The Depth from the Skin to the Celiac Artery Measured Using Computed Tomography is a Simple Predictive Index for Longer Operation Time During Laparoscopic Distal Gastrectomy

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Title: The depth from the skin to the celiac artery measured using computed tomography is a simple predictive index for longer operation time during laparoscopic distal gastrectomy

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Key words: Laparoscopic distal gastrectomy; Longer operation time; Simple predictive index

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Abstract

Background: Body mass index (BMI) is commonly used to classify obesity. However, BMI does not always reflect the degree of visceral fat. This study aimed to clarify the usefulness of measuring the depth from the skin to the celiac artery using computed tomography, as a simple predictive index for longer operation time during laparoscopic distal gastrectomy (LDG).

Methods: From September 2012 to March 2016, 66 patients who underwent LDG with D1+ lymph node dissection were included. The depth from the skin to the bifurcation of the celiac artery was defined as 'skin-to-celiac artery distance (SCD)'. The patients were divided into two groups based on the median operation time (time scenarios from omentum incision to specimen extirpation and infrapyloric and suprapancreatic lymph node dissections (I-LND, S-LND) were assessed). The factors eliciting a longer operation time than the median operation time were investigated.

Results: From omentum incision to specimen extirpation, BMI, thickness of subcutaneous fat (TSF), and SCD ($P=0.002$, $P=0.039$, $P<0.001$) were the factors associated with longer operation time. Furthermore, BMI, TSF, and SCD in I-LND ($P=0.008$, $P=0.022$, $P<0.001$) and BMI and SCD in S-LND ($P<0.001$, $P<0.001$) were associated with longer operation time. The multivariate analysis showed that a long SCD was the only significant independent factor to predict an operation time longer than the median operation time ($P=0.001$). The best cutoff level of SCD calculated using the receiver operating characteristic curve was 88 mm.

Conclusions: This study demonstrated that SCD is a simple predictive index for longer operation time during LDG.

Introduction

Gastric cancer is a common malignant disease worldwide. The standard surgical procedure for gastric cancer is gastrectomy with lymph node dissection. A number of studies have reported the safety and feasibility of laparoscopic distal gastrectomy (LDG) for gastric cancer [1-4]. Therefore, this procedure has become an alternative for the treatment of gastric cancer. However, obesity is a major technical limiting factor for LDG because of substantial operative difficulties caused by abundant visceral fat and a narrow operating field.

Body mass index (BMI) is commonly used to classify obesity [5]. A high BMI was previously related to prolonged operation time, increased intraoperative bleeding, postoperative complications, postoperative hospital death, and poor long-term outcomes [6-9]. However, BMI does not always reflect the degree of visceral fat because fat distribution differs greatly among individuals [10]. Several reports suggested that visceral fat area is more strongly associated with postoperative complications than BMI [11, 12]. However, estimating visceral fat requires special equipment and technical capabilities that are difficult to procure.

During LDG, suprapancreatic lymph node dissection around the celiac artery involves the deepest surgical field in the body. Therefore, we hypothesized that the depth of the celiac artery in the body may serve as an index associated with operative difficulty, including a prolonged operation time. This study aimed to clarify the usefulness of measuring the depth of the celiac artery by using preoperative contrast-enhanced computed tomography (CECT) as a simple predictive index for longer operation time during LDG.

Material and Methods

Patients

From September 2012 to March 2016, 563 patients with gastric cancer underwent gastrectomy at the Hyogo Cancer Center, Japan. Of these patients, 236 underwent laparoscopic gastrectomy. A total of 160 patients underwent LDG with D1+ lymph node dissection, including 70 patients who were treated by surgeons who were board certified by the Japanese Society of Endoscopic Surgery (JSES). To be a board-certified surgeon of the JSES, an applicant is required to perform more than 20 laparoscopic gastrectomies or alternative advanced laparoscopic surgeries within 3 years. The applicant is also required to submit a non-edited video of these surgery for review by at least two board-qualified referees. Of the 70 patients, 4 patients were excluded, 3 patients were screened by non-CECT, and 1 patient had vascular anomaly of the common hepatic artery, which was not detected at the superior border of the pancreas and branched from the left gastric artery. Patients who underwent LDG with D2 lymph node dissection were also excluded. A total of 66 patients who underwent LDG with D1+ lymph node dissection were ultimately included. For generalization, we also investigated 84 patients treated by non-certified surgeons (among 90 patients, 6 patients were excluded due to screening by non-CECT or vascular anomaly).

In this retrospective study, the International Union Against Cancer TNM staging system was used for gastric cancer staging [13]. The lymph node stations and tumor locations were defined using the Japanese Gastric Cancer Association definitions (JGCA) [14].

The clinical, surgical, and pathological records of the patients were obtained from our database and individual electronic medical records. The data collection and

analysis were approved by the institutional review board of the Hyogo Cancer Center.

The patients were divided into two groups based on the median operation time (time scenarios from greater omentum incision to specimen extirpation and infrapyloric and suprapancreatic lymph node dissections were assessed). Certified surgeons (H.G. and S.K.) reviewed all surgical videos and measured operation times using a protocol defined for each scenario. The measurement of infrapyloric lymph node dissection (I-LND) time started from exposure of the right gastroepiploic vein. The right gastroepiploic vein was divided and the adipose tissue containing lymph nodes was dissected from the pancreas. The right gastroepiploic artery was exposed and divided. I-LND time was measured until dividing of the infrapyloric vessels. Suprapancreatic lymph node dissection (S-LND) time was measured starting from the cutting of the suprapancreatic membrane. The adipose tissue containing lymph nodes was dissected along the common hepatic artery. The right gastric artery and vein were exposed and divided. The left gastric artery and vein were exposed and divided. S-LND time was measured until dissection of the adipose tissue containing lymph nodes along the celiac artery. The factors eliciting an operation time longer than or equal to the median operation time were investigated. We excluded cases involving reconstruction because the reconstruction procedure was performed with the intracorporeal or extracorporeal approach. Additionally, we compared operation times for 33 cases of anterior half and 33 cases of posterior half to investigate the influence of a surgeon's learning curve. On the other hand, for the patients treated by non-certified surgeons, we investigated only total operation times by extracting data from operative records because most video data were not available.

Surgical procedures

LDG was performed using five trocars. The first 12-mm trocar was inserted transumbilically, and 12-mm and 5-mm trocars were inserted above and to the right of the umbilicus. Two additional 12-mm trocars were inserted above and to the left of the umbilicus. The carbon dioxide pneumoperitoneum was maintained at 10 mmHg and the patients were positioned on the operating table with the head elevated. Lymph node dissection was performed using an ultrasonically activated device through the four operative trocars. The definition of D1+ lymph node dissection was consistent with the JGCA guidelines [15]. D1+ lymph node dissection involves removal of the perigastric lymph nodes and stations 7 (along the trunk of the left gastric artery), 8a (along the common hepatic artery), and 9 (along the celiac artery). All cases were completed with the same operative procedure during lymph node dissection. In our institution, LDG with D1+ lymph node dissection is indicated for cT1N0 tumors that do not meet the criteria for endoscopic mucosal and submucosal resection [15]. We performed reconstruction after the specimens were extirpated. For the anastomosis technique, Billroth I reconstruction was the first choice. However, Roux-en-Y reconstruction was performed when excessive tension was expected in the anastomosis and when the patient had a hiatal hernia or reflux esophagitis.

Definition of the depth of the celiac artery from the abdominal wall

We reviewed the preoperative CECT images of all patients and identified the skin surface and the celiac artery bifurcation using the axial view. In all cases, we determined cancer staging using CECT in the supine position. Subsequently, the shortest distance from the skin surface to the bifurcation of the celiac artery was

measured (Fig. 1). The shortest distance from the skin to the bifurcation of the celiac artery was defined as the ‘skin-to-celiac artery distance (SCD)’.

Statistical analysis

All statistical analyses were performed with JMP version 11.0 software (SAS Institute Inc., Cary, NC, USA). Categorical variables are presented as numbers (percentages). The groups were compared using the Chi-squared or Fisher’s exact test. All continuous variables are presented as the medians (range). The medians were compared using the Mann -Whitney test. *P*-values less than 0.05 were considered significant. A multivariate logistic regression model was used to adjust for potential confounding factors. Variables that achieved a probability value less than 0.05 in the univariate analysis were subsequently introduced into the multivariate analysis.

Receiver operating characteristic curve

The receiver operating characteristic (ROC) curve plots the sensitivity of a test versus its false positive rate (1 - specificity) for all possible cut points. The area under the ROC curve (AUC) is an indicator of test accuracy. The precise cutoff level was determined using the AUC and the highest sum values of sensitivity and specificity as indicators [16]. In this study, the ROC curve of the predictive factor for longer operation time was used to identify the appropriate cutoff level to predict operation times longer than or equal to the median operation time.

Postoperative outcomes

The patients were divided into two groups based on the cutoff level of the

predictive factor for longer operation time calculated by the ROC curve. Postoperative C-reactive protein (CRP) levels and hospital stay were compared between the two groups.

Results

Patient characteristics and surgical outcomes

The clinicopathological characteristics and surgical outcomes of the 66 patients included in this study are summarized in Table 1. More than two-thirds of the patients were male. The median age and median BMI were 64 years, and 22.7 kg/m^2, respectively. Sixty-two (94%) of the patients had pStage I disease. The median operation time was 274 (range, 184 -444) min, and the median blood loss was 30 (range, 5 -200) ml. The proportions of Billroth I and Roux-en-Y reconstruction were 65.2% and 34.8%, respectively. The median number of retrieved lymph nodes was 46 (range, 19 -88). No conversion to an open procedure occurred. With regard to postoperative intraabdominal infections (grade II or higher in the Clavien -Dindo classification), pancreas-related infection occurred in two patients (3.0%), but anastomotic leakage and intraabdominal abscess were not observed [17]. No deaths occurred in this study.

Factors causing an operation time longer than the median operation time

The univariate and multivariate analyses identified several factors that were associated with an operation time longer than the median operation time (Tables 2 -4). During the operation time from greater omentum incision to specimen extirpation, no significant differences were found in age, sex, tumor location, histological type, retrieved lymph nodes, or blood loss between the two groups. BMI and thickness of subcutaneous fat (TSF) were significantly associated with an operation time longer than the median operation time ($P=0.002$, $P=0.039$). SCD was also significantly associated with an operation time longer than the median operation time ($P<0.001$). The multivariate analysis showed that SCD was the only significant independent factor for

an operation time longer than the median operation time (*P=0.001*) (Table 2). The operation time during I-LND is shown in Table 3. BMI, TSF, and SCD were significantly associated with an operation time longer than the median operation time (*P=0.008, P=0.022, P<0.001*). The multivariate analysis showed that SCD was the only significant independent factor for an operation time longer than the median operation time (*P=0.003*). The results for S-LND are shown in Table 4. BMI and SCD were significantly associated with an operation time longer than the median operation time (*P<0.001, P<0.001*). The multivariate analysis showed that SCD was the only significant independent factor for an operation time longer than the median operation time (*P<0.001*).

Appropriate cutoff level of SCD

To identify the appropriate cutoff level of SCD to predict operation times longer than or equal to the median operation time, we calculated the ROC curve (Fig. 2). The best cutoff level of SCD to predict an operation time from greater omentum incision to specimen extirpation was 88 mm. For the operation times during I-LND and S-LND, the best cutoff levels of SCD were 81 and 88 mm, respectively.

Postoperative outcomes

The relationship between postoperative outcomes and the cutoff level of SCD calculated by the ROC curve is shown in Table 5. A long SCD was significantly associated with high postoperative CRP levels (days 1, 3, and 7) and long hospital stay (*P=0.019*, *P<0.001*, *P<0.001*, *P=0.013*).

Certified surgeons' learning curve

The median operation times for anterior half cases (until specimen extirpation, during I-LND and S-LND) were 167 (range, 79 -242) min, 30 (range, 14 -72) min, and 53 (range, 26 -91) min, respectively. The median operation times for posterior half cases were 168 (range, 93 -307) min, 31 (range, 14 -73) min, and 47 (range, 29 -120) min, respectively. No significant differences were found in operation times between the two half cases (*P=0.862*, *P=0.574*, *P=0.626*).

Results of the patients treated by non-certified surgeons

For the patients treated by non-certified surgeons, the univariate and multivariate analyses identified several factors that were associated with an operation time longer than the median operation time (Table 6). No significant differences were found in age, tumor location, histological type, retrieved lymph nodes, blood loss, or TSF between the two groups. Sex, BMI, and SCD were significantly associated with an operation time longer than the median operation time (*P=0.014, P=0.003, P<0.001*). The multivariate analysis showed that SCD was the only significant independent factor for an operation time longer than the median operation time (*P=0.025*).

Discussion

The relationship between the surgical outcomes of laparoscopic gastrectomy and obesity as determined by BMI and visceral fat area has been increasingly reviewed [18, 19]. BMI is commonly used to classify obesity, but it does not always reflect the operative difficulty caused by extensive visceral fat in the surgical field. This study showed that the depth of the celiac artery in the body was significantly correlated with operation time. Furthermore, the distance from the skin to the celiac artery was a stronger predictive index for longer operation time than BMI during LDG. The present study was a precise investigation using video data of surgery performed by certified surgeons, and the results of the non-certified surgeons were the same. Therefore, SCD was available regardless of a surgeon's experience.

In laparoscopic surgery, surgeons often experience less mobility of the operative trocars in patients with extensive subcutaneous fat than in conventional cases. In this study, TSF correlated with longer operation time. However, SCD was the only significant independent factor for long operation time, possibly because SCD may reflect abdominal accessibility and a large physique. A long SCD may make it difficult to access a target in the abdominal cavity. Although we could not evaluate the distance to the celiac artery with pneumoperitoneum pressure, we consider that the distance to the target with pneumoperitoneum pressure is roughly proportional to the distance calculated by preoperative CT scan.

A few studies have reported that a large abdomen and extensive visceral fat are associated with longer operation time [20, 21]. This study is the first to investigate the correlation between a patient's abdominal shape and operation time during each step of lymph node dissection in LDG. A long SCD strongly correlated with operation time

during lymph node dissection in both the suprapancreatic step and the infrapyloric step. This finding was obtained even though the surgical field of I-LND is superficial in the body and far from the celiac artery. Because I-LND was performed from each patient's left side in this study, the distance from the skin to the surgical field of I-LND, which is located on the right side of a patient, may be longer than that of S-LND, which is located in the center of a patient. This is a possible reason that the cutoff level of SCD associated with longer operation time during I-LND was lower than that of S-LND. When the SCD is long, the distance from the skin to most surgical fields during lymphadenectomy in LDG may be long.

Some devices can be useful to shorten operation time during lymph node dissection in LDG in patients with a long SCD. First, rotation of the operating table may improve a narrow surgical field caused by abundant visceral fat [22]. Second, although we did not add any ports in the present study, an additional port may decrease operation time by shortening the distance from the skin to the deep surgical field in patients with a long SCD.

We also revealed that a long SCD is associated with high postoperative CRP levels and a long hospital stay. Furthermore, there was no correlation between operation time and postoperative CRP levels or hospital stay, and postoperative complications were very few. It is possible that in patients with a long SCD, some inflammatory reactions may be triggered that are not clinically evident (such as panniculitis), subsequently prolonging hospital stay.

The present study has several limitations. First, it was a retrospective study with a small sample size performed at a single institution. However, the quality of surgery for all cases was well controlled, with a stable operation time and few operative

complications by certified surgeons of laparoscopic surgery. Second, we did not compare our index with other methods of measuring the visceral fat area using special hardware such as Slim Vision (KGT, Tokyo, Japan) and Fat Scan software version 3 (N2 systems Inc., Osaka, Japan) [11, 18, 23]. However, SCD can be determined from conventional preoperative CT more easily and inexpensively than with the use of special hardware.

In conclusion, SCD is easily obtainable using preoperative CT images and serves as a predictive index for longer operation time in lymph node dissection during LDG. Even in patients with a low BMI, the SCD may be long. Therefore, the study of preoperative CT images is important for planning safe and unobstructed surgery.

Compliance with ethical standards

Conflicts of interest

The authors declare that they have no conflict of interest.

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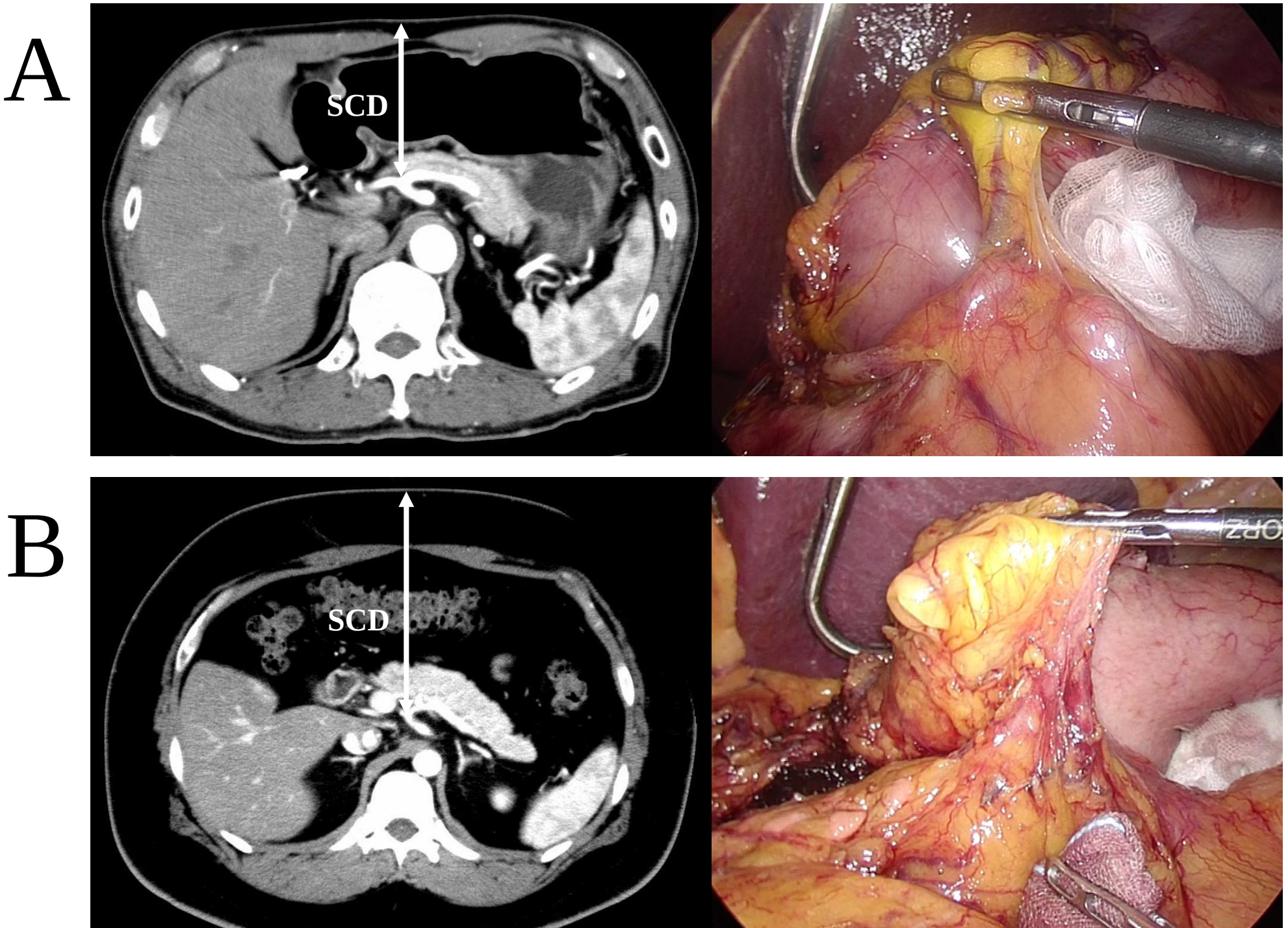
Figure legends

Fig. 1: Findings from enhanced computed tomography scans and the gastropancreatic fold in thin (A) and obese patients (B).

Fig. 2: Receiver operating characteristic (ROC) curve of skin-to-celiac artery distance (SCD) for an operation time from greater omentum incision to specimen extirpation that was longer than the median operation time (A)

ROC curve of SCD for operation time longer than the median operation time during infrapyloric lymph node dissection (B)

ROC curve of SCD for operation time longer than the median operation time during suprapancreatic lymph node dissection (C)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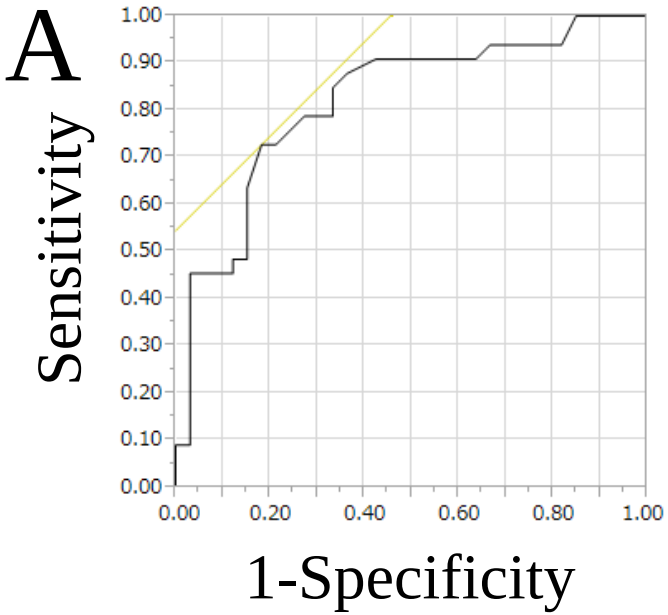
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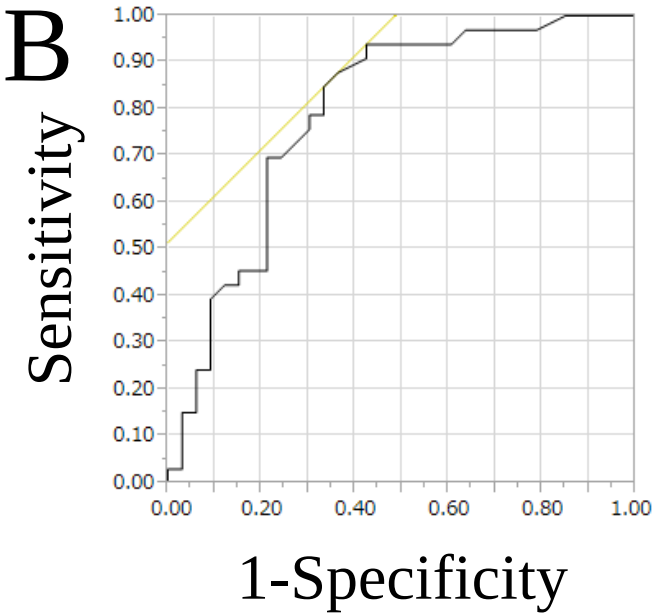
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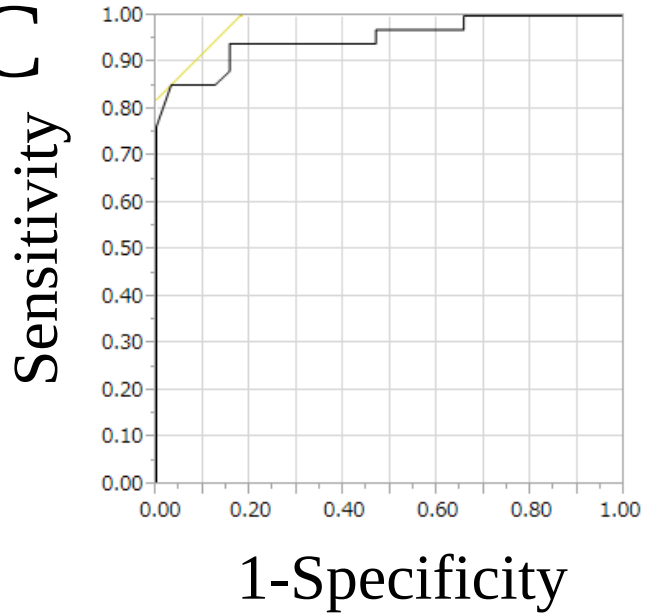
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Table 1: Clinicopathological characteristics

Parameters		n=66
Age	Median (range), y	64 (36–85)
Sex	Male	50 (75.8%)
	Female	16 (24.2%)
Body Mass Index	Median (range), kg/m^2	22.7 (17.0–35.9)
Tumor location	Upper	4 (6.1%)
	Middle	28 (42.4%)
	Lower	34 (51.5%)
Total Operation time	Median (range), min	274 (184–444)
Until specimen extirpation[a]	Median (range), min	167 (79–307)
Infrapyloric lymph node dissection[b]	Median (range), min	30 (14–73)
Suprapancreatic lymph node dissection[c]	Median (range), min	50 (26–120)
Blood loss	Median (range), ml	30 (5–200)
Type of reconstruction	Billroth I	43 (65.2%)
	Roux-en-Y	23 (34.8%)
Conversion to open procedure		0 (0%)
Retrieved lymph nodes	Median (range)	46 (19–88)
Histological type	Differentiated	35 (53.0%)
	Undifferentiated	31 (47.0%)
pStage	IA	55 (83.4%)
	IB	7 (10.6%)
	IIA	1 (1.5%)
	IIB	3 (4.5%)
Postoperative intraabdominal infectious[d]	Pancreas-related infection	2 (3.0%)
	Anastomotic leakage	0 (0%)
	Intraabdominal abscess	0 (0%)
Postoperative death		0 (0%)

[a] From greater omentum incision until specimen extirpation

[b] From exposure of the right gastroepiploic vein until dividing of the infrapyloric vessels

[c] From the cutting of the suprapancreatic membrance until dissection of the adipose tissue containing lymph nodes along the celiac artery

[d] Grade II or higher in Clavien-Dindo classification [17]

Table 2: Associations between patient characteristics and median operation time from greater omentum incision to specimen extirpation

	Univariate analysis			Multivariate analysis	
Parameters	Shorter group (n=33)	Longer group (n=33)	*P* value	Odds Ratio (95% CI)	*P* value
Age (years)	60 (40–85)	66 (36–84)	0.153		
Sex (male : female)	23:10	27 : 6	0.389		
Tumor location (middle : lower : upper)	16 : 14 : 3	12 : 20 : 1	0.261		
Histological type (differentiated : undifferentiated)	17 : 16	18 : 15	0.851		
Retrieved lymph nodes	45 (21–88)	46 (19–82)	0.753		
Blood loss (ml)	20 (5–100)	30 (10–150)	0.255		
Body mass index (kg/m^2)	21.1 (17.0–27.8)	23.2 (17.9–35.9)	0.002	1.15 (0.86–1.54)	0.354
Thickness of subcutaneous fat (mm)	11 (2–22)	13 (5–28)	0.039	0.96 (0.85–1.09)	0.559
SCD (mm)	70 (50–118)	92 (59–131)	< 0.001	0.91 (0.86–0.97)	0.001
Postoperative CRP levels (mg/dl)					
POD 1	4.6 (0.5–14.7)	6.5 (1.4–11.4)	0.407		
POD 3	5.8 (1.2–23.9)	8.8 (2.2–24.7)	0.203		
POD 7	1.5 (0.2–15.6)	3.3 (0.2–11.0)	0.083		
Postoperative hospital stay (days)	9 (8–30)	10 (8–38)	0.577		

SCD: Skin–to–celiac artery distance; *CI:* Confidence interval; *CRP:* C–reactive protein; *POD;* Postoperative days

Table 3: Associations between patient characteristics and median operation time during infrapyloric lymph node dissection[a]

	Univariate analysis			Multivariate analysis	
Parameters	Shorter group (n=33)	Longer group (n=33)	*P* value	Odds Ratio (95% CI)	*P* value
Age (years)	60 (40–85)	66 (36–84)	0.096		
Sex (male : female)	24 : 9	26 : 7	0.775		
Body mass index (kg/m^2)	21.0 (17.0–29.1)	23.0 (19.6–35.9)	0.008	1.13 (0.86–1.49)	0.369
Thickness of subcutaneous fat (mm)	11 (2–22)	13 (5–28)	0.022	0.94 (0.83–1.06)	0.289
SCD (mm)	69 (50–125)	90 (59–131)	< 0.001	0.92 (0.88–0.98)	0.003

SCD: Skin-to-celiac artery distance; *CI:* Confidence interval

[a] From exposure of the right gastroepiploic vein until dividing of the infrapyloric vessels

Table 4: Associations between patient characteristics and median operation time during suprapancreatic lymph node dissection[a]

	Univariate analysis			Multivariate analysis	
Parameters	Shorter group (n=32)	Longer group (n=34)	*P* value	Odds Ratio (95% CI)	*P* value
Age (years)	63 (40–85)	66 (36–80)	0.317		
Sex (male : female)	21 : 11	29 : 5	0.149		
Body mass index (kg/m^2)	20.2 (17.0–27.3)	24.2 (19.2–35.9)	< 0.001	0.92 (0.60–1.39)	0.686
Thickness of subcutaneous fat (mm)	11 (2–25)	13 (6–28)	0.122		
SCD (mm)	69 (50–88)	99 (61–131)	< 0.001	0.84 (0.76–0.93)	< 0.001

SCD: Skin-to-celiac artery distance; *CI:* Confidence interval

[a] From the cutting of the suprapancreatic membrance until dissection of the adipose tissue containing lymph nodes along the celiac artery

Table 5: The relationship between postoperative outcomes and SCD

Parameters	SCD < 88 mm (n=36)	SCD ≥ 88 mm (n=30)	*P* value
Postoperative CRP levels (mg/dl)			
POD 1	4.4 (0.5–10.5)	6.2 (1.4–14.7)	0.019
POD 3	4.3 (1.2–20.2)	9.2 (1.5–24.7)	< 0.001
POD 7	1.0 (0.2–6.9)	3.3 (0.2–15.6)	< 0.001
Postoperative hospital stay (days)	9 (8–12)	11 (8–38)	0.013

SCD: Skin-to-celiac artery distance; *CRP:* C-reactive protein; *POD;* Postoperative days

Table 6: Associations between patient characteristics and median operation time in patients treated by non-certified surgeons

	Univariate analysis			Multivariate analysis	
Parameters	Shorter group (n=42)	Longer group (n=42)	*P* value	Odds Ratio (95% CI)	*P* value
Age (years)	65 (30-89)	67 (34-83)	0.154		
Sex (male : female)	20 : 22	34 : 8	0.014	0.38 (0.13-1.14)	0.082
Tumor location (middle : lower : upper)	21 : 21 : 0	24 : 17 : 1	0.445		
Histological type (differentiated : undifferentiated)	23 : 19	27 : 15	0.505		
Retrieved lymph nodes	40 (22-80)	36 (19-70)	0.364		
Blood loss (ml)	20 (5-50)	30 (5-180)	0.056		
Body mass index (kg/m^2)	21.0 (16.0-26.1)	23.3 (16.6-30.8)	0.003	1.05 (0.81-1.39)	0.703
Thickness of subcutaneous fat (mm)	13 (4-28)	12 (2-31)	0.619		
SCD (mm)	75 (40-98)	94 (41-117)	< 0.001	0.95 (0.89-0.98)	0.025

SCD: Skin-to-celiac artery distance; *CI:* Confidence interval