Original communication:

Impact of the gastrojejunal anatomical position as the mechanism of delayed gastric emptying following pancreatoduodenectomy

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ABSTRACT

Objective: This study investigated the impact of gastrojejunal anatomical position on the incidence of delayed gastric emptying (DGE) following pancreatoduodenectomy.

Methods: A total of 160 patients were included in the retrospective analysis. The relative anatomical position of the gastrojejunostomy was evaluated using the coronal and sagittal plane images of computed tomography on postoperative day 7; the coronal cardia anastomotic angle (CCAA) and the sagittal fundus anastomotic angle (SFAA) were measured. In the validation study, 64 consecutive patients were enrolled, and gastric emptying was evaluated using water-soluble contrast medium. The extent of gastric emptying was graded as grade I (no gastric dilatation and no stasis), grade II (gastric dilatation but no stasis), and grade III (gastric dilatation and stasis).

Results: Patients with grades B (n=8) and C (n=22) DGE were included in the “DGE group” (n=30), and the others were included in the “non-DGE group” (n=130). The CCAA was not significantly different between the two groups, whereas the SFAA was significantly greater in the DGE group compared to the non-DGE group (median 50.3 vs. 64.5 degree, p<0.001). Multivariate analysis, including various risk factors of DGE, indicated that an SFAA >60 degrees was the only independent risk factor of DGE (odds ratio, 16.59). In the validation study, the median degree of SFAA increased as the gastric emptying grade increased (grade I, 44.3 degrees; grade II, 55.3 degrees; grade III, 60.7 degrees; p=0.014 by ANOVA).

Conclusions: The gastrojejunal anatomical position following pancreatoduodenectomy has a significant impact on the incidence of DGE.

INTRODUCTION

Delayed gastric emptying (DGE) is one of the most common complications following pancreatoduodenectomy, along with postoperative pancreatic fistula. There have been numerous reports in terms of the risk factors for DGE; these risk factors include the reconstruction method (1), high body mass index (BMI) (2-4), pancreatic fistula (5, 6), intraabdominal abscess (6, 7), diabetes (8), loss of gastrointestinal hormonal production (9), and others. However, none of these factors are definite causes of DGE, and the precise mechanism for the occurrence of DGE is still unclear.

Several studies have indicated that resection of the pyloric ring reduces the incidence of DGE following pancreatoduodenectomy (10, 11). In terms of the reconstruction method, the ante-colic gastrojejunal reconstruction is superior to the retro-colic method in reducing the incidence of DGE (1, 12). Therefore, since 2006, in the author's institution, subtotal stomach preserving pancreatoduodenectomy (SSPPD) with ante-colic gastrojejunal reconstruction have been routinely performed. However, the incidence rate of DGE has still been unsatisfactory.

A previous study from the authors' institution demonstrated that the relative anatomical position of gastrojejunostomy to the cardia has a significant impact on gastroesophageal reflux disease (GERD) following distal gastrectomy with Roux-en-Y reconstruction (13). The results of this study indicate the importance of the relative anatomical position of gastrojejunostomy for gastric emptying. Therefore, it can be hypothesized that the anatomical position of gastrojejunostomy also has an impact on the occurrence of DGE following pancreatoduodenectomy. However, this type of analysis has never been performed before.

In the current study, firstly, retrospective analysis for the impact of the relative anatomical position of the gastrojejunostomy, which is measured using the coronal and sagittal plane images from computed tomography (CT), on the incidence of DGE after SSPPD with ante-colic reconstruction was performed. Subsequently, a validation study was performed to investigate the correlation between the relative anatomical position of the gastrojejunal anastomosis and gastric emptying evaluated using water-soluble contrast medium (Gastrografin®).

PATIENTS AND METHODS

Patients

In the retrospective analysis, patients who underwent SSPPD from January 2006 to July 2015 in the Department of Surgery, Nagoya University Hospital in Nagoya, Japan, were included to determine the importance of gastrojejunal anatomical position for the incidence of DGE. Furthermore, prospective data collection, including CT scan and upper gastrointestinal series on postoperative day (POD) 7, was performed as part of a validation study from August 2015 to March 2017. The study protocol was approved by the Nagoya University Hospital Human Research Review Committee and was registered in the University Medical Information Network (http://www.umin.ac.jp/, ID; UMIN000016433).

Recording of Clinical Parameters

The following clinical parameters were recorded: age, gender, body mass index (BMI), history of diabetes mellitus, preoperative serum albumin level, preoperative diagnosis, the main pancreatic duct diameter measured by preoperative axial CT scan images, history of preoperative cholangitis, preoperative biliary drainage, operation time, intraoperative blood loss, and incidence of intraoperative allogenic blood transfusion. The texture of the pancreas was judged intraoperatively and recorded as “soft” or “hard” by the operating surgeon.

Postoperative complications were defined by the Clavien-Dindo classifications (14). The incidence of postoperative infectious complications, including wound infection, intra-abdominal abscess, sepsis, and pneumonia, were also recorded. Postoperative pancreatic fistula was classified according to the updated definition by International Study Group of Pancreatic Surgery (ISGPF) in 2016 (15). DGE was also classified according to the criteria of the ISGPF (16).

Surgical Procedure

In all patients, SSPPD was performed with the modified Child reconstruction methods. The stomach was resected at 3 cm on the oral side of the pyloric ring. As the first step in reconstruction, the proximal jejunum was brought up through the transverse mesocolon, and a hepaticojejunostomy was performed. Subsequently, a pancreatojejunostomy was performed using either a duct-to-mucosa or an invagination procedure (17). Thereafter, a loop of jejunum approximately 40 to 60 cm distal to the hepaticojejunostomy was brought up in the antecolic manner, and an end-to-side gastrojejunostomy with an anti-peristaltic fashion was performed. In all cases, a polyethylene knotted pancreatic duct drainage tube (Sumitomo Bakelite Co., Tokyo, Japan) was inserted into the main pancreatic duct of the remaining pancreas, and the tube was exteriorized through the end of the blind loop of the jejunum. Different sizes of pancreatic duct drainage tubes (4–7.5 Fr) were used depending on the size of the main pancreatic duct. An 8-Fr polyethylene jejunal tube was separately inserted as a route for enteral nutrition and replacement of drained pancreatic juice. The tip of this enteral tube was placed distal to the gastrojejunal anastomosis. When the Braun enteroenterostomy was performed, it was added 20 cm distal to the gastrojejunostomy with an approximately 3 cm anastomotic orifice. Part of the patients (n=68) were included in the randomized controlled study for Braun anastomosis registered in the University Hospital Medical

Information Network (http://www.umin.ac.jp; registration number ID 000006093) (18).

Postoperative Feeding

Enteral feeding was initiated on POD 1 with 250 ml of 5% dextrose solution and on POD 2 with 200 ml of an enteral nutrient (1 kcal/ml; ANOM®; Otsuka Pharmaceutical Factory, Tokushima, Japan). Feeding was then increased gradually to 1,200 ml/day by POD 7. Patients usually began fluid intake on POD 2 and oral feeding on POD 4, and enteral feeding was gradually decreased as oral intake increased. Total parenteral nutrition was not used, and the central venous catheter inserted in the operating room was removed on POD 1.

Evaluation of the Anatomical Position of the Gastrojejunostomy to the Cardia and Fundus

The relative anatomical position of the gastrojejunostomy to the cardia or fundus was measured using the coronal images or multi-planar reconstructed sagittal images obtained via multi-detector (MD)-CT on POD 7 (Figure 1). The relative lateral position of the gastrojejunostomy to the cardia was evaluated using the coronal plane images, whereas the relative ventral position of the gastrojejunostomy to the fundus was evaluated using the sagittal plane images. The center of the esophagogastric (EG) junction was defined as point A in the coronal plane images. The center of the gastrojejunostomy was defined as point B in both the coronal and sagittal plane images (Figure 1). The utmost dorsal position of the gastric fundus was defined as point C in the sagittal plane. The point where the vertical line from point A intersects the horizontal line from point B was defined as point Oc in the coronal plane images. Similarly, the point where the vertical line from point C intersects the horizontal line from point B was defined as point Os in the sagittal plane images. ∠OcAB was defined as the coronal cardia anastomotic angle (CCAA), and ∠OsCB was defined as the sagittal fundus anastomotic angle (SFAA).

Upper Gastrointestinal Series

In the validation study, all patients underwent oral intake of 50 ml Gastrografin® in a standing position on POD 7. Gastric emptying was monitored by radiographic video for one minute. The extent of gastric emptying was graded as follows: Grade I, no gastric dilatation and no gastric stasis; Grade II, gastric dilatation but no gastric stasis; and Grade III, gastric dilatation and gastric stasis (Figure 2).

Statistical Analysis

The data were analyzed using JMP® version 11 for Windows® (SAS Institute Inc., Cary, NC, USA). Data were expressed as medians and ranges for continuous variables. Continuous data were compared between the two groups using the Mann-Whitney U test. Categorical data were compared using the χ^2 test or Fisher's exact test, as appropriate. The predictive value of the gastrojejunal anatomical parameter for DGE was assessed using a receiver operating characteristic (ROC) curve analysis, and the area under the ROC curve (AUC) was calculated to determine the cut-off value. Cut-off values were determined to maximize the Youden index (sensitivity + specificity - 1), and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated for these cut-off values. The correlation between the two variables was determined by Spearman's rank correlation coefficient. Multiple logistic regression analysis was used to examine the associations between the incidence of DGE and various clinical factors. The one-way analysis of variance (ANOVA) and post hoc test were used to determine whether there were any statistically significant differences among the multiple groups. A P value <0.05 was considered as statistically significant.

RESULTS

Retrospective Study

In the retrospective analysis, 11 patients with postoperative complications with Clavien-Dindo (14) scores IV and V (2 patients with surgery-related death) were excluded because these patients could not start oral intake due to re-operation, intubation in the intensive care unit, or unstable general condition. Additionally, 21 patients were excluded because they did not undergo a CT scan after surgery. Consequently, a total of 160 patients were enrolled in this study. All CT scans were performed on POD 7.

Preoperative characteristics

Among 160 analyzed patients, 12 patients (8%) developed grade A, 8 patients (5%) developed grade B, and 22 patients (14%) developed grade C DGE. Patients with grades B and C DGE were defined as the "DGE group" and the others as the "non-DGE group". The preoperative patient characteristics in both the DGE (n=30) and non-DGE (n=130) groups are summarized in Table 1. No significant differences were observed between the DGE and non-DGE groups in terms of the preoperative characteristics.

Intraoperative characteristics

With respect to intraoperative characteristics, the operation time and intraoperative blood loss were not significantly different between the two groups (Table 1). In both groups, more than 60% of patients had a soft pancreas. The variability of operative procedures, including Braun anastomosis, type of pancreatojejunostomy, and combined portal vein resection, were comparable between the two groups.

Postoperative complications

The incidence rate of major complications with Clavien-Dindo score III was significantly higher in the DGE group (Table 1). The incidence of grade B/C pancreatic fistula was not significantly different between the two groups. Among the infectious complications, the incidence rate of an intra-abdominal abscess was significantly higher in the DGE group compared to the non-DGE group. The postoperative hospital stay was significantly longer in the DGE group compared to the non-DGE group.

Relative anatomical position of the gastrojejunostomy

The degree of the CCAA was not significantly different between the two groups (Figure 3). In sharp contrast, the degree of SFAA was significantly greater in the DGE group compared to the non-DGE group. The ROC curve analysis indicated that the optimal cut-off value of SFAA in predicting the occurrence of DGE was 60 degrees (Figure 4).

Clinical factors associated with SFAA

There was a positive correlation between BMI and SFAA ($p=0.001$), although the correlation coefficient was not high (Spearman's rho =0.256) (Supplementary Figure). Moreover, SFAA was significantly higher in patients with postoperative pancreatic fistula, intra-abdominal abscess, and major complication with Clavien-Dindo score III or more (Supplementary Table).

Factors associated with DGE (multivariate analysis)

Multivariate analysis was performed by including the possible risk factors of DGE, such as high BMI, diabetes mellitus, Braun anastomosis, operation time, intraoperative blood loss, pancreatic fistula, intraabdominal abscess, and an SFAA >60 degrees. Among these risk factors, only an SFAA >60 degrees was identified as an independent risk factor of DGE (odds ratio, 16.59; 95% confidence interval, 6.07–50.50; Table 2).

Prospective Validation Study

Sixty-four consecutive patients who underwent SSPPD were enrolled in the validation study (from August 2015 to April 2017). All patients agreed with the participation of this study and no patient was excluded. Among them, clinically significant DGE was observed in four patients. As was observed in the retrospective analysis, SFAA was significantly greater in patients with DGE (62.4 degrees) compared to those without DGE (46.7 degrees) (p=0.023). The gastric emptying defined by upper gastrointestinal series was graded as grade I in 46 patients, grade II in 14 patients, and grade III in 4 patients (Figure 5). The incidence rates of DGE were 0% in grade I, 14% (n=2) in grade II, and 50% (n=2) in grade III. The median degree of SFAA increased as gastric emptying grade increased (44.3 in grade I, 55.3 in grade II, and 60.7 in grade III). Non-parametric ANOVA revealed a significant difference in the degree of SFAA among the three grades (p=0.014). Furthermore, post hoc analysis indicated that the degree of SFAA was significantly greater in patients with grade III compared to those with grade I (p=0.015). The degree of SFAA also tended to be greater in patients with grade II compared to those with grade I (p=0.056).

DISCUSSION

The current study clearly demonstrated that the gastrojejunal anatomical position following the antecolic reconstruction of a gastrojejunostomy plays a key role in developing DGE following pancreatoduodenectomy. Although there have been numerous reports in terms of the incidence and risk factors for DGE (19-22), previous reports simply correlated the clinical factors and the occurrence of DGE, while the mechanism of DGE has not been fully investigated. This study sought to clarify the mechanism of DGE from anatomical configuration viewpoints. In the retrospective analysis, with multivariate analysis including various clinical risk factors of DGE, a greater ventral deviation of gastrojejunostomy in a sagittal plane (SFAA >60 degrees) was identified as the only significant independent risk factor of DGE with a high odds ratio. The impact of other risk factors such as high BMI, pancreatic fistula, and intra-abdominal abscess were much less than high SFAA. In contrast to the deviation of gastrojejunostomy in the sagittal plane, that in the coronal plane did not have any impact on the incidence of DGE. Moreover, in the validation study, the extent of gastric emptying, evaluated using water-soluble contrast medium on POD 7, was correlated with the degree of SFAA. These results clearly indicated that the ventral deviation of gastrojejunostomy has a significant impact on the incidence of DGE.

In general, DGE occurs within one week after surgery and lasts for 3 to 4 postoperative weeks in severe cases. However, symptoms of DGE usually subside over the postoperative course without any interventional treatment. In this study, CT scans were performed only on POD 7 and were not performed after the symptoms of DGE had subsided. Therefore, the difference between SFAA measured on POD 7 and that measured after the recovery from DGE is unknown. Nevertheless, the anatomical position of gastrojejunostomy may not change much during the first 3 to 4 weeks after surgery. In fact, even after 3 to 6 months after surgery, SFAA measured by CT scan images taken as an outpatient follow up was not significantly different from that measured on POD 7 (data not shown). Therefore, it is speculated that the anatomical position of gastrojejunostomy (static factor) is important for the development of DGE in the early postoperative course because gastric motility (dynamic factor) has not fully recovered during this period. However, in the late phase after surgery, gastric motility might be recovered, and the gastric contents can be emptied irrespective of the unfavorable anatomical configuration of gastrojejunostomy. To test this hypothesis, gastric motility (dynamic factor) in early and late phases after pancreatoduodenectomy and its association with the incidence of DGE should be evaluated in a future study.

Through this study, it was found that the anatomical position of gastrojejunostomy (SFAA) had a significant impact on the incidence of DGE. Then, what should be done to prevent the incidence of DGE throughout the perioperative course? First of all, one should be conscious of creating the ideal angle in the sagittal plane as much as possible during surgery. As indicated in this study, BMI was significantly correlated (although the correlation coefficient was not high) to SFAA meaning that high amount of intra-abdominal fat may increase the degree of SFAA. However, the amount of intra-abdominal fat is not easy to change. Therefore, it may be difficult to decrease SFAA by the surgical approach alone. It was also found that SFAA was significantly higher in patients with postoperative pancreatic fistula, intra-abdominal abscess, and major complications. These results imply that intra-abdominal inflammation (mostly induced by pancreatic fistula after pancreatoduodenectomy) may induce severe adhesion around the gastrojejunostomy and pull up the anastomotic site to the ventral side and finally increase SFAA. Therefore, it may be better to prevent the incidence of pancreatic fistula as much as possible. However, it is also difficult to prevent especially in patients with soft pancreas and small main pancreatic duct diameter. One of the solutions for patients with high SFAA is to let them lean forward after a meal to offset an unfavorable anatomical configuration (to decrease SFAA) and to facilitate gravity-dependent emptying from the stomach (Figure 6). In fact, two patients with gastric emptying grade III did not have clinically significant DGE. In these patients, the gastric content was smoothly emptied, in spite of high SFAA, while they were taking a position of leaning forward.

In terms of the reconstruction procedure, one of the possible suggestions is to fix the gastrojejunostomy at the caudal side of the transverse colon to decrease SFAA. Reconstructing the gastrojejunostomy in a retrocolic manner may also decrease SFAA. However, several previous reports (1, 12) and meta-analyses (22, 23) have already indicated that the incidence of DGE is even higher in patients with retrocolic reconstruction compared to those with antecolic reconstruction. It is speculated that the mechanism of DGE may be different between cases of antecolic and retrocolic reconstructions. This controversial issue should be further addressed in a future study.

There are several limitations in this study. This was a single institutional study that included only a small number of patients. A large-scale, prospective, and multiple institutional study should be performed to confirm the importance of the relative anatomical position of gastrojejunostomy to the gastric fundus in patients undergoing pancreatoduodenectomy. Previously, reported risk factors of DGE, such as high BMI (7), diabetes mellitus (8), Braun anastomosis (24-26), and the incidence of pancreatic fistula (6, 27-30), did not show any association with the incidence of DGE in the current study. Only an incidence of intraabdominal abscess was significantly associated with the incidence of DGE. Nevertheless, as shown in the multivariate analysis, a large SFAA (>60 degrees) was identified as the only independent risk factor of DGE and its effect may overwhelm other previously reported risk factors of DGE.

In conclusion, for the first time, this study reported the importance of the anatomical position of the gastrojejunal anastomosis as a risk factor for DGE following antecolic reconstruction in patients undergoing pancreatoduodenectomy. A greater ventral deviation of the gastrojejunostomy relative to the gastric fundus may require a stronger gastric peristalsis to empty the gastric contents against gravity, which may be a major mechanism of DGE.

FIGURE LEGENDS

Figure 1

Method for measurement of the relative anatomical position of the gastrojejunostomy to the cardia or gastric fundus. The center of the esophagogastric (EG) junction was defined as point A (coronal plane). The utmost dorsal position of the gastric fundus was defined as point C (sagittal plane). The center of the gastrojejunostomy was defined as point B (coronal and sagittal planes). ∠OcAB was defined as the coronal cardia anastomotic angle (CCAA), whereas ∠OsCB was defined as the sagittal fundus anastomotic angle (SFAA).

Figure 2

Gastric emptying grade evaluated in an upper gastrointestinal series.

Figure 3

Coronal cardia anastomotic angle (CCAA) and sagittal fundus anastomotic angle (SFAA) in patients with and without DGE.

Figure 4

The ROC curve of the sagittal fundus anastomotic angle (SFAA) for predicting DGE.

Figure 5

Gastric emptying grade and SFAA.

Figure 6

Upper gastrointestinal series in a patient with DGE and gastric emptying grade III. Severe stasis of Gastrografin® was observed (SFAA=67 degree) in a standing position. However, the gastric contents were emptied smoothly in a bending position (SFAA decreased to 37 degree).

Supplementary Figure

Correlation between the body mass index (BMI) and sagittal fundus anastomotic angle (SFAA). A, retrospective cohort (n=160); B, prospective validation cohort (n=64).

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TABLE 1.
Characteristics of the enrolled patients

	Non-DGE (n=130)	DGE (n=30)	P value
Preoperative characteristics			
Age [years]	66 (36-85)	67 (48-86)	0.392
Gender, male/female	87/43	21/9	0.746
Body mass index [kg/m^2]	21.3 (15.2-37.8)	21.0 (15.4-25.8)	0.603
Diabetes mellitus, n (%)	30 (23.1)	5 (16.7)	0.444
Serum albumin [g/dl]	3.8 (2.5-5.0)	4.0 (1.6-4.8)	0.184
Diagnosis, n (%)			0.883
Pancreatic cancer	48 (36.9)	9 (30.0)	
Cholangiocarcinoma	33 (25.4)	7 (23.3)	
Intraductal papillary mucinous neoplasm	16 (12.3)	4 (13.3)	
Ampullary carcinoma	14 (10.8)	5 (16.7)	
Others*	19 (14.6)	5 (16.7)	
Main pancreatic duct diameter [mm]	3.1 (1.0-15.6)	3.1 (1.8-9.7)	0.739
Preoperative cholangitis, n (%)	11 (8.5)	1 (3.3)	0.336
Preoperative biliary drainage, n (%)	69 (53.1)	15 (50.0)	0.761
Intraoperative characteristics			
Operation time [min]	492 (295-1006)	512 (343-1143)	0.387
Blood loss [ml]	1103 (99-6851)	1189 (89-10639)	0.552
Allogenic blood transfusion, n (%)	33 (25.4)	8 (26.7)	0.885
Braun anastomosis, n (%)	37 (28.5)	14 (46.7)	0.054
Soft pancreas, n (%)	84 (64.6)	21 (70.0)	0.576
Pancreatojejunostomy procedure, n (%)			0.464
Duct-to-mucosa	121 (93.1)	29 (96.7)	
Invagination	9 (6.9)	1 (3.3)	
Combined portal vein resection, n (%)	28 (21.6)	2 (6.7)	0.060
Postoperative complications and hospital stay			
Major complications (C-D score >III), n (%)	59 (45.4)	22 (73.3)	0.006
Pancreatic fistula (Grade B, C)	36 (27.7)	11 (36.7)	0.331
Infection complication, n (%)	33 (25.4)	10 (33.3)	0.376
Wound infection	12 (9.2)	4 (13.3)	0.500
Intra-abdominal abscess	15 (11.5)	9 (30.0)	0.011
Sepsis	13 (10.0)	2 (6.7)	0.572
Pneumonia	4 (3.1)	2 (6.7)	0.351
Postoperative hospital stay [day]	29 (11-116)	43 (25-109)	<0.001

Continuous variables are expressed as the median (range).

* "Others" includes duodenal tumors (n=9), pancreatitis (n=7), pancreatic neuroendocrine tumors (n=4), pancreatic cystic tumors (n=3), and gallbladder carcinoma (n=1).

TABLE 2.
Risk factors associated with the incidence of DGE

Variables	No. of patients	No. of patients with DGE (%)	Multivariate	
			Odds ratio (95% C.I.)	P value
Body mass index [kg/m^2]				0.060
≤21	75	16 (21.3)	1.00	
>21	85	14 (16.5)	0.37 (0.12-1.04)	
Diabetes				0.520
No	125	25 (20.0)	1.00	
Yes	35	5 (14.3)	0.66 (0.16-2.29)	
Braun anastomosis				0.082
No	109	16 (14.7)	1.00	
Yes	51	14 (27.5)	2.57 (0.93-7.38)	
Operation time [min]				0.257
≤500	85	14 (16.5)	1.00	
>500	75	16 (21.3)	1.80 (0.65-5.16)	
Blood loss [ml]				0.573
≤1000	69	12 (17.4)	1.00	
>1000	91	18 (19.8)	0.74 (0.25-2.13)	
Pancreatic fistula (Grade B, C)				0.834
No	113	19 (16.8)	1.00	
Yes	47	11 (23.4)	0.86 (0.18-3.42)	
Intra-abdominal abscess				0.156
No	136	21 (15.4)	1.00	
Yes	24	9 (37.5)	3.11 (0.65-16.12)	
SFAA [degree]				<0.001
≤60	127	11 (8.7)	1.00	
>60	33	19 (57.6)	16.59 (6.07-50.50)	

95% C.I., 95% confidence interval; SFAA, sagittal fundus anastomotic angle

SUPPLEMENTARY TABLE.
Postoperative factors and SFAA

	SFAA [degree]		
Retrospective cohort (n=160)	**Absent**	**Present**	**P value**
Pancreatic fistula (Grade B, C)	50.5 (15.1-89.7)	54.6 (29.4-75.9)	0.013
Intra-abdominal abscess	50.5 (15.1-89.7)	57.6 (29.4-75.9)	0.002
Major complications (C-D score=III)	50.0 (15.1-89.7)	53.9 (24.7-75.9)	0.005
Prospective validation cohort (n=64)	**Absent**	**Present**	**P value**
Pancreatic fistula (Grade B, C)	44.3 (19.6-76.4)	53.2 (40.0-68.7)	0.053
Intra-abdominal abscess	46.8 (19.6-76.4)	60.3 (42.4-68.7)	0.088
Major complications (C-D score=III)	46.5 (19.6-76.4)	55.1 (26.6-70.5)	0.103

Continuous variables are expressed as the median (range).
SFAA, sagittal fundus anastomotic angle

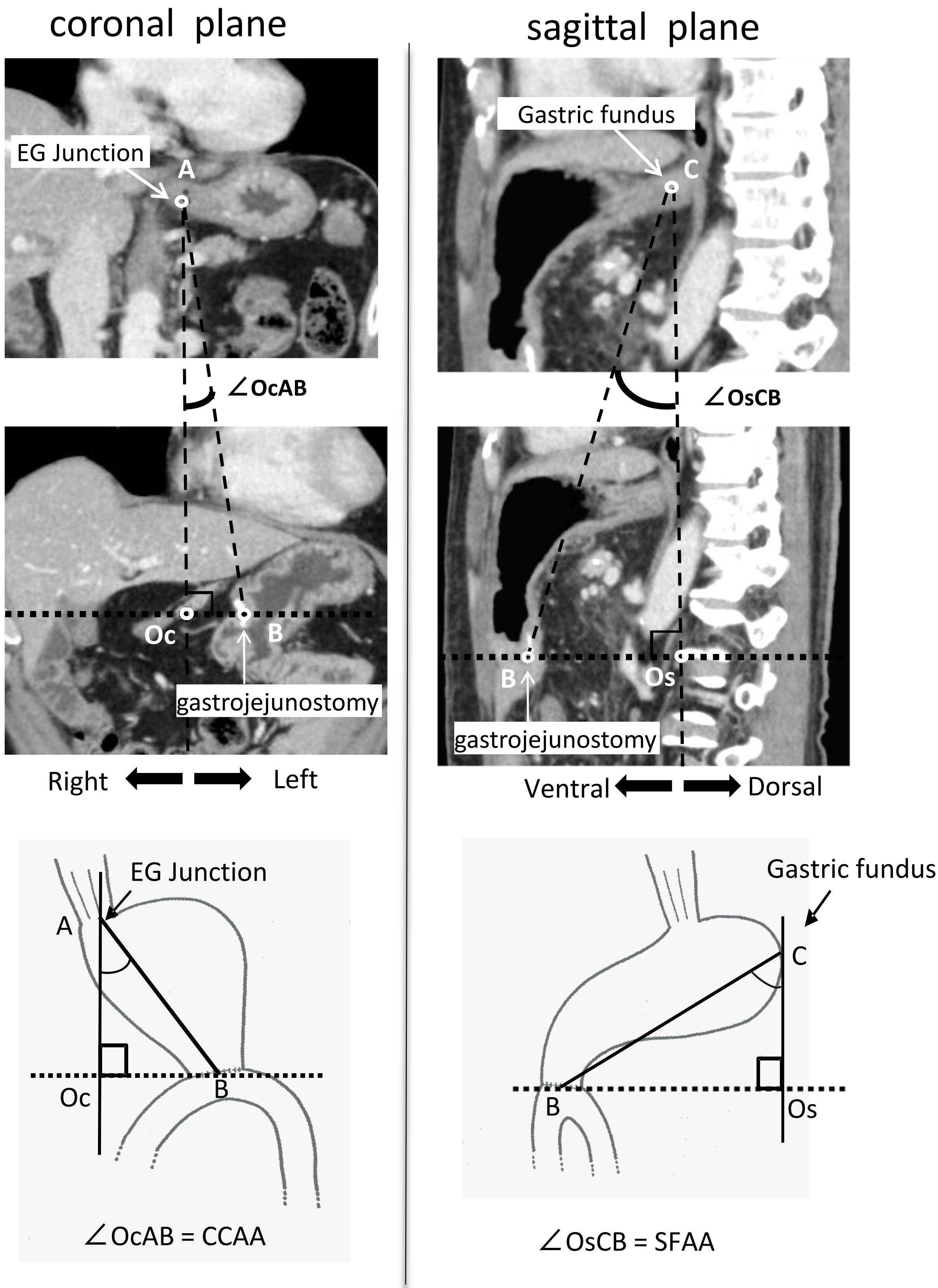
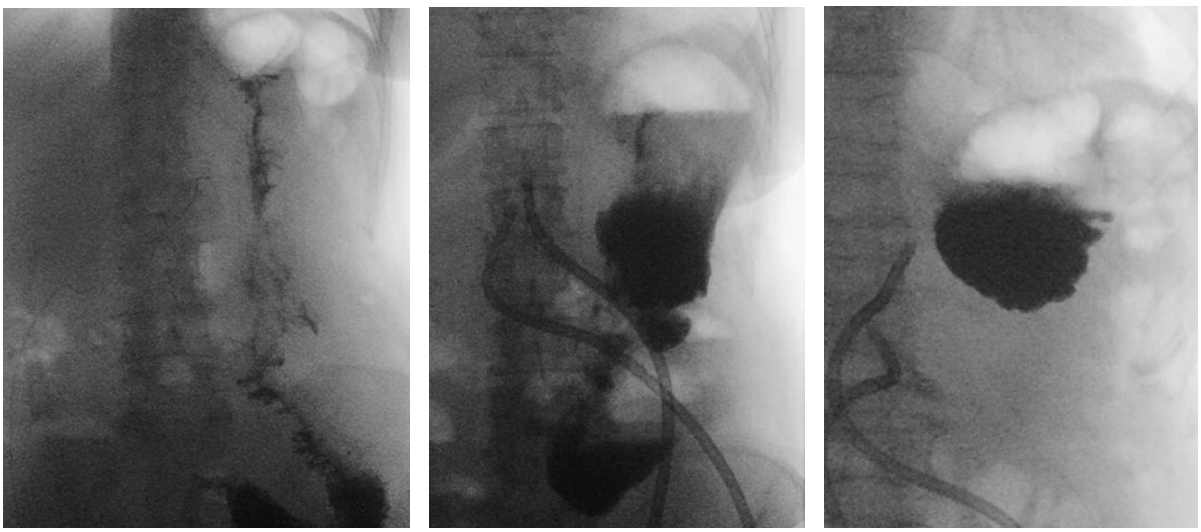

coronal plane
sagittal plane
EG Junction
A
Gastric fundus
C
∠OcAB
∠OsCB
Oc
B
gastrojejunostomy
Os
Right
Left
Ventral
Dorsal
∠OcAB = CCAA
∠OsCB = SFAA

Figure 1



Grade I

Gastric
dilatation (–)
stasis (–)

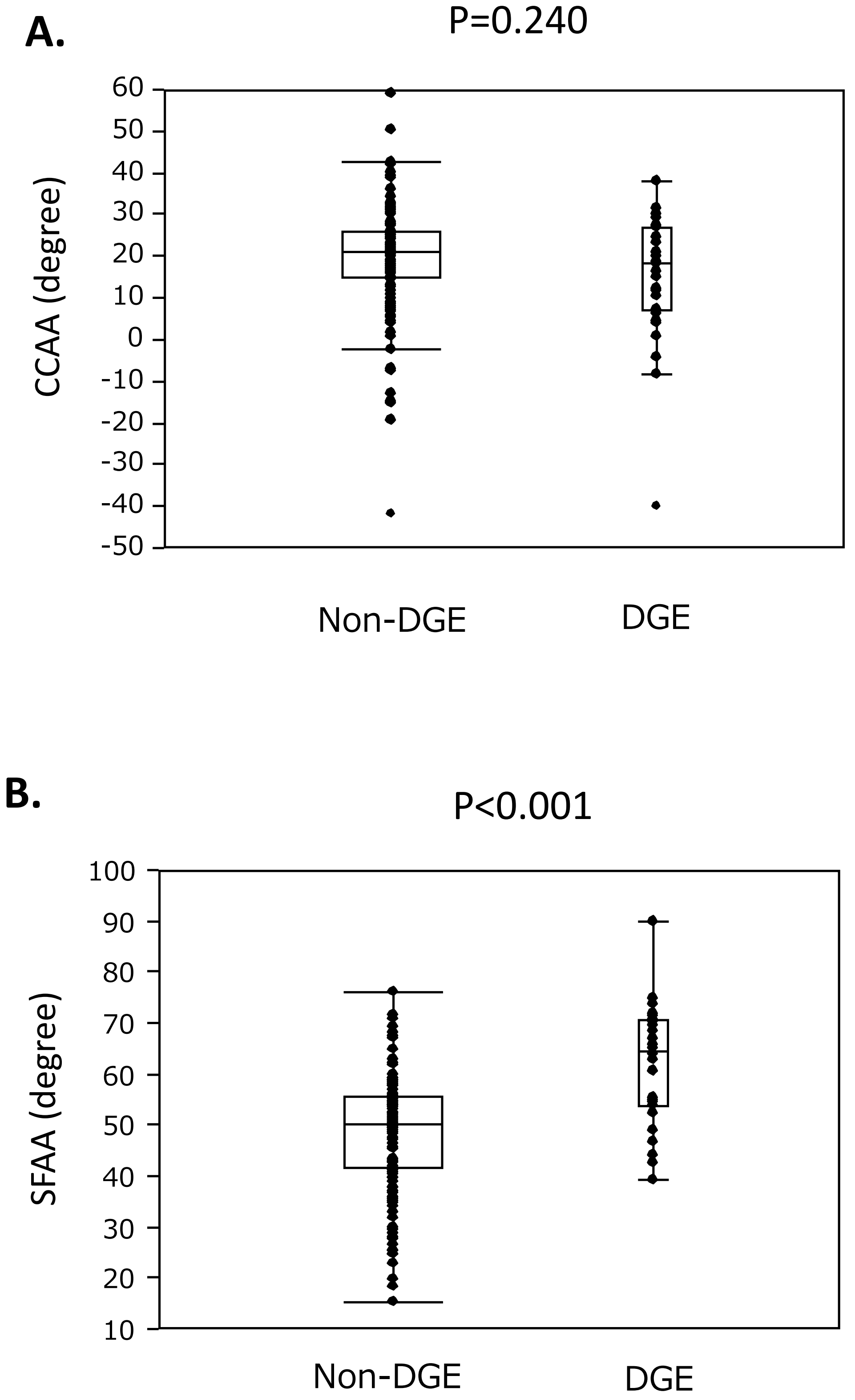
Grade II

Gastric
dilatation (+)
stasis (–)

Grade III

Gastric
dilatation (+)
stasis (+)

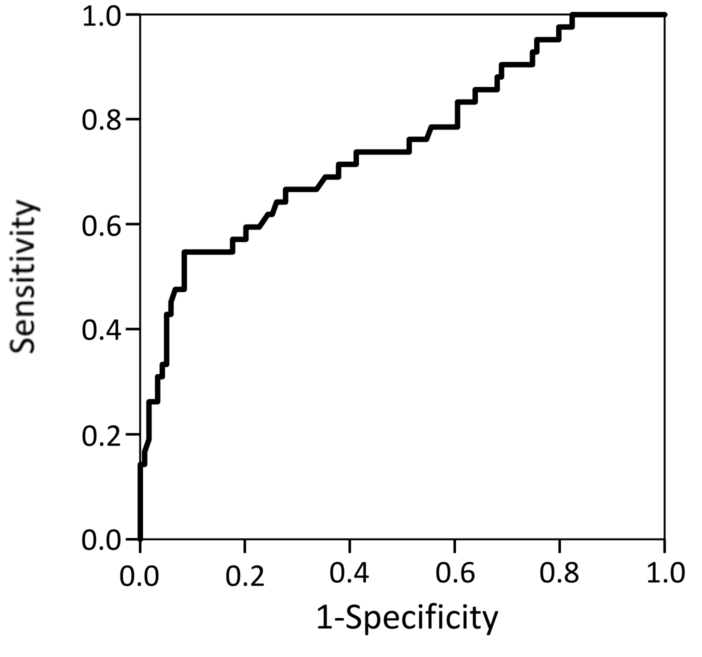
Figure 2



A.
P=0.240
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
CCAA (degree)
Non-DGE
DGE
B.
P<0.001
100
90
80
70
60
50
40
30
20
10
SFAA (degree)
Non-DGE
DGE

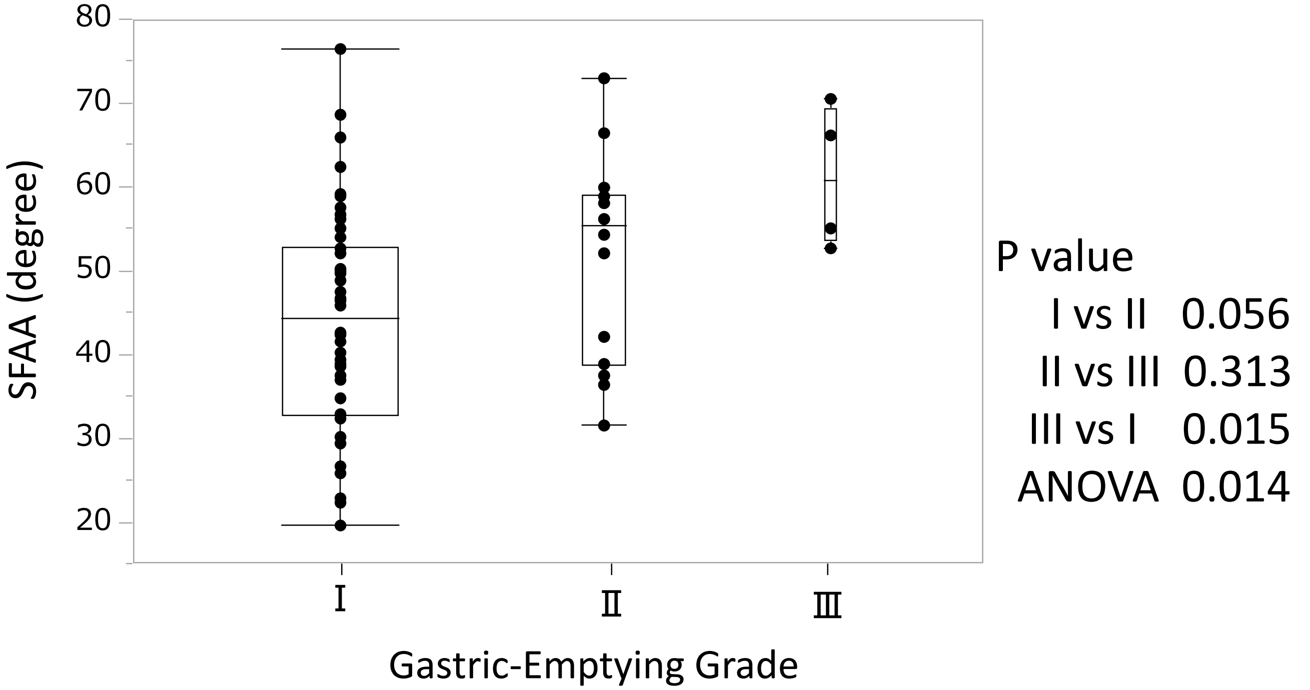
Figure 3

Sagittal Fundus Anastomotic Angle (SFAA)



AUC 0.79
Cut -off 60 degree
Sensitivity 63%
Specificity 89%
Positive Predictive Value 58%
Negative Predictive Value 91%

Figure 4



Gastric-Emptying Grade	I (n = 46)	II (n = 14)	III (n = 4)
DGE, n (%);	0 (0%)	2 (14%)	2 (50%)

Figure 5

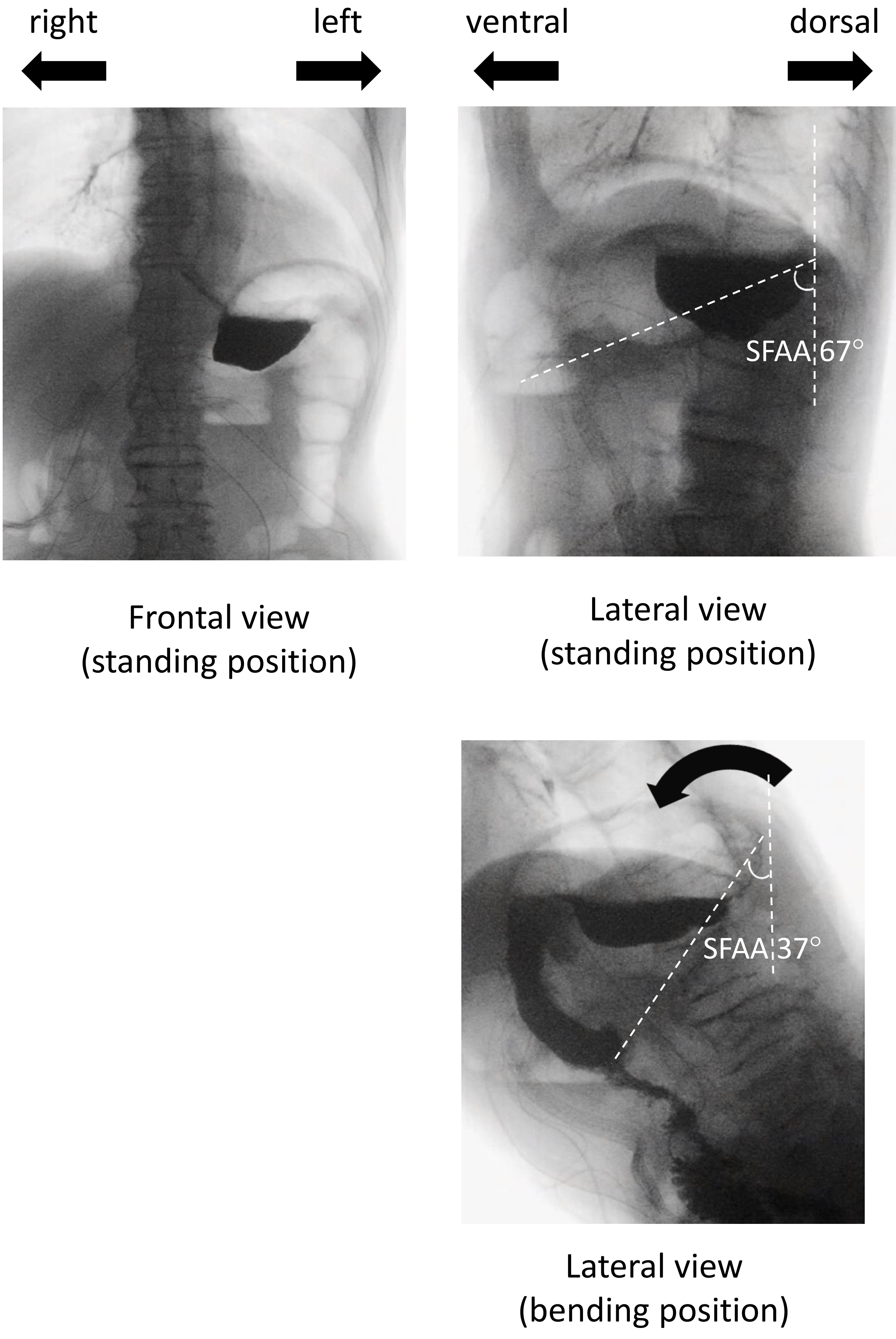
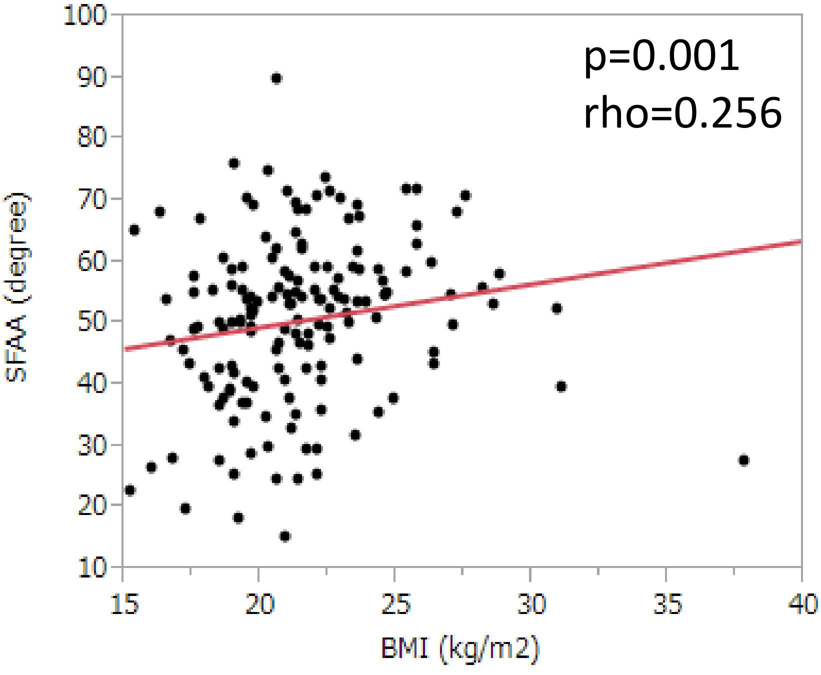
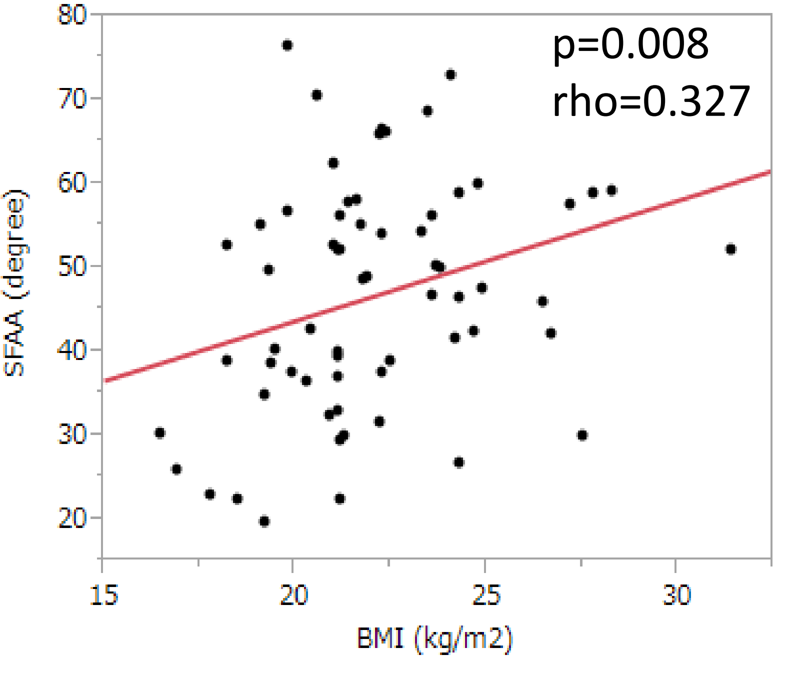

right
left
ventral
dorsal
SFAA 67°
Frontal view
(standing position)
Lateral view
(standing position)
SFAA 37°
Lateral view
(bending position)

Figure 6

A.



B.



Supplementary Figure 1