ORIGINAL

Utility of virtual three-dimensional image analysis for laparoscopic gastrectomy conducted by trainee surgeons

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Abstract : *Purpose* The aim of this study was to investigate the utility the three-dimensional (3D) imaging for laparoscopic gastrectomy performed by trainee surgeons. *Methods* 3D-reconstruction was performed using multi-detector computed tomography (MDCT) and SYNAPSE VINCENT software. Trainee surgeons made 3D-imaging and checked the anatomical structure. Thirty-three patients who underwent laparoscopic gastrectomy (LG) for gastric cancer were examined. Trainees performed 19 LG, while specialists performed 14 LG. The vascular pattern and the surgical outcomes were evaluated. *Result* 3D imaging depicted the correct positional relationship between the gastric vasculatures and the organs. Regarding vascular pattern detected by 3D imaging, the origins of the infrapyloric artery were the right gastroepiploic artery in 12 cases (36%), the gastroduodenal artery in eight cases (24%), the bifurcation of the right gastroepiploic artery and gastroduodenal artery in seven cases (21%), and not detected in one case (3%). The types of confluence of the infrapyloric vein were the right gastroepiploic vein in 16 cases (48%), the anterior superior pancreatoduodenal vein in 10 cases (30%), and not detected in seven cases (21%). Surgical outcomes were not different between trainee group using intraoperative 3D image with the specialist in instruction group without the intraoperative 3D image. *Conclusions* Preoperative 3D imaging might contribute to successful and safe LG by trainee surgeons. J. Med. Invest. 66 : 280-284, August, 2019

***Keywords* :** *three-dimensional image, laparoscopic gastrectomy, trainee surgeons*

INTRODUCTION

Laparoscopic surgery has dramatically improved over the past two decades, and the indications for laparoscopic surgery have been widened within the gastrointestinal surgery field. Laparoscopic gastrectomy is becoming a standard procedure for early gastric cancer in Japan and Korea. A nationwide survey by the Japan Society of Endoscopic Surgery (JSES) reported that 4,765 cases of laparoscopic gastrectomy were performed in 1 year in Japan (1). However, for trainee surgeons, laparoscopic gastrectomy has several difficult components, including lymph node dissection and resection of several blood vessels. Misunderstanding of the local anatomy can result in severe complications, such as pancreatic fistula and intraoperative bleeding.

To reduce surgical complications and plan accurate operations, patients should be evaluated using precise and comprehensive imaging techniques preoperatively for accurate delineation of the local anatomy. Recently, preoperative evaluation of the vasculature based on a three-dimensional (3D) imaging technique resulted in a significantly improved surgical outcome for patients undergoing abdominal surgery (2-7). In gastrectomy, only a few studies have investigated the utility of 3D imaging (4, 5), and there are no reports concerning about the utility of 3D imaging technique as an educational tool for gastrectomy performed by trainee surgeons.

Therefore, the aim of this study was to investigate the utility of the 3D imaging in laparoscopic gastrectomy performed by trainee surgeons.

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METHODS

Patients

Thirty-three patients (male, n = 22 ; male, n = 11 ; mean age, 66 years) who underwent laparoscopic gastrectomy for gastric cancer during the period between January 2013 and May 2014 in Tokushima University Hospital were examined in this study. Trainees performed 19 laparoscopic gastrectomies, while specialists performed 14 laparoscopic gastrectomies. Trainees were beginners in terms of laparoscopic gastrectomy and had 6-10 years of experience as surgeons after graduation from medical school. Specialists were qualified surgeons according to the endoscopic surgical skill qualification system of the Japanese Society for Endoscopic Surgery.

Imaging technique

Multi detector computed tomography (MDCT) examinations were performed using Aquilion 16 (Toshiba Medical Systems Corporation, Tochigi, Japan) at the University of Tokushima. We adopted a multiphase computed tomography (CT) protocol to acquire three image sets (arterial, portal, and equilibrium phases). The scans for each phase were acquired at 15 seconds (arterial), 30 seconds (portal), and 180 seconds (equilibrium phase) after the administration of the nonionic contrast material, iopamidol (Iopamiron 370 ; Nihon Schering, Osaka, Japan), at a rate of 3 mL/s. Data from the arterial and portal phases were utilized in this study. Details of the imaging method were reported previously (7).

Processing of gastric vessel data

Three-dimensional (3D) -reconstruction of the gastric vasculature was performed using data from contrast enhanced MDCT and SYNAPSE VINCENT software (FUJIFILM MEDICAL CO.LTD., TOKYO JAPAN) (7). Whole stomach, pancreas, spleen, portal vein, gastric artery, and gastric vein were extracted from MDCT scans and traced, and 3D images were integrated. Since blood vessels were not automatically traced by this software, they were identified and manually traced using 1-mm intervals from axial 2-dimensional images, followed by reconstruction of 3D images (Figure 1). Trainee surgeons made 3D imaging and checked anatomical variation and positional relationship preoperatively.

Surgery

The number of each lymph node station was classified according to the Japanese Classification of Gastric Carcinoma (8). Surgical indication and lymph node dissection was defined by Japanese gastric cancer treatment guidelines 2010 (ver. 3) (9). Standardized surgical procedures were performed by the trainee or specialist. The reconstruction method was the Billroth I, Roux-en Y in distal gastrectomy, Billroth I in pylorus-preserving gastrectomy, esophagogastrostomy in proximal gastrectomy, and Roux-en Y in total gastrectomy. This study included two trainees, who were the Board Certified Surgeon of Japan society of surgery, Board Certified Surgeon in Gastroenterology of japan society of gastoroentelogical surgery. Both of the trainee had enough experience of laparoscopic surgery as an operator over 150 cases. The specialist was the qualified surgeon of Endoscopic surgical skill qualification system (ESSQS) of Japan Society for Endoscopic Surgery. In all cases, qualified surgeon of ESSQS qualified surgeon participated in the surgery.

Statistical analysis

All statistical analysis was performed using statistical software (JMP 8.0.1., SAS Campus Drive, Cary, 27513 NC, USA). Clinical variables were analyzed with the chi-square test and Mann-Whitney *U* test. Statistical significance was defined as $p < 0.05$.

RESULTS

Vascular pattern detected by 3D imaging

Table 1 shows the vascular patterns of gastric vessels detected by preoperative 3D imaging. The origins of infrapyloric artery

Table 1. Vascular pattern determined by three-dimensional (3D) imaging

Characteristic	No of patients (%)
Origin of IPA	
RGEA	36% (12)
GDA	24% (8)
ASPDA	21% (7)
ASPDA + GDA	12% (4)
Not detected	3% (1)
Origin of LGEA	
SPA main duct	64% (21)
SPA lower branch	36% (12)
PGA	
Detected	67% (22)
Not detected	33% (11)
Distance between PGA bifurcation of SPA	47 mm
Confluence of IPV	
RGEV	48% (16)
ASPDV	30% (10)
Not detected	21% (7)
Confluence of LGV	
PV	55% (18)
SPV	39% (13)
Bifurcation	6% (2)

ASPDA : anterior superior pancreaticoduodenal artery, ASPDV : anterior superior pancreaticoduodenal vein, GDA : gastroduodenal artery, IPA : infrapyloric artery
IPV : infrapyloric vein, LGEA : left gastroepiproic artery, LGV : left gastric vein,
SPA : splenic artery, SPV : splenic vein, PGA : posterior gastric artery, PV : portal vein

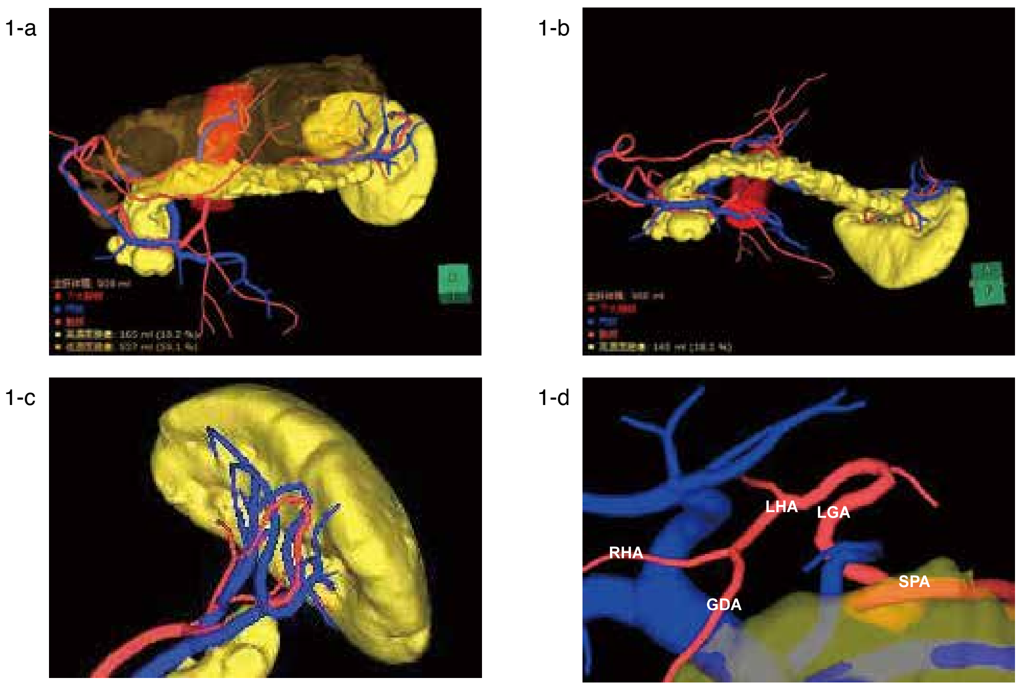

Figure 1. Three-dimensional (3D) image of gastric surgery : a) coronal view, b) laparoscopic view, c) vascular anomaly, d) complicated vasculature in splenic hilum

(IPA) (Figure 2-a) were the right gastroepiploic artery (RGEA) in 12 cases (36%), the gastroduodenal artery (GDA) in eight cases (24%), the bifurcation of the RGEA and GDA in seven cases (21%), and not detected in one case (3%). The origins of the left gastroepiploic artery (LGEA) (Figure 2-b) were the splenic artery (SPA) main duct in 21 cases (64%) and the SPA lower branch in 12 cases (36%). The posterior gastric artery (PGA) was detected in 22 cases (67%). The distance between the PGA and the bifurcation of SPA was 47 mm. The types of confluence of the infrapyloric vein (IPV) (Figure 2-c) were the right gastroepiploic vein (RGEV) in 16 cases (48%), the anterior superior pancreaticoduodenal vein (ASPDV) in 10 cases (30%), and not detected in seven cases (21%). The types of confluence of the left gastric vein (LGV) (Figure 2-d) were the portal vein (PV) in 18 cases (55%), the splenic vein (SPV) in 13 cases (39%), and the bifurcation of the PV and SPV in two cases (6%).

Utility of 3D simulation as an educational tool for trainee surgeons

3D imaging is useful to know the anatomical structure such as the vascular anomaly or complicated vasculature for example splenic hilum (Figure 1). We used the 3D imaging for intraoperative navigation. Figure 3 shows 3D imaging and actual

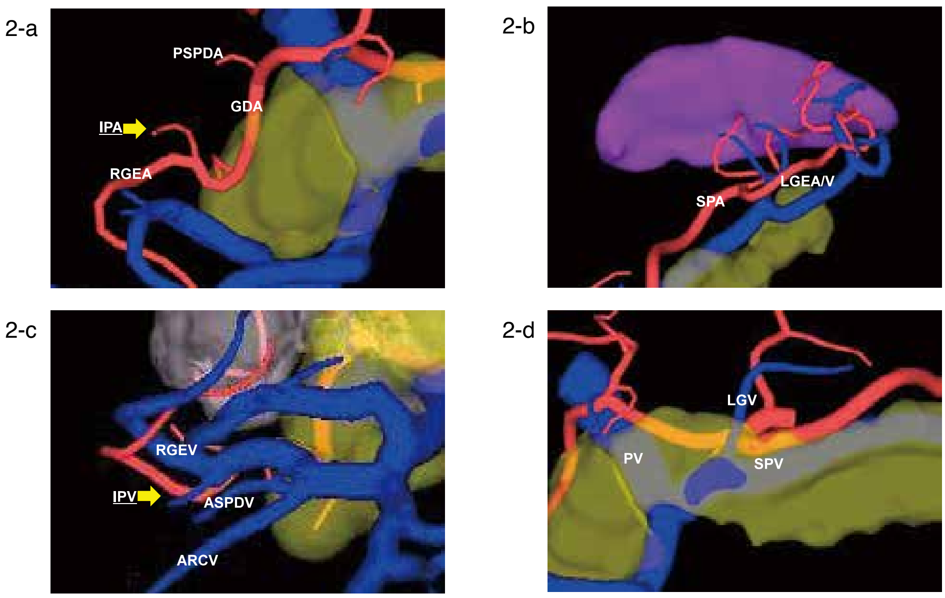

Figure 2. Vascular pattern determined by three-dimensional (3D) imaging : a) infrapyloric artery, b) left gastroepiploic artery, c) infrapyloric vein, d) left gastric vein

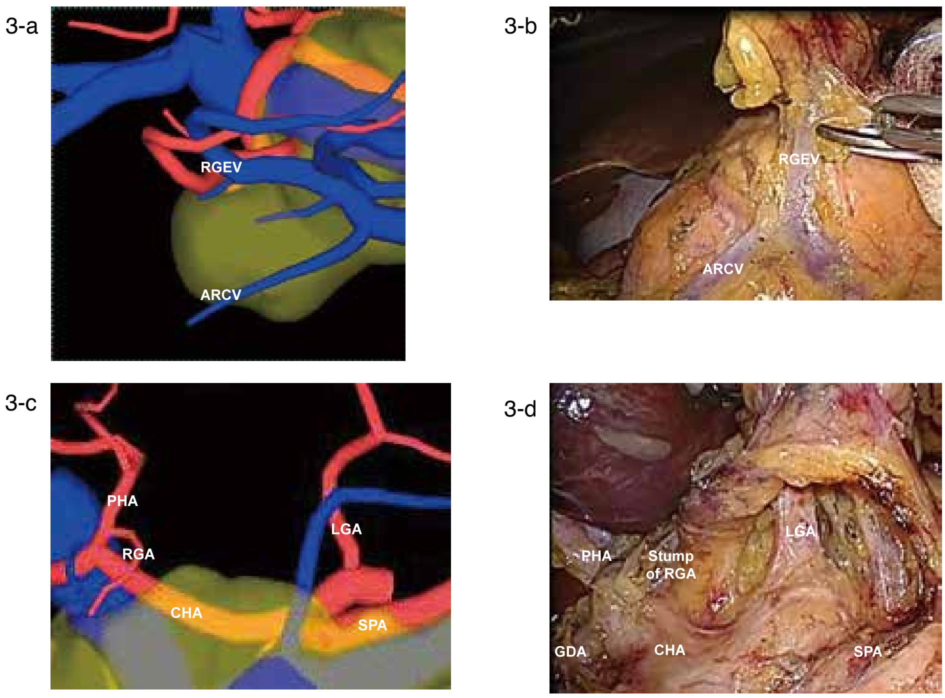

Figure 3. Three-dimensional (3D) image and actual laparosocpic view conducted by trainee surgeon a) 3D imaging in #6 lymph node dissection, b) laparoscopic view in #6 lymph node dissection, c) 3D imaging in suprapancreatic lymph node dissection, d) laparoscopic view in suprapancreatic lymph node dissection

surgical view conducted by trainee surgeon. 3D imaging enabled depiction of a view that was similar to that seen during actual laparoscopic surgery. Thirty-three patients who underwent laparoscopic gastrectomy were assigned to one of two groups : the trainee group (n = 19) or the specialists group (n = 14). Table 2 shows the patients characteristic and surgical outcomes. There were no significant differences with regard to age, gender, body mass index, surgical procedure, lymph node dissection, or fStage between trainee group using intraoperative 3D image with the specialist in instruction group without the intraoperative 3D image. With regard to surgical outcomes, there were no significant difference in intraoperative bleeding (trainee group : 61 ± 64 ml vs. specialists group 54 ± 42 ml), operative time (trainee group : 385 ± 50 min vs. specialists group 379 ± 117 min), number of harvested lymph nodes, duration of postoperative hospital stay, or mortality and morbidity between the two groups.

Table 2. Patients' characteristic and surgical outcome

Characteristic	Trainee (n = 19)	Specialists (n = 14)	*P* value
Age	65 ± 10	68 ± 9	N.S
Gender (male/female)	12/7	10/4	N.S
BMI	22.5 ± 3.1	22.9 ± 3.5	N.S
fStage (I/II/III)	10/6/3	6/6/2	N.S
Surgical Procedure			
(LADG/LAPG/LATG)	15/2/2	7/2/5	N.S
D1/D1+/D2	1/11/7	1/9/4	N.S
Blood loss (ml)	61 ± 64	54 ± 42	N.S
Operative time (min)	385 ± 50	379 ± 117	N.S
Harvested lymph node	24.8 ± 9.3	24.2 ± 9.9	N.S
Postoperative hospital stays	15.3 ± 4.3	14.5 ± 4.2	N.S
Mortality (%)	0	0	N.S
Morbidity (%)	10.5	7.1	N.S
Stasis (%)	5.3	0	
Intraperitoneal abscess (%)	5.3	0	
Anastomotic stenosis (%)	0	7.1	

LADG : laparoscopic assisted distal gastrectomy, LAPG : laparoscopic assisted proximal gastrectomy, LATG : laparoscopic assisted total gastrectomy

DISCUSSION

The present study demonstrated the utility of preoperative 3D imaging as educational tools for laparoscopic gastrectomy by trainee surgeons. 3D-simulation techniques contribute to a better understanding of the anatomy and any vascular anomalies. The combination of contrast-enhanced MDCT and 3D fusion software provided clear anatomic assessment of the gastric vasculature, stomach, pancreas, and spleen. It enabled trainee surgeons to easily and safely perform laparoscopic gastrectomy.

Advances in imaging techniques and simulation software now enable precise liver surgery, pancreatic surgery, and laparoscopic gastrectomy (2-7). We previously described the utility of simulation software for liver surgery, which enabled us to detect a venous branching pattern, venous congestion area, and the positional relationship of the hepatic hilum for liver surgery (6,7). With regard to pancreaticoduodenectomy, detection of inferior pancreaticoduodenal artery (IPDA) and assessment of IPDA ligation using 3D-CT resulted in a decrease in intraoperative blood loss (3). For patients undergoing gastrectomy, preoperative assessment with 3D imaging allowed identification of the left gastric artery and vein, the right gastric artery, and the replaced left hepatic artery (4, 5).

Anatomical variations of the gastric vasculature are common. In particular, arterial variations are found in 10%-20% of cases (10). In the current study, we found IPA and IPV anomalous variations. The origins of the IPA were the RGEA in 12 cases (36%), the GDA in eight cases (24%), the bifurcation of the RGEA and GDA in seven cases (21%), and not detected in one case (3%). Our findings are consistent with those from a previous study, which showed that the origins of IPA were the GDA in 64%, the ASPDA in 21%, the RGEA in 13%, and the posterior superior pancreaticoduodenal artery in 2% (11). The confluence of the IPV was the RGEV in 16 cases (48%), the ASPDV in 10 cases (30%), and not detected in seven cases (21%). This is the first report to characterize the confluence of the IPV. The detection rate of IPV was still low. The CT protocol should be improved to detect thin blood vessels. The posterior gastric artery (PGA) is very important in gastrectomy, because the PGA is the border between the 11p and the 11d lymph node (8). Further, misidentification of PGA can lead to massive bleeding or pancreatic fistula. The PGA was detected in 22 cases (67%) via preoperative 3D imaging. Our detection rate was lower than that in a previous report (12). The distance between the PGA and the bifurcation of splenic artery was 47 mm. This preoperative information was helpful to guide lymph node dissection above the pancreas and to guide resection of the PGA.

In our institute, the trainee, who have enough experience of gastrointestinal surgery as Board Certified Surgeon of Japan society of surgery, or Board Certified Surgeon in Gastroenterology of japan society of gastrointestinal surgery, start to perform LG with qualified surgeon of ESSQS qualified surgeon of Japan Society for Endoscopic Surgery. Our top-priority was patients' safety. We always consider the patients' safety and the quality of the surgery, including LG.

Regarding learning curve, 40 to 60 cases are required to become proficient in laparoscopic gastrectomy (13-15). Tokunaga suggested that educational system maintained surgical quality. Training requires sufficient experience as an assistant and scopist, standardization of the surgical procedure, and team participation instructions (16-18), as suggested by experience in a high-volume center (more than 200 cases a year). However, it might be difficult to establish an optimal educational system in the majority of the institutes. In the current study, the operative time and blood loss in the trainee group were comparable to those in the specialist's group. No major complications were observed in either group. 3D imaging generated a view that is similar to that seen during actual laparoscopic surgery. We believe that 3D imaging is a reliable educational tool for laparoscopic gastrectomy performed by trainee surgeons.

In conclusion, preoperative 3D imaging contributed to successful and safe laparoscopic gastrectomy by trainee surgeon.

CONFLICT OF INTEREST STATEMENT

Masaaki Nishi and other co-authors have no conflict of interest.

ETHICAL STATEMENT AND CONSENT

All procedures followed were in accordance with the Helsinki Declaration of 1964 and later versions. Ethics Committees' approval is unnecessary for this study.

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