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Impact of Inferior Mesenteric Artery Occlusion on the Calibre of Collateral Arteries of the Colon

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Abstract. *Background/Aim: The inferior mesenteric arteries (IMA) are occluded in some colorectal cancer patients. This study evaluated the impact of IMA occlusion on the calibre of collateral arteries. Patients and Methods: As an IMA obstruction model, 20 patients who underwent abdominal aortic aneurysm surgery, with ligated, excluded, or embolised IMA, were enrolled. Changes in the calibre of the left colic arteries (LCAs) and marginal arteries after surgeries were evaluated. Results: The cross-sectional area of the LCA significantly increased after surgery (4.34 mm^2 vs. 6.34 mm^2, p=0.0009) and that of the marginal artery did not change significantly (2.69 mm^2 vs. 3.01 mm^2, p=0.33). Conclusion: The calibre of the LCA increased after IMA occlusion. The descending branch of the LCA should be confirmed preoperatively to preserve blood flow during a low tie procedure.*

Colorectal cancer is the fourth most common cancer worldwide (1), with anastomotic failure as its well-known surgical complication. The anastomotic leakage can lead to reoperation, prolonged hospital stay, and local recurrence (2, 3).

Therefore, various measures have been adopted to prevent suture failure (4). Anastomotic leakage in colorectal surgery can be caused by insufficient blood flow to the anastomotic site in the intestinal tract (5, 6). A fluorescence technique using indocyanine green is sometimes used to confirm blood flow to the anastomotic site (7, 8).

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Key Words: Inferior mesenteric artery, left colic artery, marginal arteries, colorectal surgery.

The proportion of patients with lifestyle-related diseases such as arteriosclerosis has increased owing to the prolonged life expectancy and the development of surgical therapy (9). Angiography of the inferior mesenteric artery (IMA) revealed that the mesenteric artery is stenotic or occluded in 8.4% of elderly patients (10). When mesenteric arteries are occluded, it is important to preserve the collateral blood flow to the anastomotic site during colorectal surgery. After the IMA is dissected during surgery for sigmoid cancer, the marginal artery hypertrophies and serves as a collateral artery (11).

During surgery for lower rectal cancer, the IMA can be ligated *via* the high tie and low tie methods. In the high tie procedure, the IMA is ligated at the root, and the blood flows in the anastomotic site from the marginal artery. In the low tie procedure, the IMA is ligated below the bifurcation of the LCA, preserving the blood flow of the LCA. Although no difference was observed in the overall survival between the two procedures (12-16), the low tie method is reported to have the potential to decrease anastomotic leakage (17-20). When IMA is occluded, the high tie procedure may have little influence on the blood flow to the sigmoid colon. Therefore, this study aimed to evaluate the change in the calibre of collateral mesenteric arteries before and after IMA occlusion. It is difficult to evaluate the calibre change of the mesenteric artery because most of these patients do not undergo computed tomography (CT) before IMA occlusion is observed.

During surgery for abdominal aortic aneurysms (AAA), the IMA is ligated, excluded, or embolised (21). Therefore, patients who underwent AAA surgery were evaluated as an IMA obstruction model.

Patients and Methods

Patient selection. We reviewed 89 cases who underwent surgery for AAA between January 2015 and December 2017. These included open surgical repair (OSR) and endovascular aneurysm repair (EVAR). Those who underwent contrast-enhanced CT before and

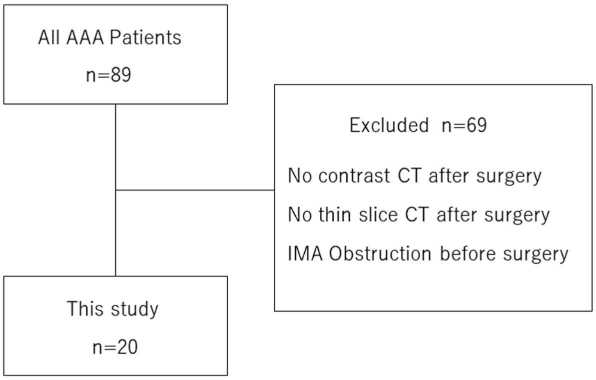

Figure 1. *Patient selection. Overall, 20 patients were enrolled in the study. AAA: Abdominal aortic aneurysms; CT: computed tomography; IMA: inferior mesenteric artery.*

>3 months after surgery were selected. Patients whose IMAs were already obstructed before the operation were excluded (Figure 1). Finally, 20 patients were enrolled in our study. This study was approved by the ethics committee of the University of Tokyo (No 3316-4). Informed consent was obtained from all patients.

Evaluation of the cross-sectional area of vessels. The cross-sectional area of the vessel thickness was evaluated using 3D angiography. An enhanced CT scan performed during the arterial phase. Arterial phase CT was performed using the bolus tracking method and a previously described method (22). CT scans were reviewed using a Picture Archiving and Communication System workstation (General Electric Medical Systems, Milwaukee, WI, USA). The volume rendering technique was used to reconstruct 3D images of mesenteric arteries (Figure 2). The cross-sectional area was calculated by measuring the volume and length of each artery. The volumes of the LCA and marginal artery were measured automatically using ZIO Station 2 (Ziosoft, Osaka, Japan) (Figure 2A), which is also used by some facilities in neurosurgery and other fields to evaluate vascular travel and occlusion (23). The length of the LCA was also calculated automatically (Figure 2B). The volume and length were measured from the LCA origin to the terminal branch. It was difficult to measure the whole volume of the marginal artery of the descending colon, especially before the AAA surgery, owing to its small calibre. Therefore, the volume of the marginal artery was evaluated only at the measurable site before the surgery, and the volume after the surgery was measured at the same site. The length of the measured marginal artery was 12.8-80.3 mm (median, 34.5 mm).

Results

Patient characteristics. The characteristics of 20 patients are presented in Table I. Fifteen patients were men, and 80% underwent EVAR surgery. Additionally, many of them were smokers and alcohol abusers. Contrast-enhanced CT was performed for all patients within 1 month before the surgery. The last preoperative and the first postoperative contrast-enhanced CT scans were included in the analysis.

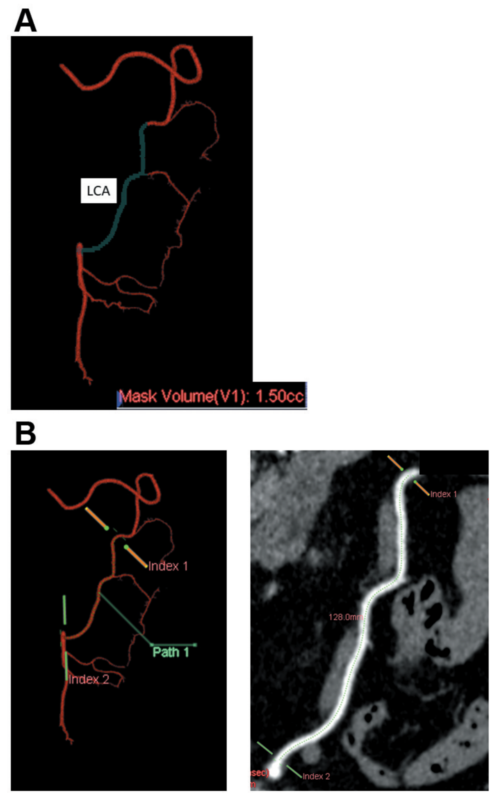

Figure 2. *Measurement of arterial thickness. (A) Measurement of the volume of the left colic artery. When the artery is selected, the volume is calculated automatically. (B) Measurement of the length of the left colic artery. When the origin and terminal branches of the left colic artery are selected, the length is calculated automatically. In this case, the cross-sectional area is calculated as follows: 1,500 mm^3/128 mm=11.7 mm^2.*

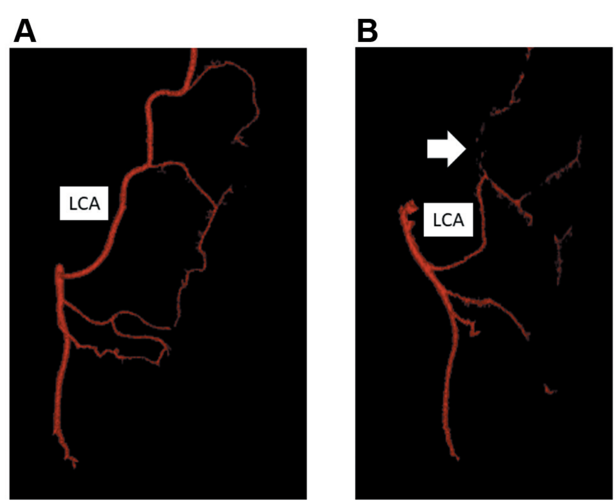

Figure 3. *3D angiography (A) before and (B) after surgery for AAA. The calibre of collateral arteries increased after the surgery. Particularly, the calibre of the ascending branch of the left colic artery (LCA, arrow) increased in this case. AAA, Abdominal aortic aneurysms.*

Table I. *Patient characteristic (n=20).*

	Number
Age	
Median (range)	74 (60-90)
Gender	
Male	15 (75%)
Female	5 (25%)
Body mass index	
Median (range)	22.6 (17.9-28.3)
Surgery for AAA	
Open surgical repair	4 (20%)
EVAR	16 (80%)
Smoking Brinkman index >400	
Yes	13 (65%)
No	7 (35%)
Hypertension	
Yes	10 (50%)
No	10 (50%)
Diabetes mellitus	
Yes	3 (15%)
No	17 (85%)
Dyslipidemia	
Yes	11 (55%)
No	9 (45%)
Postoperative day of CT after surgery	
Median (range)	505 (135-1468)

AAA: Abdominal aortic aneurysm; EVAR: endovascular aneurysm repair.

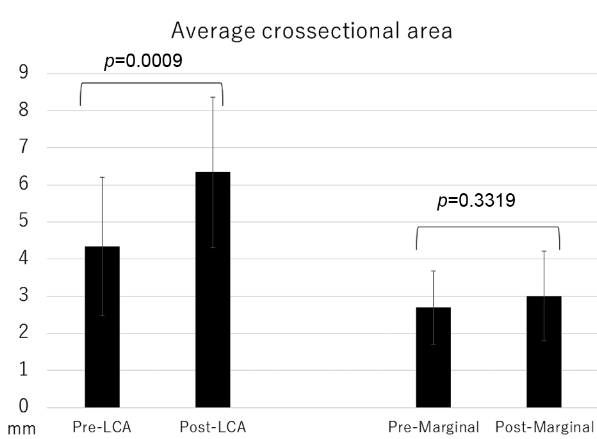

Figure 4. *After AAA surgery, the LCA's mean calibre cross-sectional area increased with statistical significance, but no such trend was observed for the marginal artery. AAA: Abdominal aortic aneurysms; LCA: left colic artery.*

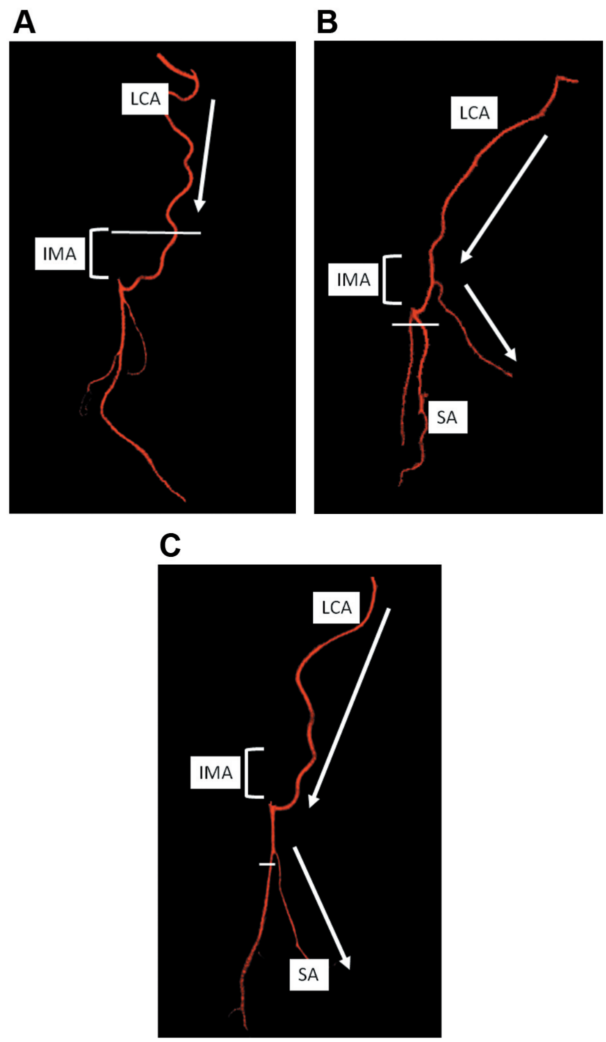

Figure 5. *High tie and low tie procedure for the case of an occluded IMA. (A) During the high tie procedure, the IMA is ligated at the root, and the LCA is usually dissected at the same level. During the low tie procedure, (B) with LCA's descending branch, blood is allowed to flow from the LCA to the marginal artery through the descending branch of the LCA. (C) Without the LCA branch, the IMA should be dissected below the branch of the sigmoid artery to preserve the blood flow from the LCA.*

Change in the calibre of the LCA and marginal artery. The typical 3D angiography findings before and after AAA surgery are presented in Figure 3. The calibre of the LCA is increased in several of the cases. The change in the average cross-sectional area is presented in Figure 4. After the AAA surgery, the average cross-sectional area of the LCA significantly increased from 4.34 mm^2 before surgery to 6.34 mm^2 after surgery (p=0.0009). The average increase rate was 58%. Moreover, the average cross-sectional area of the marginal artery was 2.69 mm^2 before surgery and 3.01 mm^2 after surgery (p=0.33), with no significant difference, and the average increase rate was only 17%. After the AAA surgery, none of the cases showed symptoms related to colonic ischemia, including persistent diarrhoea and haematochezia.

Discussion

In this study, the LCA increased in calibre after occluding the IMA. Furthermore, no difference was observed between the pre- and postoperative calibres of the marginal artery. When a blood vessel is occluded, remodelling occurs, and collateral blood flow develops. In our study, the LCA hypertrophied after IMA occlusion, suggesting that the LCA was important as the collateral artery. During surgery for lower rectal cancer, the IMA can be ligated *via* the high tie and low tie methods. In the high tie procedure, the IMA is ligated at the root, which may have little influence on the blood flow to the sigmoid colon. In the case of an occluded IMA, no ischemic event was detected postoperatively. However, during the high tie procedure, the LCA is usually dissected at the level of the root of IMA (Figure 5A). In this study, hypertrophy of LCA was observed, and the calibre of the marginal artery did not change, which suggests that the high tie procedure may reduce the blood flow to the colon even in the case of an occluded IMA. During the low tie procedure, ligating IMA just below the LCA can impair the blood flow in the LCA. With LCA's descending branch, the blood flows from the backflow of the LCA to the marginal artery through this descending branch (Figure 5B). However, without the LCA branch, the IMA should be ligated below the branch of the sigmoid artery during the low tie procedure (Figure 5C). Therefore, it is essential to ensure the branching patterns of the IMA and LCA preoperatively.

Our study has some limitations. First, since the LCA and marginal artery are small vessels, their calibres were not measured. Instead, the volume of these arteries was automatically measured using the volume rendering technique. Second, the calibre of the arteries can change depending on spasms or blood pressure. In some cases, the cross-sectional areas of the LCA and marginal artery decreased after occluding the IMA. The calibre of the artery evaluated using CT angiography may not have accurately reflected the blood flow.

In conclusion, after IMA occlusion, the calibre of the LCA increased, but that of the marginal artery remained unchanged. During the low tie procedure, the descending branch of the LCA should be confirmed preoperatively, and the level at which the IMA is ligated should be changed to preserve the backflow of the LCA.

Conflicts of Interest

All the Authors have no conflicts of interest to declare in relation to this study.

Authors' Contributions

TI: Study conception and design, acquisition of data, and drafting of the manuscript, KM: study concept and design, acquisition of data, and drafting of the manuscript , HS: acquisition of data, HN: analysis and interpretation of data, KK: analysis and interpretation of data, KS: analysis and interpretation of data, SE: analysis and interpretation of data, JK: analysis and interpretation of data, HI: analysis and interpretation of data, YY: analysis and interpretation of data, SA: analysis and interpretation of data, YN: analysis and interpretation of data, HA: analysis and interpretation of data, HS: analysis and interpretation of data, TT: analysis and interpretation of data, KH: analysis and interpretation of data, drafting of the manuscript, SI: study conception and design, analysis and interpretation of data, drafting of the manuscript.

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