and subtotal colectomy [30–32].

However, a confusing nomenclature is often reported in the literature regarding the resection of distal transverse colon cancer. According to the results of a survey by a French intergroup surgeon, ligation of vessels is not standardized, even with the same name of operation [33]. Future studies should standardize the definition of surgical techniques for distal transverse colon tumors. For example, there is a method to define surgical techniques according to the blood vessel to be ligated [34] (Table 1).

Anastomosis after left hemicolectomy

Sometimes, there is confusion regarding the definition of left hemicolectomy and segmental splenic flexure colectomy. For true left hemicolectomy, anastomosis using the Deloyers procedure with rotation of the ileocolic pedicle is challenging [35].

Extended versus segmental resection for distal transverse colon tumors

A network meta-analysis investigated four surgical procedures (subtotal colectomy, extended right hemicolectomy, left hemicolectomy, and splenic flexure colectomy) for distal transverse colon cancer [34]. This study showed that the utilization rates of minimally invasive surgery, reoperation, anastomotic dehiscence, mortality, harvested lymph nodes (≥ 12), local recurrence, distant recurrence, and overall survival were not significantly different among the four techniques. The proportions of postoperative ileus and primary anastomosis were higher in patients who underwent extended right hemicolectomy. Extended hemicolectomy seems not appropriate as a routine procedure, particularly due to worse postoperative bowel function and slower recovery. A nationwide retrospective cohort study from Italy compared 791 segmental versus 513 extended resections for distal transverse

colon cancer [36], which showed that long-term and short-term outcomes were similar between the two groups.

Modified complete mesocolic excision of the distal transverse colon

Previously, we investigated the outcomes of modified complete mesocolic excision between the distal transverse colon and the proximal descending colon using a multicenter database of 383 patients [37]. Modified complete mesocolic excision consists of ligation of the root of the left colic artery, with lymph node dissection around the inferior mesenteric artery. Lymph node dissection around the inferior mesenteric vein was performed with or without ligation of the vein. The visceral fascial layer was dissected sharply from the parietal layer. We found that the oncological outcomes of modified complete mesocolic excision for distal transverse colon cancer were similar to those of descending colon cancer. So, modified complete mesocolic excision is an acceptable management option for distal transverse colon cancer.

CONCLUSION

Transverse colon cancer is rare cancer that is technically challenging to resect. When comparing extended and segmental resections, extended resection was associated with a higher incidence of postoperative ileus. Anastomotic leakage developed more frequently in segmental resection. Long-term outcomes were similar between the two groups. However, the results in the mid-transverse colon were contradictory. Laparoscopy has short-term advantages compared to laparoscopic and open surgery. Long-term outcomes were similar between the two groups. For transverse colon cancer, tailored surgery that considers the skills of the surgeons, anatomy of patients, and tumor status is necessary.

NOTES

Authors' contributions

Conceptualization, Investigation: JWP
 Formal analysis, Methodology: JWP, HJK
 Writing—original draft: JWP, HJK
 Writing—review & editing: JWP
 All authors read and approved the final manuscript.

Conflict of interest

All authors have no conflicts of interest to declare.

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