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Impact of remnant stomach volume and anastomosis on nutrition and body composition in gastric cancer patients

Koeun Lee[a,b,1], Kyung Won Kim[b,1], Jung-Bok Lee[c], Yongbin Shin[b], Jin Kyoo Jang[b], Jeong-Hwan Yook[a], Byung-Sik Kim[a], In-Seob Lee[a,*]

[a] Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, South Korea
[b] Department of Radiology, Asan Image Metrics, Asan Medical Center, University of Ulsan College of Medicine, Seoul, South Korea
[c] Division of Biostatistics, Center for Medical Research and Information, Asan Medical Center, University of Ulsan College of Medicine, Seoul, South Korea

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ABSTRACT

Background: In gastrectomy for gastric cancer, oncologic safety including secure resection margin is considered important while less attention is given to maximizing remnant stomach volume (RSV). Nutrition and body composition are important postoperative factors for patient well-being. In this prospective observational study, we investigated the effects of RSV and anastomosing method on nutrition, anemia, and body composition change.

Methods: We enrolled 247 patients who underwent curative laparoscopic gastrectomy (Billroth-1: 111, Billroth-2: 31, Roux-en-Y: 38, total gastrectomy: 67) for stage 1 gastric cancer between 2015 and 2016. Their clinicodemographic characteristics and laboratory data were collected. RSV, area of abdominal muscle, and subcutaneous/visceral fat were measured using CT data.

Results: Patients with larger RSV and those who underwent Billroth-1 exhibited smaller reduction in hemoglobin and nutritional parameters during the first three postoperative months, and showed better recovery in the aforementioned variables as well in the first postoperative year. Visceral fat was the most affected factor by gastrectomy, and abdominal muscle and subcutaneous/visceral fat were better preserved in patients with larger RSV. The proportion of sarcopenic patients was also the smallest in the Billroth-1 group and larger RSV group. Patients who underwent total gastrectomy showed the highest degree of deterioration in all parameters.

Conclusions: Estimating RSV and body composition by using CT offers valuable clinical information. The Billroth-1 procedure and larger RSV were associated with better postoperative nutritional variables and reduced prevalence of sarcopenia among gastric cancer patients after gastrectomy. When performing gastrectomy in stage 1 gastric cancer patients, RSV should be considered.

1. Introduction

Gastric cancer is currently the most common malignancy in Korea [1]. As a result of national surveillance program using endoscopy, early or stage 1 gastric cancer now comprises more than 60% of all surgically treated gastric cancers [2]. Early diagnosis and advance in surgical techniques, including laparoscopic gastrectomy, have resulted in significant increases in long-term survival; consequently, more focus is given to quality of life and nutritional status among gastrectomized patients.

After gastrectomy, most patients experience sequelae such as decreased oral intake, weight loss, and decline in physical activity. Several studies have reported postoperative deterioration of nutritional parameters, including hemoglobin, protein, albumin, and cholesterol levels [3–6]. Decreased stomach volume, as well as rapid intestinal transit time and malabsorption, are among the main causes of such changes. Nevertheless, guidelines on gastric cancer surgery are solely focused on oncologic aspects including resection margin rather than maximizing remnant stomach volume (RSV) [7,8].

Importantly, decreased physical activity and weight loss observed in patients who have undergone gastrectomy highly mimic the pathophysiological cascade of sarcopenia. Sarcopenia is a geriatric syndrome

* Corresponding author. Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, 88, Olympic-ro 43-gil, Songpa-gu, Seoul, 05505, South Korea.

E-mail address: inseoblee77@gmail.com (I.-S. Lee).

[1] These authors contributed equally as first authors to this work.

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characterized by progressive and generalized loss of skeletal muscle mass and strength, and it is highly prevalent in gastric cancer patients treated with surgery [9]. Although some studies have evaluated and described the implications of sarcopenia on surgical outcomes and prognosis in gastric cancer patients [10–12], no study has investigated the relationship between postoperative nutrition and changes in body composition, including abdominal muscle, visceral/subcutaneous fat, and sarcopenia after surgery in relation to RSV and anastomosis method.

Computed tomography (CT) is one of the most advanced imaging techniques available today, and it enables highly accurate estimation of RSV (Huh et al.) [13] and body composition [14,15]. We therefore used CT scan data to analyze RSV and body composition changes in gastrectomized patients, and investigated the influence of RSV and anastomosis method on nutrition and body composition change during the first postoperative year.

2. Materials and methods

The Institutional Review Board of the Asan Medical Center approved this prospective, observational, registry-based cohort study. This study followed the Strengthening of the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [16].

2.1. Patients

A gastrointestinal surgeon (I.S.L) has prospectively built a comprehensive registry of his patients, beginning 2015. The registry includes information on patient demographic characteristics, preoperative examination results, surgical procedures, pathologic diagnoses, and the postoperative course and outcomes. Another co-author of this article, a radiologist (K.W.K) has provided imaging information to the registry, as follows: three-dimensional (3D) computed tomography (CT) gastroscopic volumetry to estimate RSV and regular follow-up CT scans to assess body composition.

Eligible patients were those treated with laparoscopic gastrectomy for stage 1 gastric adenocarcinoma and followed up without recurrence or adjuvant therapy. Inclusion criteria were as follows: (a) patients who were treated with laparoscopic gastrectomy for gastric adenocarcinoma with a curative intent between January 2015 and December 2016 at Asan Medical Center, (b) who were between 18 and 85 years of age, (c) were follow up for more than 1 year, and (d) those who fulfilled the follow-up protocol. Exclusion criteria were: (a) patients who underwent adjuvant chemotherapy after the surgery, (b) those who received neoadjuvant chemotherapy prior to the surgery, (c) patients with remnant or recurrent gastric cancer, (d) cases with any synchronous malignancy, and (e) patients who were lost to follow-up.

From the surgical registry, 439 patients underwent surgery for gastric carcinomas during that period. We excluded 192 patients for the following reasons: adjuvant or neoadjuvant chemotherapy (n = 26), enrollment in another study for stage 1B cancers (n = 28), synchronous malignancy (n = 12), lack of appropriate CT scans (n = 111), and follow-up loss (n = 15). Finally, a total of 247 patients were included in the analysis (Fig. 1).

About initial two thirds of patients started to drink water 24 h following the operation and a liquid diet was permitted on postoperative day 3. After passing flatus, a soft diet was introduced. The remaining a third of patients began to sip water from the morning of the day after surgery, while a liquid and soft diet was permitted on the evening of postoperative days 1 and 2, respectively, according to the introduction of the enhanced recovery after surgery program.

2.2. Medical data collection

The demographic characteristics of patients including age, sex, weight, height, and body mass index (BMI) were recorded at the first clinic visit. Laboratory investigations, such as hemoglobin (Hb), serum protein/albumin, and cholesterol were checked before surgery. We also documented any information about previous history of chemotherapy, previous gastric cancer, and synchronous malignancy. During the postoperative follow-up period, nutritional factors, including hemoglobin, protein/albumin, and cholesterol levels were measured at all appointments. Parameters associated with anemia, including iron, ferritin, and vitamin B12 (vitB12) were checked prior to surgery, at postoperative 6 month and 1 year. CT images assisted preoperative tumor staging. After 3 postoperative months, CT volumetry was performed to measure RSV, as well as to detect any recurrence. Conventional CT was done for surveillance 1 year after surgery (Fig. 1).

Nutritional risk index (NRI) was calculated using the following formula: NRI = (1.519 × serum albumin g/L) + 0.417 × (present weight/usual weight) × 100, with usual weight being the value measured during preoperative evaluation period [17].

Information related to surgery was also gathered, including the type of operation (distal vs. total gastrectomy), type of anastomosis in the distal gastrectomy group (Billroth-1[gastroduodenostomy], Billroth-2 [gastrojejunostomy], and Roux-en-Y gastrojejunostomy), and the pathologic staging (Fig. S1).

2.3. Acquisition of CT gastrography

We previously reported on the feasibility of 3D CT gastrography for volumetric measurement of a RSV in distal gastrectomy patients [13] and followed the protocol for the current study. All patients underwent the 3D CT at 3 months after the surgery for estimation of RSV (Fig. 2).

2.4. CT image analysis

2.4.1. Assessment of remnant stomach volume

A clinically trained image analyst (K.L.) analyzed the CT images, and another radiologist (K.W.K) double-checked the results. CT volumetry of the remnant stomach was performed using conventional 2D axial CT images with a 5-mm slice thickness. At each slice, the entire perimeter of the remnant stomach was manually outlined using the picture archiving and communication system. We summed the enclosed areas measured at each section. The volume of the remnant stomach was determined by multiplying the summed areas (cm^2) and slice thickness (0.5 cm).

2.4.2. Assessment of body composition

Body composition was evaluated with abdominal CT using the Asan-J software application, which was developed based on ImageJ (NIH, Bethesda, MD, USA). Two consecutive axial CT images at the inferior endplate of the L3 lumbar vertebra level were chosen and then averaged for each patient. Using Asan-J, we summed the total abdominal muscle area (TAMA) (cm^2), including all muscles in the field (psoas, paraspinalis, transversus abdominis, rectus abdominis, quadratus lumborum, and internal/external obliques), with predetermined thresholds for the Hounsfield units (HU) on CT. The visceral fat area (VFA) (cm^2) and the subcutaneous fat area (SFA) (cm^2) were also outlined and evaluated using adipose tissue thresholds on CT.

The TAMA was adjusted to stature by dividing the muscle area by the patient's height squared, which is termed as TAMA index [TAMAI = TAMA (cm^2)/height (m^2)]. Sarcopenia was defined using cutoff criteria suggested by Prado et al.: < 38.4 cm [2]/m^2 in women and < 52.4 cm [2]/m^2 in men [14].

2.5. Statistical analysis

Demographic data were expressed as means ± standard deviation (SD). Quantitative data for statistical variables were expressed as least square (LS) means ± standard deviation (SD).

The influence of RSV on nutritional factors and body composition

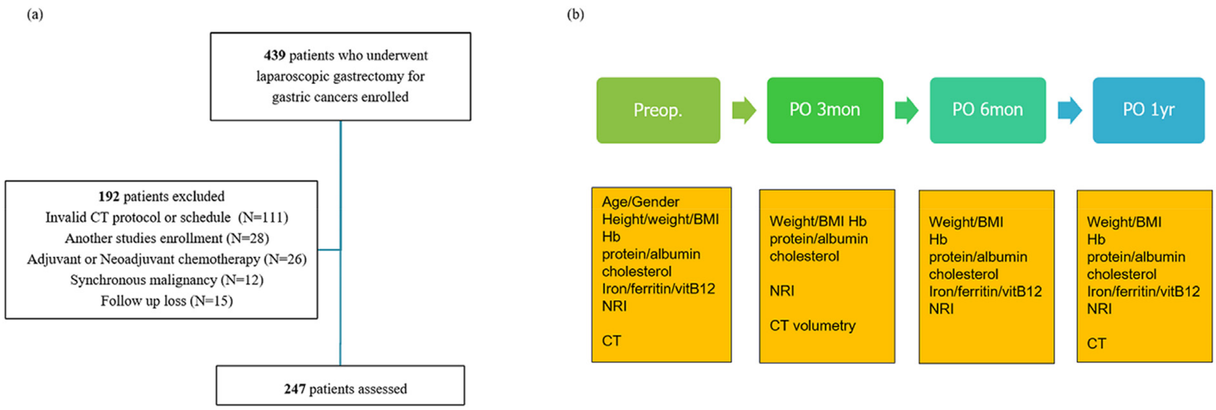

Fig. 1. Diagram showing eligibility criteria and follow-up protocol
(a) the exclusion process of eligible patients (b) follow up protocol for patient during 1 year after operation (PO: postoperative).

was evaluated based on a generalized linear mixed model. Patients were divided into four groups according to RSV: the RSV_{small} ($RSV \leq 200\,cm^3$), RSV_{medium} ($200 < RSV \leq 500\,cm^3$), RSV_{large} ($RSV > 500\,cm^3$), and TG (total gastrectomy without remnant stomach, RSV $0\,cm^3$) groups.

The influence of anastomosis type on nutritional factors and body composition was also evaluated based on generalized linear mixed models (GLMMs). For this analysis, the patients were divided into four groups according to anastomosis type: the DG_{B1} (Billroth-1 anastomosis), DG_{B2} (Billroth-2 anastomosis), DG_{RYGJ} group (Roux-en-Y anastomosis), and TG groups. P-values ≤ 0.05 were considered to indicate statistically significant differences. Throughout this article, P_1 is the P value that reflects the time effect, P_2 reflects the group effect, and P_3 reflects the time–group interaction between the four groups.

All statistical analyzes were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

3. Results

3.1. Patients

A total of 247 consecutive patients were included in the analysis. Mean patient age at the time of operation was 57.1 years, and 152 of the patients were males. Mean height and weight were 162.7 cm and 64.5 kg, respectively. Distal gastrectomy was performed in 180 patients; 111 of these used Billroth-1 anastomosis, 31 used Billroth-2 anastomosis, and 38 used the Roux-en-Y technique for anastomosis. On the other hand, reconstruction of gastrointestinal continuity was made using the Roux-en-Y method in all 67 TG cases. The patient demographic characteristics and surgery related variables are summarized according to the type of reconstruction method and volume of remnant stomach in Tables 1 and 2.

With regard to an anastomosing method after distal gastrectomy, Billroth 1 procedure was the most preferred one. If not possible, Roux-en-Y gastrojejunostomy for patients not more than 70 years old and Billroth 2 for elderly people were considered due to concern for remnant stomach cancer by biliopancreatic reflux. The mean RSV in the distal gastrectomy group was $274.14\,mm^3$. RSV was highest in DG_{B1} group ($328.5 \pm 193.0\,mm^3$), followed by the DG_{RYGJ} group ($208 \pm 141.3\,mm^3$) then the DG_{B2} group ($160.5 \pm 101.9\,mm^3$).

3.2. Influence of RSV on nutrition, anemia, and body composition

3.2.1. Nutrition

Protein/lipid-related parameters, including NRI, protein, albumin, and cholesterol decreased during the first 3 months after surgery and increased up to similar or higher levels than the preoperative state at postoperative 1 year in the DG groups. The RSV_{large} group had the smallest reduction of these values at postoperative 3 month and the largest increase at 1 year, (NRI: $P_3 < 0.0001$, total protein: $P_3 = 0.0204$, cholesterol: $P_3 = 0.0044$, albumin: $P_3 = 0.0802$, respectively) (Fig. 3, Table S1). The TG group showed a continuous decrease of NRI and less recovery of the other nutritional values.

3.2.2. Anemia

Hemoglobin level was lowest at postoperative 3 month and recovered thereafter in all groups. The largest drop in hemoglobin was observed in the TG group, and the best hemoglobin recovery was in the RSV_{large} group, and this change was statistically significant in terms of the time–group interaction ($P_3 = 0.0108$). For iron, contrary to the TG group with postoperative levels lower than the preoperative levels, all DG groups showed an increase in iron levels after surgery, and this was most notable in the RSV_{large} group ($P_3 = 0.0214$). Ferritin continuously decreased after surgery, but there were no significant differences

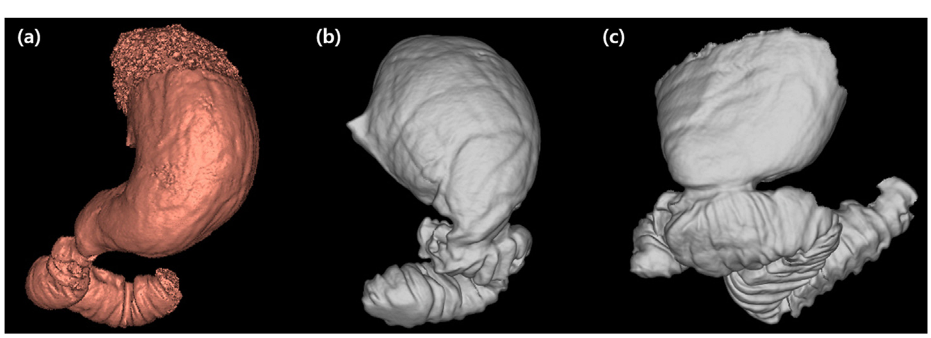

Fig. 2. Computed Tomography (CT) gastrography images
3D CT reconstruction images of patients who underwent Billroth-1 anastomosis (a), Billroth-2 anastomosis (b), Roux-en-Y gastrojejunostomy (c).

Table 1
Clinical characteristics of 247 patients according to the type of reconstruction method.

Variables	Operation method				
	Distal gastrectomy (N = 180)	Billroth-1 (N = 111)	Billroth-2 (N = 31)	RYGJ (N = 38)	Total gastrectomy (N = 67)
Age in years	57.32 ± 11.08	57.84 ± 10.64	62.94 ± 11.00	51.21 ± 9.69	56.25 ± 10.66
Sex					
Male	113(62.7%)	68(61.2%)	24(77.4%)	21(55.2%)	39(58.2%)
Female	67(37.3%)	43(38.8%)	7(22.6%)	17(44.8%)	28(41.8%)
Height (cm)	162.91 ± 7.86	162.88 ± 8.09	162.56 ± 7.48	163.31 ± 7.65	162.16 ± 7.34
Weight (kg)	64.86 ± 9.99	64.82 ± 10.21	65.85 ± 9.90	64.20 ± 9.58	63.53 ± 11.96
BMI (kg/m^2)	24.40 ± 3.11	24.39 ± 3.14	24.86 ± 2.83	24.07 ± 3.26	24.01 ± 3.25
RSV (cm^3)	274.14 ± 183.70	328.50 ± 192.98	160.50 ± 101.86	208.07 ± 141.26	–

BMI and RSV refer to body mass index and remnant stomach volume, respectively.
Values of age, height, weight, BMI, and RSV were noted as mean ± SD.

between the groups. After 1 postoperative year, vitB12 levels were higher than during the preoperative period, and change was most marked in TG groups, with a significant change in the time–group interaction ($P_3 = 0.0002$) (Fig. 3, Fig. S2, Table S1).

3.2.3. Body composition

All patients had a decrease of BMI and body weight during the first year after gastrectomy, and weight loss was most substantial in the TG group. The RSV_{large} group experienced the least amount of weight loss, and this was statistically significant (BMI: $P_1 < 0.0001$, $P_2 = 0.0399$, $P_3 < 0.0001$, weight: $P_1 < 0.0001$, $P_2 < 0.0001$, $P_3 = 0.0021$, respectively).

With regards to body composition, visceral fat was the most affected factor by gastric cancer surgery. The reduction of visceral fat was most prominent in the TG group, which experienced a reduction of more than 70% within a year. The least substantial visceral fat losses were experienced by the RSV_{large} group. This was statistically significant with regards to both time and group effects ($P_1 < 0.0001$, $P_2 = 0.0123$, $P_3 < 0.0001$). Although the extent was smaller than visceral fat, subcutaneous fat also decreased gradually during postoperative 1 year, and the reduction was smallest in the RSV_{large} group. This was statistically significant with regards to the time–group interaction ($P_3 < 0.0001$). Both TAMA and TAMAI showed significant reductions after surgery according to time; however, there was no difference between groups (TAMA: $P_1 < 0.0001$, TAMAI: $P_1 < 0.0001$, respectively).

In terms of sarcopenia based on the criteria suggested by Prado [14], the proportions of sarcopenic patients in each group increased with time ($P_1 = 0.0012$). The TG group showed the largest increase in sarcopenic patient prevalence, followed by $RSV_{middle,}$ $RSV_{small,}$ and $RSV_{large,}$ groups; however, the differences among the groups was not statistically significant. VFA/TAMAI, as an index for sarcopenic obesity, gradually decreased in all groups. VFA/TAMAI was the most prominent in the TG group and smallest in RSV_{large} group. This was significant statistically in all terms ($P_1 < 0.0001$, $P_2 < 0.0068$, $P_3 < 0.0001$) (Fig. 3, Fig. S2, Table S2).

Graphs show the change in value over time as a percentage for the parameters including NRI (a), serum albumin (b), Cholesterol (c), Hemoglobin (d), weight (e), Visceral fat area (f), Total abdominal muscle area (g), and the proportion of patients meeting the criteria of sarcopenia (h).RSV_{small} group: RSV ≤ 200 cm^3, RSV_{medium} group: 200 < RSV ≤ 500 cm^3, RSV_{large} group: RSV > 500 cm^3, TG group: total gastrectomy without remnant stomach, RSV 0 cm [3]. NRI = Nutrition risk index, Pre = pre-operation, 3 m = 3 months after operation, 6 m: 6 months after operation, 12 m: 12 months after operation.

3.3. Influence of anastomosis on nutrition, anemia, and body composition

3.3.1. Nutrition

The DG_{B1} group had the smallest reductions of NRI, protein, albumin, and cholesterol at postoperative month 3, followed by $DG_{RYGJ,}$ $DG_{B2,}$ and TG group; this order was the same when comparing recovery towards preoperative levels for all of these variables, and the differences among the groups were statistically significant (NRI: $P_2 = 0.0002$, total protein: $P_2 = 0.0437$, cholesterol: $P_2 = 0.0015$, albumin: $P_2 = 0.0147$, respectively) (Fig. 4, Fig. S3, Table S3).

3.3.2. Anemia

When dividing patients by anastomosis method, hemoglobin level was the lowest at 3 months after surgery and its extent of decrease was the smallest in DG_{B1} group ($P_1 < 0.0001$, $P_2 = 0.0009$). Postoperative increased iron level was more prominent in the DG_{B2} and DG_{RYGJ}

Table 2
Clinical characteristics of 247 patients according to volume of the remnant stomach.

Variables	Remnant stomach volume			
	RSV ≤ 200 (N = 74)	200 < RSV ≤ 500 (N = 83)	RSV > 500 (N = 23)	Total gastrectomy (RSV = 0) (N = 67)
Age in years	58.74 ± 9.88	56.45 ± 7.93	55.87 ± 9.35	56.25 ± 10.66
Sex				
Male	46(62.1%)	52(62.7%)	15(65.2%)	39(58.2%)
Female	28(37.9%)	31(37.3%)	8(34.8%)	28(41.8%)
Height (cm)	162.41 ± 0.07	163.05 ± 5.99	164.04 ± 6.92	162.16 ± 7.34
Weight (kg)	64.94 ± 7.53	64.86 ± 8.15	64.64 ± 8.82	63.53 ± 11.96
BMI (kg/m^2)	24.60 ± 2.15	24.35 ± 2.54	23.95 ± 2.70	24.01 ± 3.25
Reconstruction method [N(%)]				
Billroth-1	30 (40.5%)	59 (71.1%)	22 (95.7%)	
Billroth-2	23 (31.1%)	8 (9.6%)	0	
RYGJ	21 (28.4%)	16 (19.3%)	1 (4.3%)	

BMI and RSV refer to body mass index and remnant stomach volume, respectively.
Values of age, height, weight, BMI, and RSV were noted as mean ± SD.

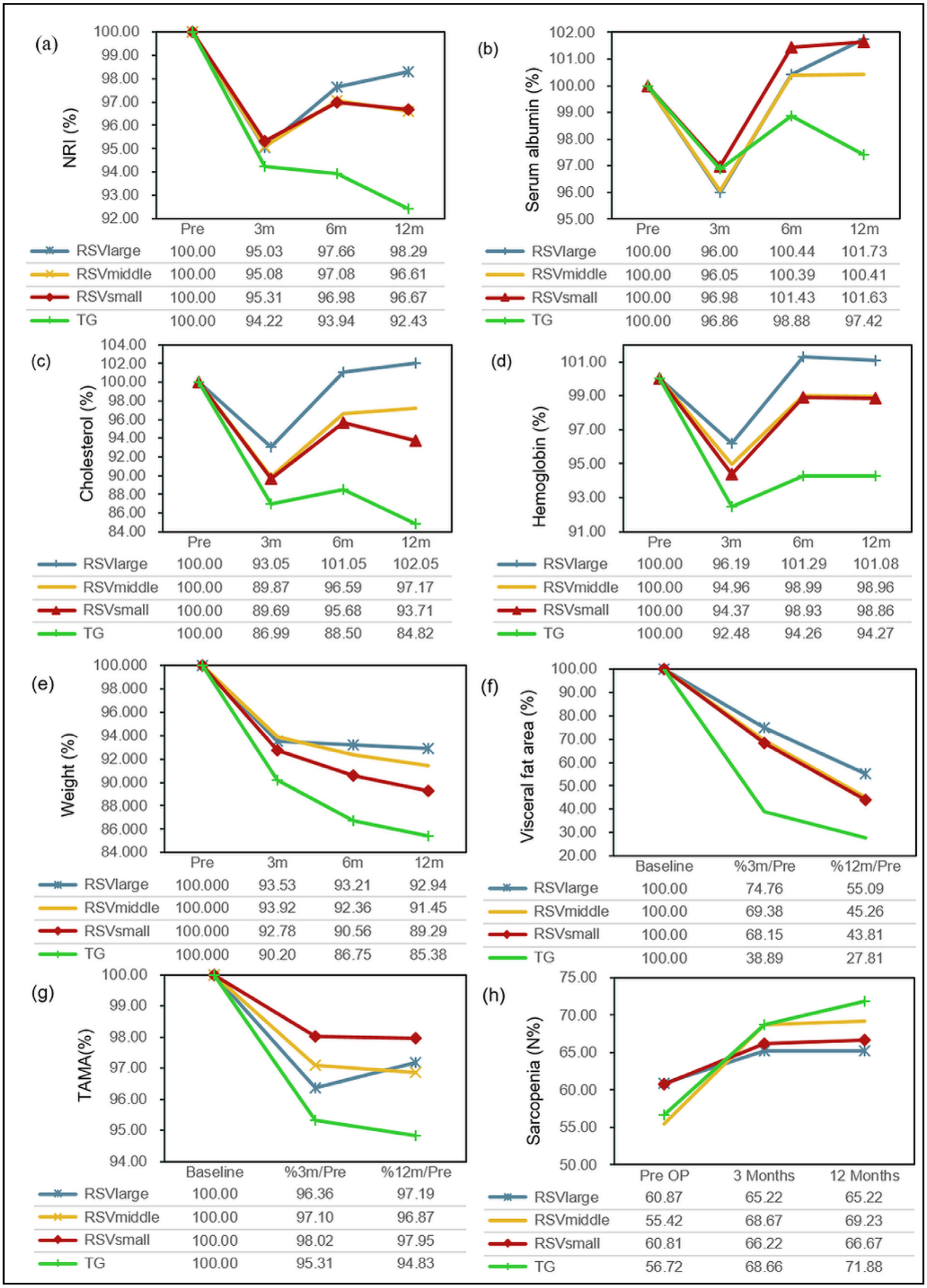

Fig. 3. Influence of remnant stomach volume (RSV) on nutrition, anemia, and body composition.

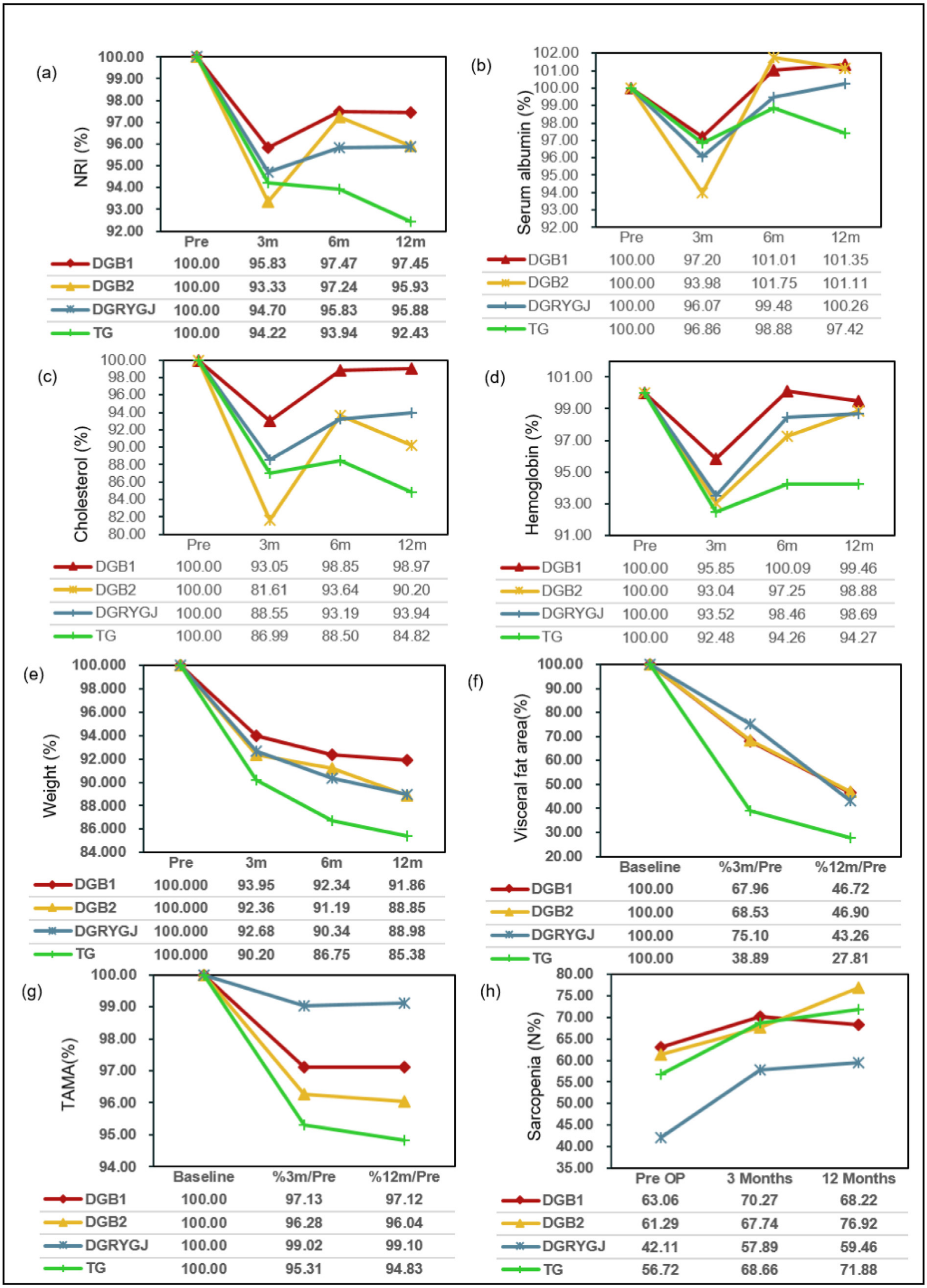

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Fig. 4. Influence of anastomosis on nutrition, anemia, and body composition
Graphs show the change in value over time as a percentage for the parameters including NRI (a), serum albumin (b), Cholesterol (c), Hemoglobin (d), weight (e), Visceral fat area (f), Total abdominal muscle area (g), and shows the proportion of patients meeting the criteria of sarcopenia (h).
DGB1 group: distal gastrectomy with Billroth-1 anastomosis, DGB2: distal gastrectomy with Billroth-2 anastomosis, DGRYGJ: distal gastrectomy with Roux-en-Y gastrojejunostomy, TG group: total gastrectomy
Pre: pre-operation, 3 m
3 months after operation, 6 m
6 months after operation, 12 m
12 months after operation.

groups compared to the DG_{B1} group, but this did not reach a statistical significance. The ferritin decrease was smallest in the DG_{B2} group ($P_2 = 0.0104$), and differences in vitB12 changes according to the interaction of time after surgery and anastomosis group was significant ($P_3 = 0.0005$) (Fig. 4, Fig. S3, Table S3).

3.3.3. Body composition

The DG_{B1} group experienced minimal body weight and BMI reductions compared to the other groups during the first year after gastrectomy (BMI: $P_1 < 0.0001$, $P_2 = 0.0191$, $P_3 < 0.0001$, weight: $P_1 < 0.0001$, $P_2 < 0.0001$, $P_3 = 0.0022$, respectively).

Visceral fat was well-preserved in the DG_{B2} group, followed by the DG_{B1} and DG_{RYGJ} groups. However, all groups commonly lost the value more than 50% of preoperative visceral fat volume ($P_1 < 0.0001$, $P_2 = 0.0002$, $P_3 < 0.0001$). On the other hand, subcutaneous fat preservation was better in the DG_{B1} group ($P_3 < 0.0001$). With regard to TAMA and TAMAI, the DG_{RYGJ} group showed a less than 1% decrease, which was smaller than the others, but this difference was not statistically significant.

The proportions of sarcopenic patients in all groups increased with time ($P_1 < 0.0001$). The DG_{RYGJ} group had the largest increase in number of patients meeting the sarcopenia criteria, followed by the DG_{B2}, TG, and DG_{B1} groups; this difference, however, was not significant. Sarcopenic obesity gradually decreased in all groups, and it was the most prominent in the TG group, followed by the DG_{RYGJ}, DG_{B1}, and DG_{B2} groups; this was statistically significant ($P_1 < 0.0001$, $P_2 < 0.0001$, $P_3 < 0.0001$) (Fig. 4, Fig. S3, Table S4).

4. Discussion

Gastrectomy induces various physiologic derangements by loss of reservoir function, diminution of acid and peptide secretion, and transection of the vagus nerve resulting in gastric atony. Iron deficiency or megaloblastic anemia is one of the most common postgastrectomy syndromes, and it arises from decreased intake and impaired absorption of iron or decreased intrinsic factor secretion from parietal cells after gastric cancer surgery. Although several studies have reported anthropomorphic and biochemical changes in patients who have undergone gastrectomy, most of them focused on demographic characteristics and laboratory findings [3–6,18,19]. To the best of our knowledge, this study is the first to investigate the influence of RSV and anastomosis method on changes in physical state and body composition based on CT images and conventional nutritional parameters during the first postoperative year among gastrectomized patients.

Minimized postoperative pain and faster recovery of bowel function are well-known advantages of laparoscopic surgery over open gastrectomy that might affect changes in body composition or nutritional state after surgery [20]. A Korean study reported that patients receiving adjuvant chemotherapy had lower hemoglobin, protein, albumin, and cholesterol levels than those who did not [6]. Therefore, we confined our study population to patients undergoing laparoscopic surgery and who were not candidates for adjuvant treatment.

A previous study reported that patients who underwent distal gastrectomy had difficulty in absorbing calories during the first 3 postoperative months [4], and our findings also showed NRI, protein, albumin, cholesterol, and hemoglobin levels reaching a nadir at 3 months in the DG groups. Body weight and BMI had a continuous decrease during the first year, although the rate decrease slowed after 3 months. Diminution of such parameters was more notable in the TG group, among whom a 15% decrease of weight and BMI and less subsequent recovery of the other values were observed, as compared to the DG groups. Regarding the variables related to anemia, ferritin (which is an iron storage protein and reflects iron stores) level reductions were commonly observed throughout the year in the DG groups regardless of RSV and anastomosis. The TG group showed a more significant decrease of ferritin level, and these between-group differences were concordant with the results of other studies [5,6]. Patients who undergo TG have an increased risk of developing vitB12 deficiency and megaloblastic anemia than those who undergo distal gastrectomy [21,22]. We hypothesized that the amount of parietal cell mass in a remnant stomach might be related to the level of vitB12, and thus the RSV_{large} group should have higher vitB12 values. However, in this study, vitB12 levels increased more markedly in the RSV_{middle} and DG_{B1} groups. To prevent anemia from iron or vitB12 deficiency, we prescribed multivitamin tablets containing these vitamins to all patients after surgery. For those undergoing TG, vitB12 was supplied via intramuscular injection at all outpatient clinic visits. This vitamin administration might have affected our results related to vitB12.

Currently, the gold standard for the quantitative assessment of intra-abdominal muscle and adipose tissue is CT or MRI [23,24]. Although a few studies have investigated body composition changes among gastrectomized patients, they have depended on non-imaging modalities, such as bioelectrical impedance or body composition analyzers [25–27]. After surgery, patients go through a regular abdomino-pelvic CT scan to detect any recurrence or metastasis. Therefore, we adopted CT as a tool to analyze body composition changes. Liedman et al. reported that weight loss after gastrectomy is because of a loss of fat volume and that fat malabsorption does not vary by differences in remnant stomach volume [28]. Also in the report by Tanaka et al., which investigated changes in visceral fat after gastrectomy, identified type of anastomsis as the significant determinants of visceral fat loss after surgery [29]. Our study also demonstrated that significant amounts of visceral or subcutaneous fat losses result from gastrectomy. However, we also observed that both cholesterol and adipose tissue levels were significantly reduced in the TG group and that there are differences even among DG groups. The RSV_{small} and DG_{RYGJ} groups exhibited prominent adipose tissue reductions and excellent muscle preservation. However, in our study, there was an age discrepancy among the DG groups, with the DG_{RYGJ} group being the youngest. This might have affect our findings related to body composition. During the first year after gastrectomy, the proportion of patients meeting the criteria of sarcopenia increased to reach over 70% in the TG group. The DG, RSV_{middle}, and RSV_{small} groups had continuous increases in numbers of sarcopenic patients. In terms of anastomosing method, the DG_{B1} group showed a smaller rise in sarcopenia prevalence.

This study demonstrated that larger RSV and Billroth-1 anastomosis has a protective effect on nutritional parameters, hemoglobin, body weight, BMI, visceral or subcutaneous fat, and development of sarcopenia. As Billroth-1 anastomosis directly connects the remnant stomach with the duodenum, ingested food can pass through the duodenum and proximal jejunum, which secures more length of small intestine and absorption of more nutrients compared to other reconstruction methods that are obliged to bypass the proximal small intestine. A larger RSV might lead to more food intake and less satiety, so it could play an important role in nutrition and metabolism. Besides the volume of the stomach itself or the malabsorption of the nutrients, some gut hormones such as gastric inhibitory polypeptide (GIP) and glucagon-like peptide-1 (GLP-1) which regulates a fat metabolism and being reported to show higher level after Roux en Y bypass than sleeve gastrectomy might play some roles in the result related with fat loss [30]. We also observed that patients who underwent TG experienced the most deterioration in all parameters. In conclusion, we therefore suggest that when performing gastrectomy in stage 1 gastric cancer patients, efforts should be made to maximize to RSV while securing oncologic safety.

This study has several limitations. First, the sample size of our cohort is relatively small. Second, despite the prospective design, our study was not a randomized one. Therefore, surgical preference might have affected the anastomosis technique or distribution of patients receiving distal gastrectomy, which could explain the small number of patients in the DG_{B2} and DG_{RYGJ} groups. Additionally, we could not observe the natural course of change in anemia-related factors because most patients took vitamin supplements during the follow-up period. As our study was founded on observation under clinical practices, it was impossible to control for such factors. Finally, because of the relatively small number of patients in the DG_{B2} and DG_{RYGJ} groups, we could not confirm a correlation between RSV and anastomosis in this study. To overcome these limitations, we continue to gather the data of more patients after study period. Nevertheless, our study is valuable because this is the first to use CT to demonstrate that Billroth-1 procedure and larger RSV are associated with improved postoperative nutritional variables and reduced prevalence of sarcopenia.

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Declarations

All of the authors have seen and agree with the content of this manuscript, and there are no financial interests to report.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.suronc.2019.09.008.

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