Usefulness of Preoperative Assessment of Perigastric Vascular Anatomy by Dynamic Computed Tomography for Laparoscopic Gastrectomy

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ABSTRACT
Background Laparoscopic surgery requires a more detailed understanding of local anatomy than does conventional open surgery. The aim of this study was to examine the usefulness of dynamic computed tomography (D-CT) for identification of the location of the left gastric vein (LGV) and existence of the aberrant left hepatic artery (ALHA) compared with conventional enhanced computed tomography (E-CT).
Methods Sixty-eight patients underwent laparoscopic-assisted gastrectomy (LAG). E-CT and D-CT were performed in 32 and 36 patients, respectively, and three-dimensional computed tomographic angiography (3D-CTA) was performed in addition to D-CT. The location of the LGV and existence of the ALHA were confirmed during LAG, and these results were compared with those determined preoperatively by CT imaging.
Results The location of the LGV as detected by preoperative E-CT and D-CT was consistent with that identified during LAG in 28 (87.5%) and 31 (88.9%) patients, respectively, with no statistical differences. The existence of the ALHA as detected by preoperative E-CT and D-CT was consistent with that identified during gastrectomy in 24 (75%) and 36 (100%) patients, respectively, with a statistical difference ($P = 0.005$). Furthermore, the type of ALHA could be identified in 10 of 12 patients (83.3%) by D-CT.
Conclusion D-CT can produce excellent images of the vascular supply, and thus undoubtedly contributes to the preoperative planning of LAG. Preoperative D-CT might be an informative tool with which to help overcome the disadvantages of LAG.

Key words anatomy; computed tomography; gastrectomy; gastric cancer; laparoscopic surgery

Gastric cancer is one of the most common cancers in Asia, and its mortality rate ranks second among all cancer deaths worldwide.[1] Complete tumor resection is the only curative treatment for this disease. In Japan, gastrectomy with D2 lymph node dissection is widely accepted as a standard treatment for locally advanced gastric cancer. The vascular anatomy of the upper abdomen is more complex than that of the lower abdomen because of vascular variations around the stomach; therefore, it is extremely important to identify these vascular variations preoperatively. Identification of these vascular variations also allows for precise lymph node dissection, which is the most important part of gastrectomy for the treatment of gastric cancer because surgeons consider the vessels to be the landmarks in lymph node dissection.

Since 1994, laparoscopic-assisted gastrectomy (LAG) has been an increasingly popular treatment method for early gastric cancer because it is considered to be minimally invasive and to improve the quality of life for patients after surgery.[2–7] Moreover, because of recent advancements in laparoscopic surgical techniques and related instruments, the indications for LAG have widened.[8] On the other hand, laparoscopic surgery has various limitations derived from the lack of direct tactile feedback and a two-dimensional display of the operative field. Therefore, it is more important to preoperatively comprehend the anatomic characteristics in patients undergoing LAG than in those undergoing open surgery.

The recent development of multidetector computed tomography (MDCT) has made it possible to perform three-dimensional computed tomographic angiography (3D-CTA), which appears to be an effective and reliable technique for evaluating the perigastric vascular anatomy.[9–15] However, this technique requires at least two scanning phases. Additionally, a significant invest-

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Abbreviations: ALHA, aberrant left hepatic artery; ALT, alanine aminotransferase; AST, aspartate aminotransferase; CA, celiac artery; CHA, common hepatic artery; CT, computed tomography; D-CT, dynamic computed tomography; E-CT, enhanced computed tomography; GDA, gastroduodenal artery; HAP, hepatic artery proper; LAG, laparoscopic-assisted gastrectomy; LGA, left gastric artery; LGV, left gastric vein; LHA, left hepatic artery; MDCT , multidetector computed tomography; POD, postoperative day; PV, portal vein; RHA, right hepatic artery; SA, splenic artery; SMA, superior mesenteric artery; 3D-CTA, three-dimensional computed tomographic angiography

ment of time and effort is needed in the reconstruction of 3D-CTA than routine computed tomography (CT). To date, no studies have compared conventional enhanced CT (E-CT) with dynamic computed tomography (D-CT) in terms of their usefulness in evaluating the perigastric vascular anatomy.

In the present study, we first determined whether either E-CT or D-CT can detect the location of the LGV and existence of the ALHA. This information is extremely important because of preventing the major complications. The aim of this study was to compare the usefulness of D-CT including 3D-CTA for identification of the perigastric vascular anatomy with that of E-CT. To this end, the location of the left gastric vein (LGV) and existence of the aberrant left hepatic artery (ALHA) were assessed by either E-CT or D-CT during a routine check for metastasis.

MATERIALS AND METHODS

Sixty-eight patients (49 males and 19 females) treated at Tottori University Hospital and pathologically diagnosed with gastric cancer were enrolled in this study. None of the patients received radiotherapy, chemotherapy, or other medical interventions before surgery. All patients underwent CT scan using MDCT preoperatively to detect metastasis from the chest to the abdomen. CT was performed with contrast media in all patients. E-CT was performed in 32 patients and D-CT in 36 patients. E-CT had already been performed in the digestive internal medicine department, and D-CT was performed when CT had not been performed at the first medical examination. All patients underwent LAG from June 2010 to June 2012. Distal gastrectomy was performed in 43 patients, total gastrectomy in 15 patients, proximal gastrectomy in 8 patients, and pylorus-preserving gastrectomy in 2 patients. CT was performed using an Aquilion 64-row multidetector CT scanner (Toshiba Medical Systems, Tokyo, Japan). Non-ionic water-soluble iodine-containing contrast agent (510 mgI/kg per 60 s in E-CT, 570 mgI/kg per 30 s in D-CT) was intravenously injected. After 120 s, patients who underwent E-CT were scanned from the chest to the abdomen. For patients who underwent D-CT, the contrast-enhanced CT arterial-phase images were obtained using the bolus-tracking method (called the “real prep method” by Toshiba Medical Systems),[16] which sets a region of interest in the aorta at the level of the bifurcation of the celiac artery and is designed so that imaging will begin when the CT number of the region of interest is 100 HU higher than that of the precontrast imaging. The scanning range delay for the first arterial phase was 20 to 25 s. Portal venous-phase scanning was started 65 s after the start of the contrast medium injection, and the liver parenchymal-phase scanning was started at 120 s to scan from the diagram to the pelvis. The scanning parameters were as follows: tube potential, 120 kVp; tube current, automatic exposure control; gantry rotation speed, 0.5 s; helical pitch factor, 0.844 in E-CT and 0.641 in D-CT. Scanning was performed with a 1-mm slice thickness in both E-CT and D-CT. Postprocessing was performed on a workstation (ZIOSTATION; Zio Software, Tokyo, Japan). 3D-CTA images of the arteries and veins were prepared separately by selecting a CT number tailored to a given target, and the images were colored. These images were then fused.

The imaging data were sent to the electronic chart, and the CT slices were saved at every 5 mm because the CT capacity for saving 1-mm slices in the electronic chart was inadequate. These 5-mm slice CT images were examined preoperatively by two surgeons (author and second author) to detect the location of the LGV and existence of the ALHA. Two surgeons specialized in gastric surgery and acquired endoscopic surgical skill qualified surgeon. Two surgeons discussed CT images each other before surgery at the same time. For the purposes of this study, the vessel connecting the portal or splenic vein to the stomach was defined as the LGV. The LGV was described as one of the following four types based on its location: i) dorsal to the common hepatic artery; ii) ventral to the common hepatic artery; iii) ventral to the splenic artery or iv) dorsal to the splenic artery (Fig. 1). The ALHA originates from the left gastric artery (LGA) and supplies a part of or the whole left hepatic lobe. The ALHA can be classified as either “replaced,” which is a substitute for a normal left hepatic artery, or as “accessory,” which is additive. However, subdivision

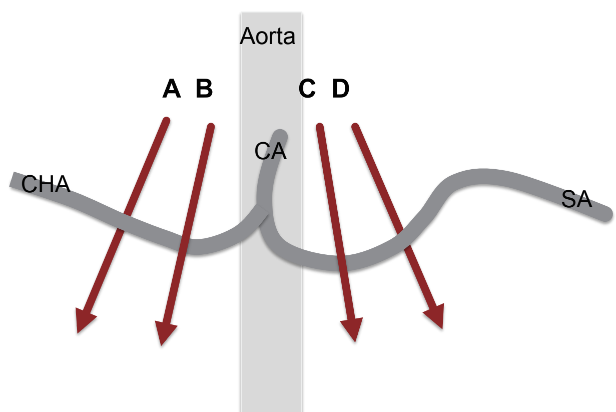

Fig. 1. LGV was described as one of the following four types based on its location: **(A)** dorsal to the common hepatic artery, **(B)** ventral to the common hepatic artery, **(C)** ventral to the splenic artery, or **(D)** dorsal to the splenic artery. CA, celiac artery; CHA, common hepatic artery; LGV, left gastric vein; SA, splenic artery.

into a "replaced" or "accessory" left hepatic artery could not be definitively shown. In the preoperative imaging evaluation and during surgery, a thick artery was usually considered as "replaced" and a thin one was regarded as "accessory".[17] Our definitions of a "replaced" and "accessory" left hepatic artery by CT imaging were as follows. If the ALHA was present by itself or the hepatic artery proper was thicker than the left hepatic artery, the ALHA was a "replaced" left hepatic artery. On the other hand, if the ALHA connected the hepatic artery proper to the left hepatic artery in the hepatic portal region or the hepatic artery proper was thinner than the left hepatic artery, the ALHA was an "accessory" left hepatic artery. The location of the LGV and existence of the ALHA were confirmed during the gastrectomy and compared with those determined preoperatively by CT imaging.

Assessment of perioperative liver function

The patients underwent routine hematological surveys of liver function as assessed by aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels preoperatively and on postoperative days (PODs) 1, 3 and 7.

Statistical analysis

Either the chi-squared test or Mann–Whitney *U*-test was used to determine statistical differences between the two groups. The accepted level of significance was $P < 0.05$. GraphPad PRISM software (GraphPad Software, San Diego, CA) was used for all statistical analyses.

RESULTS

Comparison of the location of the LGV as identified by E-CT and D-CT

The LGV was intraoperatively identified in all patients enrolled in the current study. The location of the LGV was type A in 28 patients (41.2%), type B in 7 (10.3%), type C in 28 (41.2%), and type D in 5 (7.3%). The representative CT images and intraoperative views of the LGV of each type are shown in Fig. 2. The location of the LGV as detected by preoperative E-CT and D-CT was consistent with that identified during gastrectomy in 28 (87.5%) and 31 (88.9%) patients, respectively, with no significant difference (Table 1).

Table 1. Location of the LGV

Type	E-CT	Operation	D-CT	Operation
A	15	16	11	12
B	6	7	0	0
C	5	5	20	23
D	2	4	0	1
Unknown	4	0	5	0
Total	32	32	36	36
Accuracy	87.5% (28/32)*		88.9% (31/36)*	

*There was not significantly different between the two groups. D-CT, dynamic computed tomography; E-CT, enhanced computed tomography; LGV, left gastric vein.

Assessment of ALHA by E-CT and D-CT

The existence of the ALHA was confirmed in 10 (31.3%) patients in the E-CT group and in 12 (33.3%) patients in D-CT group during laparoscopic gastrectomy. The ALHA was confirmed in only 3 of 10 patients with detection of the ALHA by E-CT (Table 2). The accuracy of evaluation of the ALHA by E-CT and D-CT was 75% (24/32) and 100% (36/36), respectively; D-CT was significantly more accurate than E-CT ($P = 0.005$) (Table 2).

Table 2. ALHA identification by either E-CT or D-CT

	Intraoperative findings	
	Present	Absent
E-CT evaluation		
Present	3	1
Absent	7	21
D-CT evaluation		
Present	12	0
Absent	0	24

*D-CT was significantly more accurate than E-CT ($P = 0.005$). ALHA, aberrant left hepatic artery; D-CT, dynamic computed tomography; E-CT, enhanced computed tomography.

Identification of the type of ALHA by D-CT

As described above, the ALHA can be classified as either "replaced" or "accessory." Representative images of a "replaced" and "accessory" ALHA by 3D-CTA are shown in Fig. 3. In the D-CT group, 12 patients had an ALHA ("replaced" in 5, "accessory" in 7). The type of ALHA could be identified in 10 of these 12 patients (83.3%) by D-CT.

Assessment of perioperative liver function

During surgery, the ALHA was divided when considered as "accessory" and preserved when considered as "replaced." The perioperative serum AST and ALT levels are presented in Fig. 4. The serum levels of AST and ALT on POD 1 were not significantly different between the ALHA-divided group (mean ± SE, 185.9 ± 50.1 and 175.4 ± 47.0 IU) and ALHA-preserved group (135.5 ± 62.8 and 132.8 ± 62.4 IU; $P = 0.91$ and $P = 0.85$, respectively). Furthermore, the serum levels of these enzymes on PODs 3 and 7 were not significantly different between the two groups.

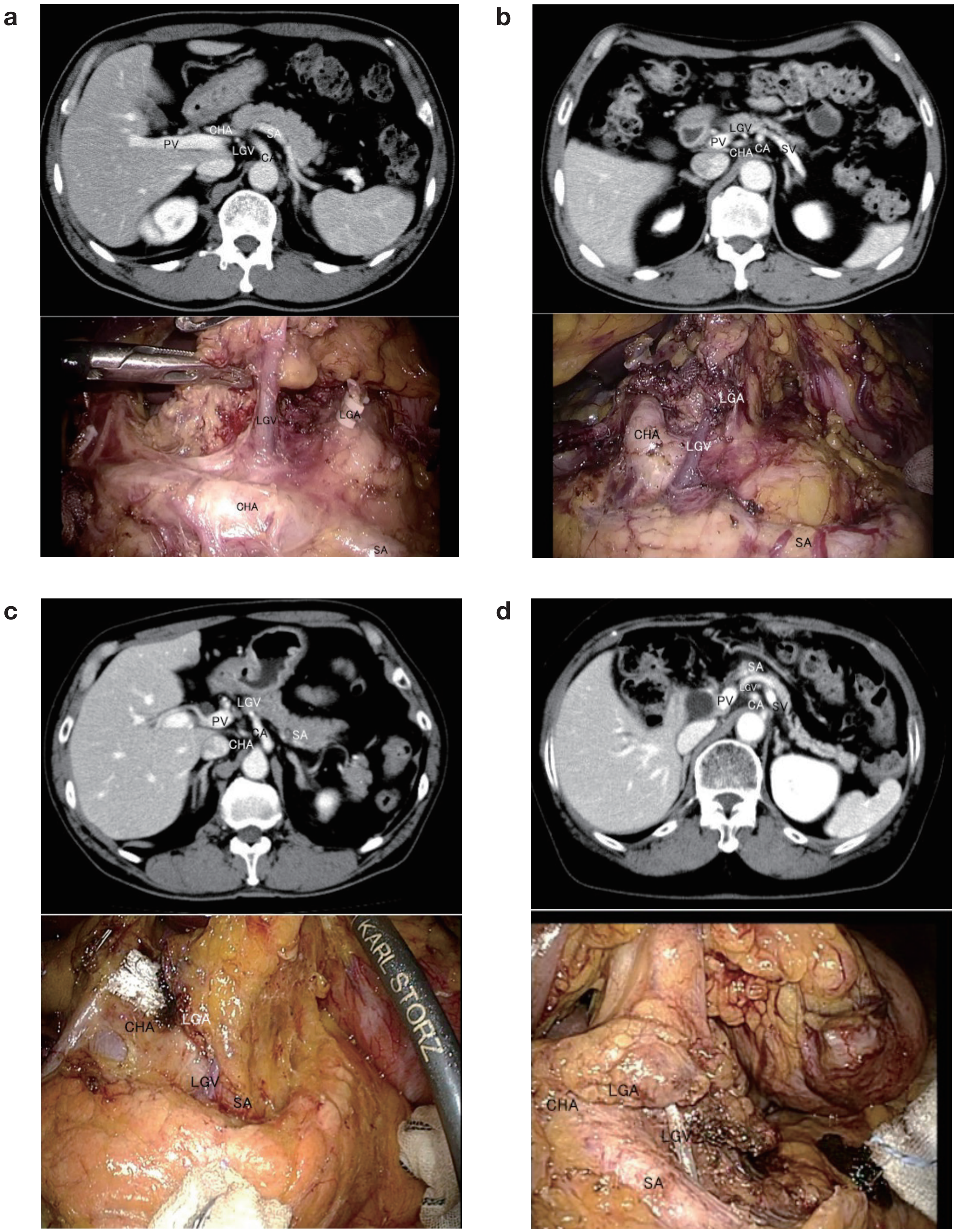

Fig. 2. Representative CT images and intraoperative views of each type of LGV.
a: Dorsal to the common hepatic artery. **b:** Ventral to the common hepatic artery. **c:** Ventral to the splenic artery. **d:** Dorsal to the splenic artery. CA, celiac artery; CHA, common hepatic artery; LGA, left gastric artery; LGV, left gastric vein; PV, portal vein; SA, splenic artery; SV, splenic vein.

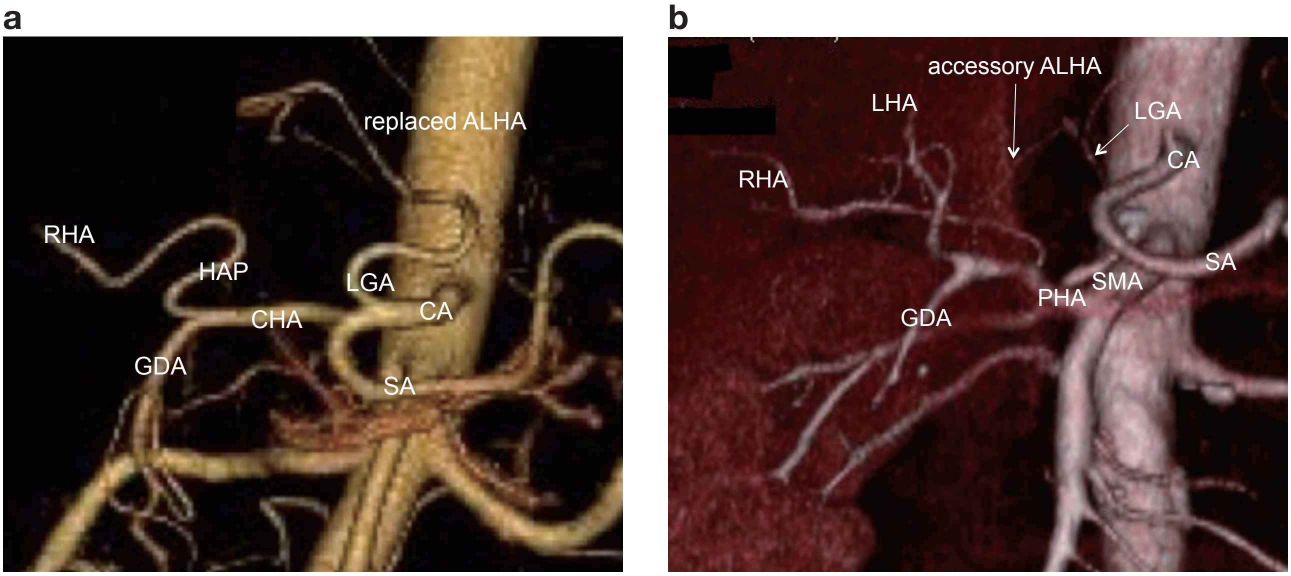

Fig. 3. Representative images of "replaced" and "accessory" ALHA by 3D-CTA.
a: Replaced ALHA: No LHA from the hepatic artery proper is present. This ALHA supplies the whole left hepatic lobe. **b:** Accessory ALHA: Arises from the LGA and connects to the HAP in the hepatic portal region. ALHA, aberrant left hepatic artery; angiography; CA, celiac artery; GDA, gastroduodenal artery; HAP, hepatic artery proper; LGA, left gastric artery; LHA, left hepatic artery; SA, splenic artery; SMA, superior mesenteric artery; RHA, right hepatic artery; 3D-CTA, three-dimensional computed tomographic angiography.

Operation time, blood loss volume, and total number of dissected lymph nodes

The operation time was 377.5 ± 100.4 and 396.6 ± 128.5 min in the ALHA-preserved group and ALHA-divided group, respectively, with no significant difference (*P* = 0.97) (Fig. 5a). The blood loss volume was 60.83 ± 86.6 and 145.6 ± 260.5 mL in the ALHA-preserved group and ALHA-divided group, respectively, with no significant difference (*P* = 0.24) (Fig. 5b). Furthermore, there was no significant difference in the total number of dissected lymph nodes between the ALHA-preserved group and ALHA-divided group (29.7 ± 9.8 vs. 47.1 ± 20.9, respectively; *P* = 0.10) (Fig. 5c).

DISCUSSION

In the present study, we first determined whether either E-CT or D-CT can detect the location of the LGV and existence of the ALHA. This information is extremely important because accidental injury of the LGV often occurs due to the various patterns of its inflow and route relative to the surrounding arteries. Because of the major blood flow within the portal vein and splenic vein, into which the LGV and mesenteric vein flow, injury to the LGV leads to heavy blood loss and difficulty in hemostasis, even in open gastrectomy. Preoperative assessment of the LGV anatomy seems to be more important in LAG than in open gastrectomy because knowledge of the LGV anatomy prior to surgery enables surgeons to confidently proceed with the manipulation around the LGV. In the present study, the type of LGV anatomy could be preoperatively detected in 87.5% of patients by E-CT and in 88.9% by D-CT. Kawasaki et al.[14] previously showed that the accuracy of detecting the correct location of the LGV by preoperative CT was 93.8%, which is similar to our findings. Importantly, there was no difference between E-CT and D-CT in terms of detecting the LGV, indicating that D-CT is not necessary to detect the correct location of the LGV.

The ALHA originates from the LGA and supplies a part of or the whole left hepatic lobe. The incidence of an ALHA varies from 6.5% to 30.0% in the literature.[17–20] The significance of this anomalous vessel has also been described in visceral surgery of the upper intestinal tract and liver transplantation.[20] During curative gastrectomy for gastric cancer, extended lymph node dissection requires division of the LGA and resection of all elements of the lesser omentum. The LGA must be exposed to complete the gastrectomy with lymph node dissection. The LGA is usually ligated and divided at its origin to allow for complete dissection of the lymph nodes. However, an ALHA arising from the LGA as a variation of the LGA is sometimes observed. An ALHA can be classified as either a "replaced" artery, which is a substitute for a normal left hepatic artery, or an "accessory" artery, which is present in addition to the normal artery. The division of a replaced left hepatic artery might induce transient liver dysfunction during the early postoperative period. Lethal complications, such as liver

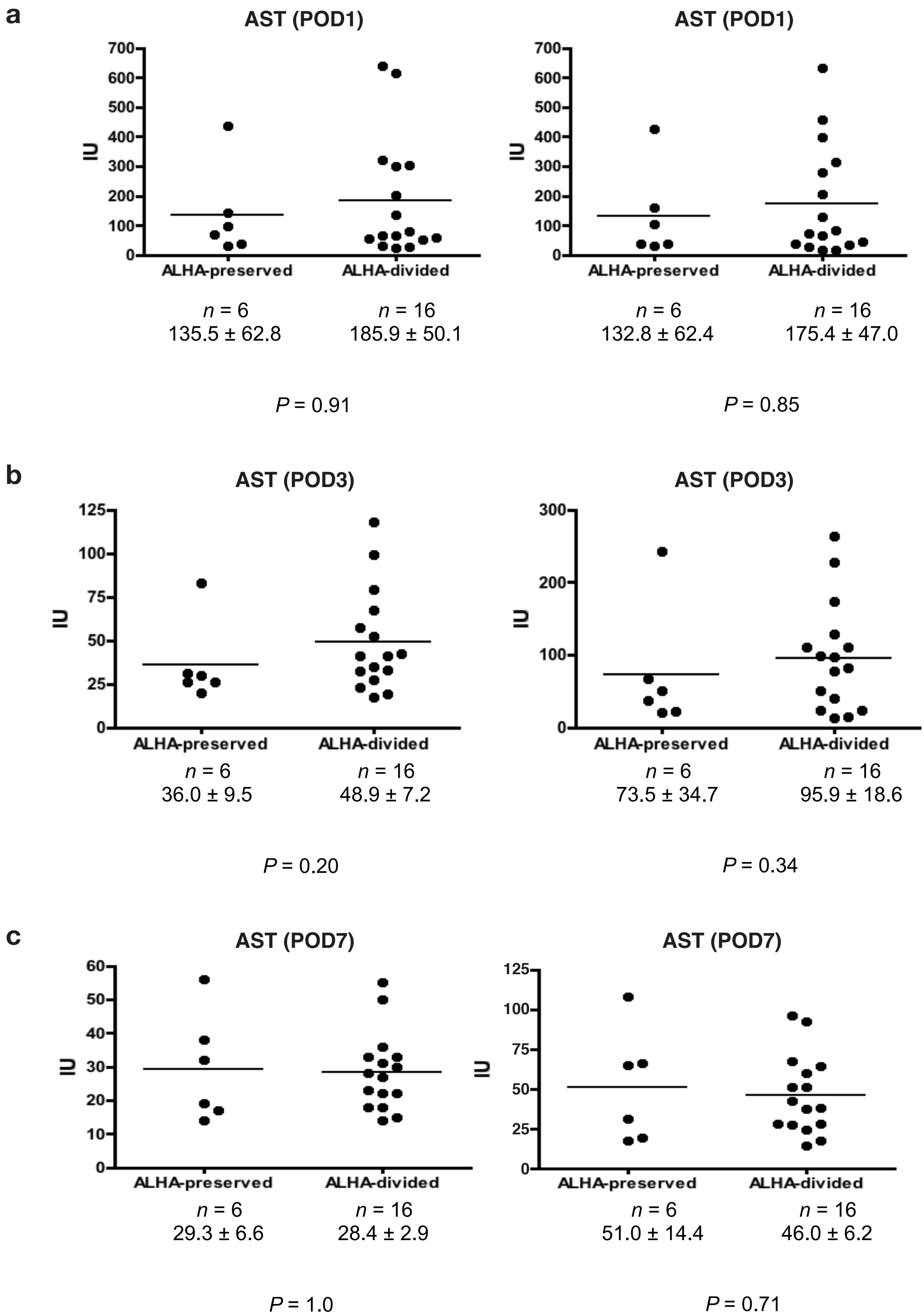

Fig. 4. Perioperative liver function.
a: The serum AST and ALT levels on POD 1 were not significantly different between the ALHA-divided group and ALHA-preserved group. **b, c:** The serum AST and ALT levels on PODs 3 and 7 were also not significantly different between the two groups. ALHA, aberrant left hepatic artery; ALT, alanine aminotransferase; AST, aspartate aminotransferase; POD, postoperative day.

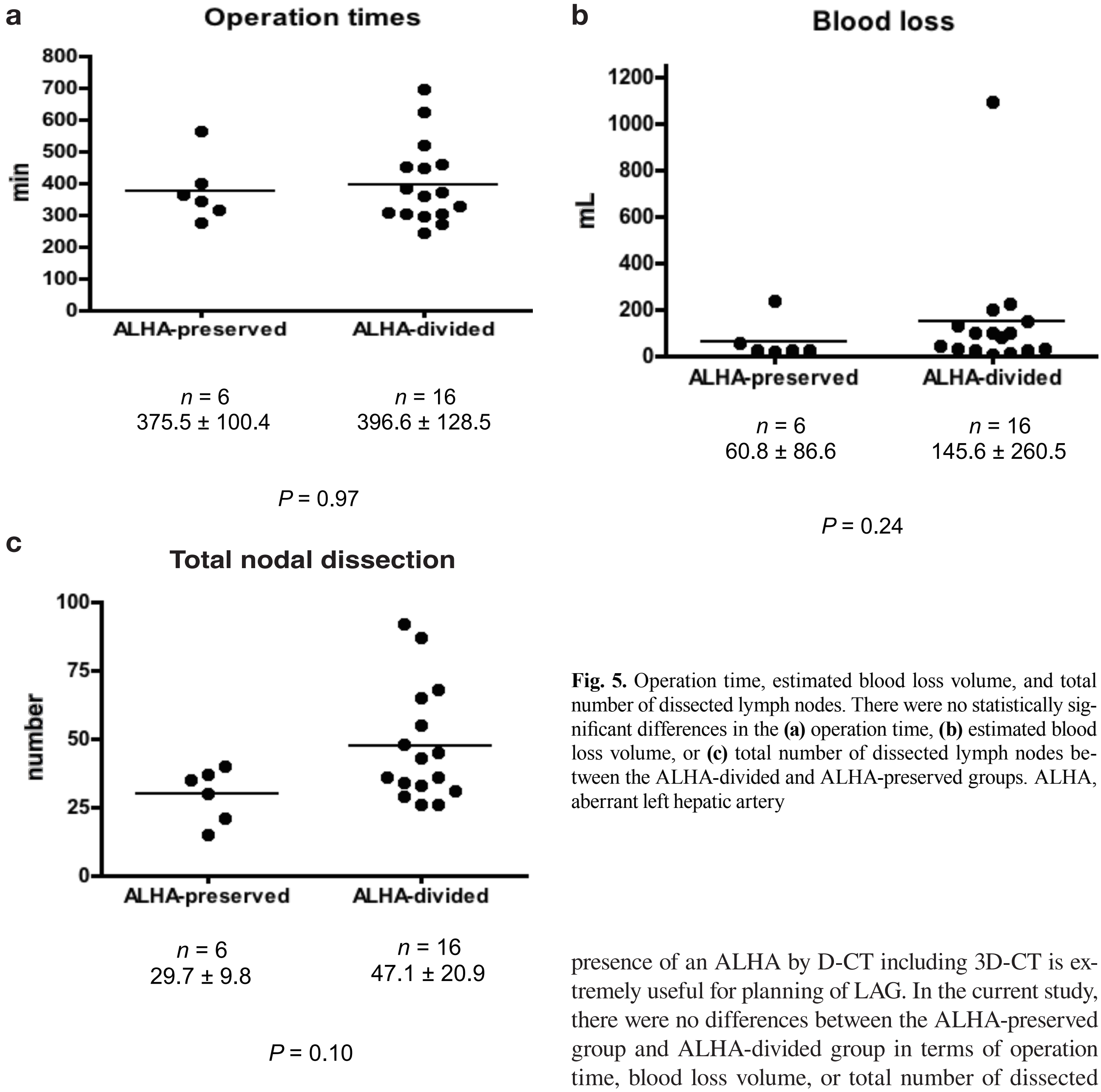

Fig. 5. Operation time, estimated blood loss volume, and total number of dissected lymph nodes. There were no statistically significant differences in the **(a)** operation time, **(b)** estimated blood loss volume, or **(c)** total number of dissected lymph nodes between the ALHA-divided and ALHA-preserved groups. ALHA, aberrant left hepatic artery

necrosis or death caused by division of the artery, have also been reported.[21–24] Therefore, it would be better to preserve a replaced ALHA to avoid lethal complications, especially in patients with early gastric cancer.[17, 24] In this study, D-CT including 3D-CTA was more useful for detection of the ALHA than was E-CT. More importantly, D-CT especially 3D-CTA was extremely useful to confirm the type of ALHA. In fact, the type of ALHA could be identified in 10 of the 12 patients (83.3%) by D-CT in the current study.

Although it is not so difficult to detect the existence of an ALHA intraoperatively, even during LAG, it is sometimes difficult to confirm the type of ALHA during the operation. Therefore, preoperative assessment of the presence of an ALHA by D-CT including 3D-CT is extremely useful for planning of LAG. In the current study, there were no differences between the ALHA-preserved group and ALHA-divided group in terms of operation time, blood loss volume, or total number of dissected lymph nodes, indicating that the ALHA-preserving procedure did not affect the quality of LAG. On the other hand, there was no difference in liver function as evaluated by the serum AST and ALT levels despite the fact that the accessory ALHA was divided, indicating that the accessory ALHA can be safely divided. Therefore, D-CT may be indispensable to avoid lethal liver-related complications.

In conclusion, our findings in the current study demonstrate that D-CT is extremely useful for assessment of the perigastric vascular anatomy before LAG for gastric cancer. Preoperative D-CT might be an informative tool with which to help overcome the disadvantages of LAG.

The authors declare no conflict of interest.

REFERENCES

1 Ries L, Eisner M, Kosary C. SEER cancer statistics review, 1975-2000. Bethesda (MD): National Cancer Institute; 2003. p. 2003.
2 Kitano S, Iso Y, Moriyama M, Sugimachi K. Laparoscopy-assisted Billroth I gastrectomy. Surg Laparosc Endosc. 1994;4:146-8. PMID: 8180768.
3 Kitano S, Shiraishi N, Uyama I, Sugihara K, Tanigawa N. A multicenter study on oncologic outcome of laparoscopic gastrectomy for early cancer in Japan. Ann Surg. 2007;245:68-72. PMID: 17197967.
4 Sakuramoto S, Kikuchi S, Kuroyama S, Futawatari N, Katada N, Kobayashi N, et al. Laparoscopy-assisted distal gastrectomy for early gastric cancer: experience with 111 consecutive patients. Surg Endosc. 2006;20:55-60. PMID: 16283580.
5 Adachi Y, Suematsu T, Shiraishi N, Katsuta T, Morimoto A, Kitano S, et al. Quality of life after laparoscopy-assisted Billroth I gastrectomy. Ann Surg. 1999;229:49-54. PMID: 9923799.
6 Jiang X, Hiki N, Nunobe S, Fukunaga T, Kumagai K, Nohara K, et al. Long-term outcome and survival with laparoscopy-assisted pylorus-preserving gastrectomy for early gastric cancer. Surg Endosc. 2011;25:1182-6. PMID: 20844895.
7 Jiang X, Hiki N, Nunobe S, Fukunaga T, Kumagai K, Nohara K, et al. Postoperative outcomes and complications after laparoscopy-assisted pylorus-preserving gastrectomy for early gastric cancer. Ann Surg. 2011;253:928-33. PMID: 21358534.
8 Uyama I, Sugioka A, Matsui H, Fujita J, Komori Y, Hasumi A. Laparoscopic D2 lymph node dissection for advanced gastric cancer located in the middle or lower third portion of the stomach. Gastric Cancer. 2000;3:50-5. PMID: 11984710.
9 Kim HS, Han HY, Choi JA, Park CM, Cha IH, Chung KB, et al. Preoperative evaluation of gastric cancer: value of spiral CT during gastric arteriography (CTGA). Abdom Imaging. 2001;26:123-30. PMID: 11178686.
10 Matsumoto A, Kitamoto M, Imamura M, Nakanishi T, Ono C, Ito K, et al. Three-dimensional portography using multislice helical CT is clinically useful for management of gastric fundic varices. AJR Am J Roentgenol. 2001;176:899-905. PMID: 11264074.
11 Takiguchi S, Sekimoto M, Fujiwara Y, Yasuda T, Yano M, Hori M, et al. Laparoscopic lymph node dissection for gastric cancer with intraoperative navigation using three-diensional angio computed tomography images reconstructed as laparoscopic view. Surg Endosc. 2004;18:106-10. PMID: 14625744.
12 Matsuki M, Tanikake M, Kani H, Tatsugami F, Kanazawa S, Kanamoto T, et al. Dual-phase 3D CT angiography during a single breath-hold using 16-MDCT: assessment of vascular anatomy before laparoscopic gastrectomy. AJR Am J Roentgenol. 2006;186:1079-85. PMID: 16554582.
13 Kumano S, Tsuda T, Tanaka H, Hirata M, Kim T, Murakami T, et al. Preoperative evaluation of perigastric vascular anatomy by 3-dimensional computed tomographic angiography using 16-channel multidetector-row computed tomography for laparoscopic gastrectomy in patients with early gastric cancer. J Comput Assist Tomogr. 2007;31:93-7. PMID: 17259839.
14 Kawasaki K, Kanaji S, Kobayashi I, Fujita T, Kominami H, Ueno K, et al. Multidetector computed tomography for preoperative identification of left gastric vein location in patients with gastric cancer. Gastric Cancer. 2010;13:25-9. PMID: 20373072.
15 Fujiwara M, Kodera Y, Satake H, Misawa K, Miura S, Nakayama G, et al. Navigation for laparoscopic gastrectomy with 3-dimensional computed tomography (3D-CT). Hepatogastroenterology. 2008;55:1201-5. PMID: 18795657.
16 Shimizu T, Misaki T, Yamamoto K, Tanaka Y, Utsunomiya K, Sueyoshi K, et al. Optimal scan delay of arterial phase scanning of hepatic CT using a real-time image reconstruction system. Clin Imaging. 1999;23:107-10. PMID: 10416087.
17 Shinohara T, Ohyama S, Muto T, Yanaga K, Yamaguchi T. The significance of the aberrant left hepatic artery arising from the left gastric artery at curative gastrectomy for gastric cancer. Eur J Surg Oncol. 2007;33:967-71. PMID: 17418995.
18 Adachi B. Das Arteriensystem der Japaner. Tokyo: Kenkyusha; 1928. p. 11-68.
19 Michels NA. Blood supply and anatomy of the upper abdominal organs with a descriptive atlas. Philadelphia: JB Lippincott; 1955. p. 248-72.
20 Hiatt JR, Gabbay J, Busuttil RW. Surgical anatomy of the hepatic arteries in 1000 cases. Ann Surg. 1994;220:50-2. PMID: 8024358.
21 Hemming AW, Finley RJ, Evans KG, Nelems B, Fradet G. Esophagogastrectomy and the variant left hepatic artery. Ann Thorac Surg. 1992;54:166-8. PMID: 1610235.
22 Friesen SR. The significance of the anomalous origin of the left hepatic artery from the left gastric artery in operations upon the stomach and esophagus. Am Surg. 1957;23:1103-8. PMID: 13488026.
23 A.S. L. The significance of the variant left accessory hepatic artery in surgery for proximal gastric cancer. Archives of Surgery. 1987;122:725-8. PMID: 3579588.
24 Oki E, Sakaguchi Y, Hiroshige S, Kusumoto T, Kakeji Y, Maehara Y. Preservation of an aberrant hepatic artery arising from the left gastric artery during laparoscopic gastrectomy for gastric cancer. J Am Coll Surg. 2011;212:e25-7. PMID: 21398157.