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HOW I DO IT

Robotic right-sided colon cancer surgery: Dissecting the outermost layer of the autonomic nerve along the superior mesenteric artery

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Abstract

In right-sided colon cancer surgery, lymph node dissection around the superior mesenteric artery is necessary but technically challenging. Here we introduce the concept of "outermost layer-oriented robotic surgery" to improve the safety, efficacy, and reproducibility of superior mesenteric artery nodal dissection. In this procedure, the thin, loose connective tissue layer between the autonomic nerve sheath of the superior mesenteric artery and adipose tissue bearing lymph nodes, termed "the outermost layer of the autonomic nerve," is dissected. The procedure exposes the outermost layer of the nerve plexus covering the surface of the superior mesenteric artery with a width of approximately 1 cm, enabling direct visualization of the anatomy of the main arteries and, if they exist, jejunal veins which cross the superior mesenteric artery ventrally. This allows for sufficient dissection of main lymph nodes at the roots of the ileocolic artery, right colic artery, and middle colic artery and minimizes the risk of unforeseen bleeding. Thirty-nine patients underwent robotic right hemicolectomy with this procedure. No intraoperative complications were observed. The median number of dissected lymph nodes was 50, including 16 main lymph nodes. The median operative time was 284 min, blood loss was 50 mL, and the median postoperative hospital stay was 8 days. Postoperative complications included two cases of Clavien–Dindo classification grade II, with no cases of grade III or higher. Chylous leakage as well as intractable diarrhea were not observed in any case. These findings demonstrate that the procedure can achieve safe and reliable lymph node clearance.

KEYWORDS
colon cancer, outermost layer, right hemicolectomy

1 | INTRODUCTION

In clinical settings, Japanese D3 lymph node dissection aims to remove the maximal number of metastatic lymph nodes by resecting up to the main lymph nodes at the root of the feeding arteries.[1] In right-sided colon cancer, lymph node dissection around the superior mesenteric artery (SMA) is technically difficult and very likely to result in complications owing to the highly variable venous anatomy and arterial anatomy of the right colon. Accordingly, most surgeons dissect only up to around the superior mesenteric vein (SMV).[2]

However, one multicenter prospective observational study of lymph node metastasis in right-sided colon cancer showed that, in right-side transverse colon cancer, 2.5% and 6.7% of metastases occurred around the SMA at the root of the middle colic artery (MCA) and the right colic artery (RCA), respectively, indicating that dissection around the SMA is necessary.[3]

Outermost layer-orientated surgery was originally proposed for gastric cancer surgery to improve the safety, efficacy, and reproducibility of suprapancreatic lymph node dissection.[4] In this procedure, the thin, loose connective tissue layer between the autonomic nerve sheath of the major arteries and the adipose tissue bearing lymphatic tissue, termed "the outermost layer of the autonomic nerve," is dissected.[5] Appropriate tension given to this thin loose connective tissue layer generates sufficient space for lymph node dissection along the major arteries.[5,6] Recent cadaveric histological studies of the SMA region revealed that the SMA nerve plexus surrounds the SMA and its branches within the paravascular sheath, whereas bowel lymph nodes and vessels are located outside.[7] This observation closely parallels the anatomical arrangement of vascular, neural, and lymphatic structures around the celiac artery. Consequently, we postulated that the principles of gastric cancer surgery could be extrapolated to right-sided colon cancer surgery, leading to the development of outermost layer-oriented surgery for right-sided colon cancer. Figure 1 shows the outermost layer of the autonomic nerve between the autonomic nerve sheath of the SMA and adipose tissue bearing lymphatic tissue.

As mentioned above, dissection around the SMA is necessary but technically difficult due to the serious risk of bleeding from major vessels. In particular, when the jejunal veins cross the SMA ventrally, which occurs in approximately 20% of cases,[8] dissection around the SMA poses a high risk. To improve the safety, efficacy, and reproducibility of SMA nodal dissection, we adopted the outermost layer-oriented surgery concept to colon cancer surgery. This strategy allows the surgeon to directly visualize the anatomy of the main vessels, thereby facilitating thorough lymphoid tissue clearance and minimizing the risk of unforeseen bleeding from main arteries, such as the ileocolic artery (ICA), RCA, and MCA. Here we introduce the concept of "outermost layer-oriented robotic surgery" for right-sided colon cancer.

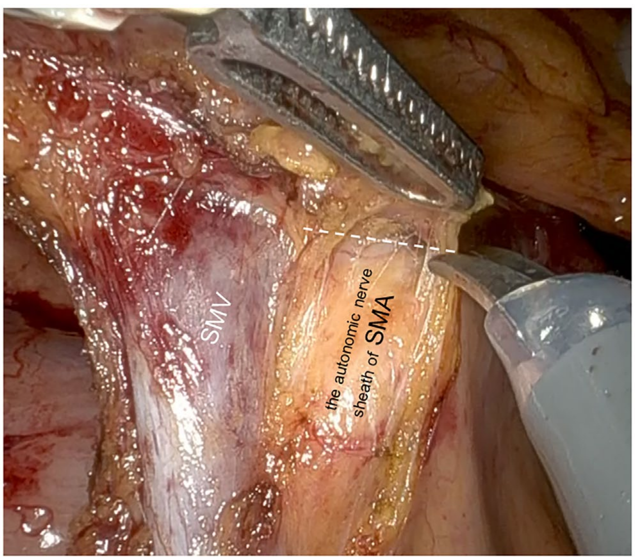

FIGURE 1 Outermost layer of the autonomic nerve between the autonomic nerve sheath of the SMA and the adipose tissue bearing lymphatic tissue. The dashed line indicates the outermost layer.

2 | SURGICAL TECHNIQUE

The patient was placed in the lithotomy position and the table in the Trendelenburg position at an angle (5–15°) and left tilt (5°). Surgery was carried out with the da Vinci Xi® Surgical System (Intuitive Surgical, Inc., CA, USA). Four 8-mm robotic ports and one assistant port were used. Trocars were placed as follows: in the right lower quadrant (#1; fenestrated bipolar forceps), lower midline quadrant (#2; optical port), left lower quadrant (#3; monopolar curved scissors), left upper quadrant (#4; Tip-Up fenestrated grasper), and one 5-mm assisted port lateral to the midpoint between trocars #3 and #4 (Figure S1).

First, we initiated the inferior (retroperitoneal) approach to mobilize the cecum and terminal ileum from the retroperitoneum by a combination of sharp and blunt dissection, until the mesocolon was separated from the retroperitoneum, duodenum, and pancreatic head at the level of the middle of the second portion of the duodenum (Figure 2A). Since the third arm employs monopolar curved scissors for this purpose, to avoid manipulating the duodenum and pancreatic head dorsally with a sharp instrument lacking tactile sensation, we prioritized the inferior approach over the medial approach.

We next moved to the medial approach (SMV & SMA approach) to perform lymph node dissection along the left (medial) margin of, not the SMV but, the SMA along the outermost layer. Using the cleared line along the left edge of the SMA as a reference, the dissection proceeded from the caudal to the cranial direction. Arm 4 was used to retract the ileocolic pedicle and the assistant port to retract the transverse mesocolon. The peritoneum overlying the SMV and SMA was dissected on the left edge of the SMA well below the level of the ileocolic vein (ICV) (Figure 2B). After exposing the SMV, the outermost layer of the autonomic nerve between the autonomic nerve sheath of the SMA and the adipose tissue bearing lymphatic tissue was dissected (Figure 2C). The outermost layer in front of the SMA nerve plexus was easily detached. This procedure exposes the outermost layer of the nerve plexus covering the surface of the SMA, which has a lateral width of approximately 1 cm. Specifically, the procedure reveals the nerve plexus in front of the SMA over a 1 cm-wide area from the caudal to cranial direction. This allows the surgeon to clearly visualize major vessels on the ventral side of the SMA. On further cranial dissection along the vascular pedicle, the ICV and ICA were identified. In the case of Figure 2, the ICA ran posterior to the SMV (Figure 2D). Both the

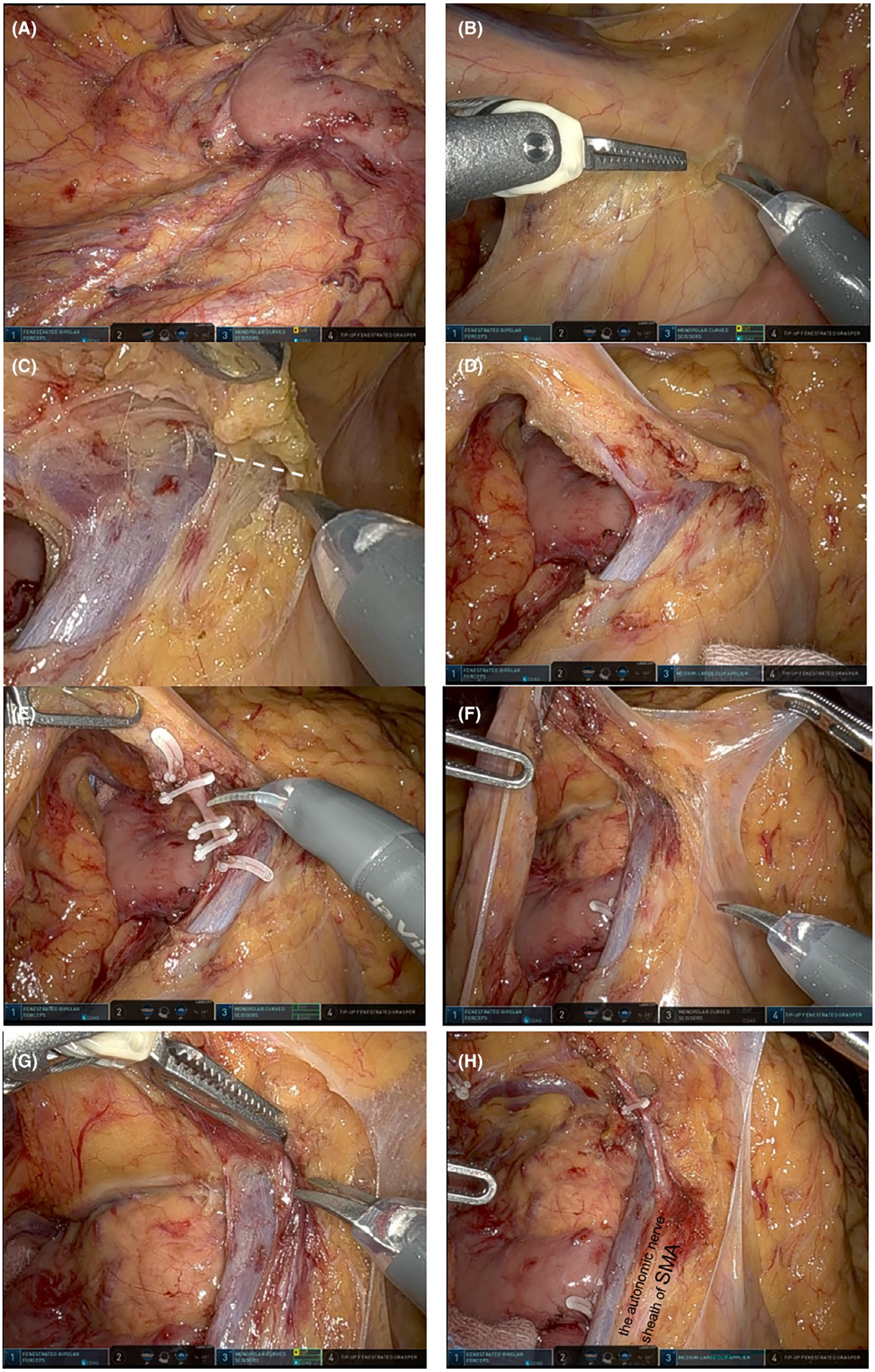

FIGURE 2 Outermost layer-oriented robotic right hemicolectomy. (A) The inferior (retroperitoneal) approach. (B) The peritoneum overlying the SMV and SMA was dissected. (C) The outermost layer of the autonomic nerve between the autonomic nerve sheath of the SMA and the adipose tissue bearing lymphatic tissue was dissected. The dashed line indicates the outermost layer of the autonomic nerve. (D) The ICA ran posterior to the SMV. (E) Both the ICV and ICA were resected. (F) Outermost layer-oriented dissection was performed cranially along the SMA. (G) The root of the MCA was identified. (H) The right branch of the MCA was dissected along with clearance of lymph nodes at the root of the MCA.

ICV and the ICA were resected at the root with a robotic Hem-o-lok (Telefex Headquarters International, Ireland) (Figure 2E). On outermost layer-oriented dissection cranially along the SMA (Figure 2F), the root of the MCA was identified (Figure 2G). Thus, dissecting the outermost layer in the cranial direction allows safe access to the root of the MCA. After exposing the bifurcation of the left and right branches of the MCA, the right branch was dissected along with clearance of lymph nodes at the root of the MCA (Figure 2H). Following ligation of the vessels, the proximal transverse colon, hepatic flexure, and ascending colon were mobilized by taking down lateral attachments, completing the colonic mobilization. Then, from a 3–5 cm incision at the umbilicus, the specimen was extracted, the terminal ileum and transverse colon were divided, and intestinal anastomosis was performed extracorporeally. See the video in Electronic Supplementary Material S1, which demonstrates the procedure of the outermost layer-oriented surgery, i.e., dissecting the outermost layer of the autonomic nerve along the SMA.

Figure 3 shows a case in which the ICA crosses the SMV ventrally (Figure 3A), which occurs in approximately 46% of cases, as well as a case in which the RCA directly originating from the SMA exists and crosses the SMV ventrally (Figure 3B), which occurs in approximately 33% of cases.[8] Dissecting the outermost layer in front of the SMA nerve plexus facilitates the identification of the origins of the ICA and RCA branching from the SMA, enabling sufficient dissection of the main lymph nodes at the root of the ICA and RCA.

One or more jejunal veins cross the SMA ventrally in approximately 20% of cases.[8] Figure 4A,B show cases in which the jejunal vein crosses just caudal and just cranial of the origin of the MCA, respectively. Outermost layer-oriented surgery which approaches from the left edge of the SMA exposes the jejunal veins with a width of approximately 1 cm, ensuring a safe path to the MCA and avoiding significant bleeding during clearance of the main lymph nodes at the root of MCA (Figure 4).

3 | DISCUSSION

Robotic systems allow surgeons to visualize anatomy in a highly magnified 3D high-definition video which provides true depth perception and crystal-clear vision. Surgeons can grasp tissues from various angles and manipulate in any direction with flexible bipolar forceps. Consequently, outermost layer-oriented robotic surgery for right-sided colon cancer is more readily achievable with robotic surgery compared to laparoscopy. Figure 1 demonstrates the visualization of the outermost layer of the SMA nerve plexus in robotic surgery, which represents the optimal dissection plane. When lifting the tissues on the ventral side of the SMA and applying tension, the "outermost layer," which represents the dissection plane at the forefront of the SMA nerve plexus, becomes apparent. Outermost layer-oriented surgery involves early identification of this dissection plane and preserving this layer during central lymph node dissection.

Short-term outcomes of robotic right-sided colon cancer surgery based on dissection of the outermost layer of the autonomic nerve along the SMA were as follows. Thirty-nine patients underwent robotic right hemicolectomy in our department from October 2022 to April 2024. No intraoperative complications, such as massive bleeding, were observed. The median number of dissected lymph nodes was 50, including 16 main lymph nodes (lymph nodes at the roots of the ICA, RCA, and MCA). The median operative time was 284 min, blood loss was 50 mL, and the median postoperative hospital stay was 8 days. Postoperative complications included two cases of Clavien–Dindo classification grade II (paralytic ileus and pulmonary emboli), with no cases of grade III or higher. Chylous leakage as well as intractable diarrhea were not observed in any case. Thus, this surgical procedure achieved adequate clearance of the main lymph nodes while avoiding postoperative complications such as chylous ascites and refractory diarrhea.

The superior aspects of this surgical procedure are as follows. First, dissecting the outermost layer of the autonomic nerve along the SMA enables sufficient dissection of the main lymph nodes at the root of

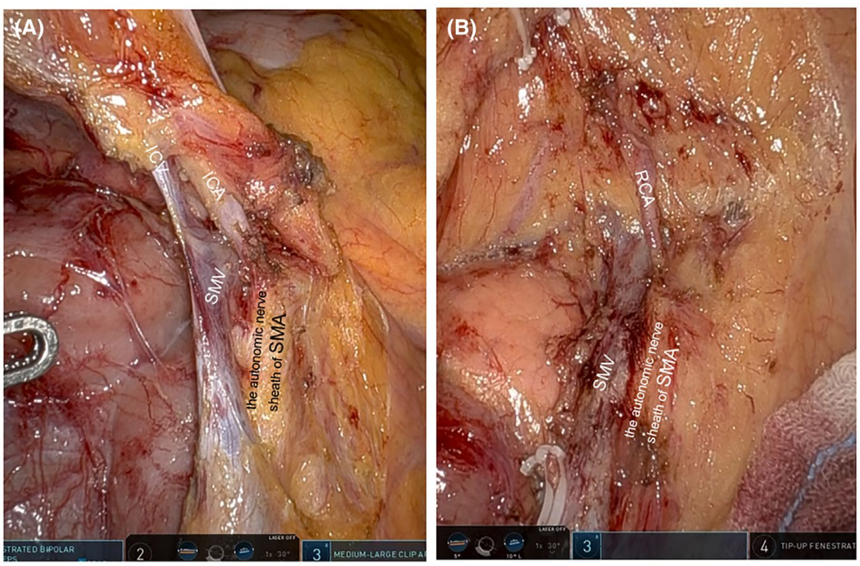

FIGURE 3 (A) A case in which the ICA crosses the SMV ventrally. (B) A case in which the RCA, which directly originated from the SMA, exists and crosses the SMV ventrally.

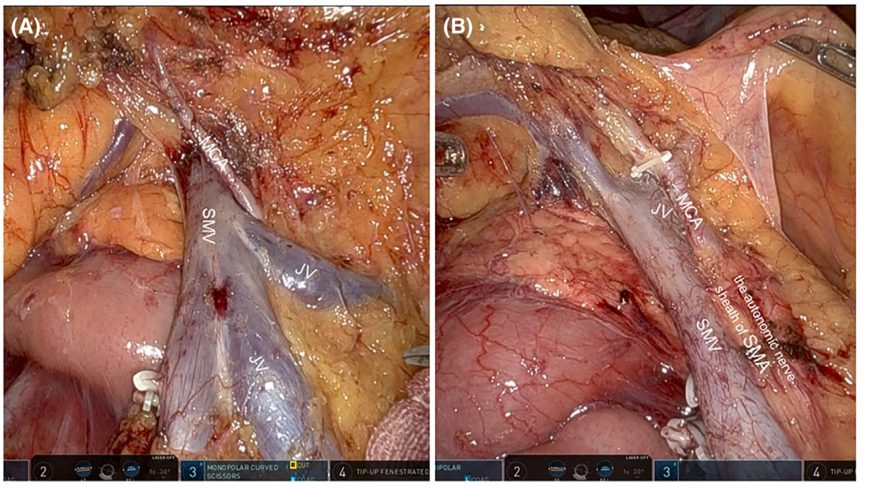

FIGURE 4 (A) A case in which the jejunal vein crosses just caudal of the origin of the MCA. (B) A case in which the jejunal vein crosses just cranial of the origin of the MCA. jv, jejunal vein.

the ICA, RCA, and MCA. Second, the procedure exposes the nerve plexus covering the SMA, which has a lateral width of approximately 1 cm. Specifically, the procedure reveals the nerve plexus in front of the SMA over a 1 cm-wide area from the caudal to cranial direction. This allows for the clear visualization of major vessels, thereby minimizing the risk of unforeseen bleeding. Third, the procedure also enables the identification of jejunal veins, if they exist, which cross the SMA ventrally with ample width for recognition, rather than as isolated points. This enhances the visualization and understanding of major vessels during dissection, thereby reducing the risk of accidental injury and unforeseen bleeding. Fourth, the procedure delineates the left side of the SMA as the clearance line, which aligns with the concepts of complete mesocolic excision and central vascular ligation commonly practiced in colon cancer surgery in Western countries.[9]

There are several limitations associated with this surgical procedure because the extent of lymph node dissection—whether along the SMA or along the SMV—for right-sided colorectal cancer is a topic of ongoing debate. First, while the outermost layer technique is beneficial for cases requiring lymph node dissection around the RCA and MCA, its efficacy is still debated particularly for locally non-advanced cancers. Second, although the outermost layer technique aims to minimize injury, lymph node dissection along the SMV may offer additional safety in certain cases such as locally non-advanced cancers. Third, the "outermost layer" cannot always be identified during dissection in some cases (e.g., the case in Figure 4A) due to overlying JV or other reasons. Despite these limitations, the advantages of the procedure indicate that the concept of "outermost layer-oriented robotic surgery" holds potential value for the management of right-sided colon cancer.

4 | CONCLUSION

We introduced the concept of "outermost layer-oriented robotic surgery" for right-sided colon cancer. This method of "clearing the ventral side of the autonomic nerve sheath of the SMA along the outermost layer of the autonomic nerve at the left edge of the SMA" is not only oncologically sound but also safe as it minimizes the risk of unforeseen bleeding.

AUTHOR CONTRIBUTIONS

Dai Shida: Conceptualization; data curation; formal analysis; investigation; methodology; writing – original draft. **Yuka Ahiko:** Conceptualization; data curation; investigation. **Naoki Sakuyama:** Conceptualization; data curation; investigation. **Satoko Monma:** Conceptualization; data curation; investigation. **Shigehiro Kojima:** Conceptualization; data curation; investigation.

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CONFLICT OF INTEREST STATEMENT

Dai Shida and other co-authors have no conflicts of interest.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Approval of the research protocol: Ethics approval was obtained from the Institutional Review Board (IRB) of the Institute of Medical Science, The University of Tokyo (IRB code: 2022-9-0524).
Informed consent: The need for written consent was waived.
Registry and the registration No. of the study/trial: N/A.
Animal Studies: N/A.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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