Postoperative Changes in Body Composition After Gastrectomy

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Nutritional status is one of the most important clinical determinants of outcome after gastrectomy. The aim of this study was to compare changes in the body composition of patients undergoing laparoscopy-assisted gastrectomy (LAG), distal gastrectomy (DG), or total gastrectomy (TG). Total body protein and fat mass were measured by performing a multifrequency bioelectrical impedance analysis using an inBody II machine (Biospace, Tokyo, Japan) in 108 patients (72 men, 36 women) who had undergone LAG (n = 24), DG (n = 39), or TG (n = 45). Changes between the preoperative data and results obtained on postoperative day 14 and 6 months after surgery were then evaluated. The mean preoperative body weight of the subjects was 57.6 ± 10.7 kg, the mean body mass index was 22.5 ± 3.4 kg/m^2, and the mean fat % was 24% ± 7%. In the immediate postoperative period (14 days), the body weight loss in the LAG group was significantly lower than in the DG and TG groups (2.5 ± 0.9 kg vs. 3.5 ± 1.8 kg and 4.0 ± 1.9 kg, respectively; $P < 0.0001$). The body composition studies demonstrated a loss of total body protein rather than fat mass. Six months after surgery, body weight was not significantly different from preoperative values in the LAG and DG groups (−1.2 ± 3.8 kg and −1.8 ± 4.7 kg, respectively), but had decreased by 8.9 ± 4.9 kg in the TG group ($P = 0.0003$). A body composition analysis revealed a loss of fat mass in the DG and TG groups. The patients who underwent gastrectomy lost body protein mass during the early postoperative period. The type and extent of surgery has an effect on long-term body mass and composition. Bioelectric impedance analysis can be used to assess body composition and may be useful for nutritional assessment in patients who have undergone gastrectomy. (J GASTROINTEST SURG 2005;9:313–319) © 2005 The Society for Surgery of the Alimentary Tract

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Weight loss is a common problem after gastrectomy; the main mechanisms implicated include impaired food intake and malabsorption.[1,2] Weight loss occurs principally during the first 3 months after surgery.[3] Patients who undergo a subtotal gastrectomy consume fewer calories during the first 3 months after surgery, after which their intake improves.[4] Nutritional status is one of the most important clinical determinants of outcome after gastrectomy.

The body can be divided into two or more compartments based on its anatomic, fluid, or chemical components.[5] The most commonly used body composition model is a two-component model, in which the body is divided into fat mass and lean body mass (Fig. 1). Multicomponent techniques allow the lean body mass to be broken down into as many as four components, such as extracellular water, total body water, body protein mass (muscle mass), and bone.

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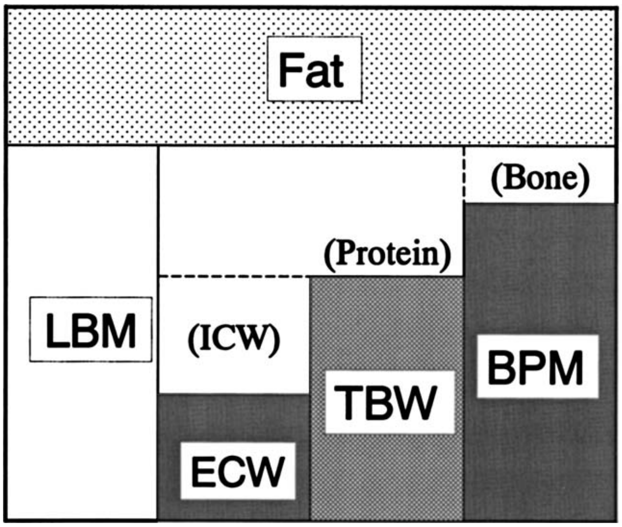

Fig. 1. Graphic representation of two-compartment and multicompartment models. According to this approach, fat is considered to be an extractable lipid and the remainder of the body weight is regarded as the lean body mass (LBM). Water is the single largest compartment, and total body water (TBW) is divided into intracellular water (ICW) and extracellular water (ECW). The lean body mass is also the sum of two fat-free components: body protein mass (BPM) and bone.

Bioelectrical impedance appears to provide a noninvasive, safe, rapid, and accurate method for evaluating body composition.[6] The method is based on the bioelectrical principle of impedance, the vector sum of resistance and reactance. Resistance is the opposition to electrical current in relation to the length and diameter of a cylinder. The human body resembles a set of serially connected cylinders (arms, trunk, and legs) with a known height and relatively constant diameter. As a result, height^2/resistance is proportional to hydrated portion of the body, such as total body water and lean body mass. By subtracting the lean body mass from the weight, the fat mass (the nonhydrated portion of the body) can be calculated.

Reactance reflects the component of impedance resulting from the presence of capacitive elements, such as the cell membrane. Multifrequency bioelectrical impedance analysis operates on the principle that the body's resistance is dependent on the frequency of the applied alternating current. Total body water is distributed between intracellular water and the extracellular water spaces, which are separated by the cell membranes. At a low frequency, the cell membranes act as capacitors, and the amount of extracellular water is predominantly measured. At a higher frequency, however, the membranes become permeable, and the total amount of body water can be measured. The ratio of extracellular water to total body water (edema index) is correlated with the ratio of the resistance at a high frequency to the resistance at a low frequency.[7] Segmental bioelectrical impedance of the arms and limbs enables the segmental body protein mass (muscle mass), as well as total body protein, to be precisely determined.[8]

Body composition is altered after surgery, and the metabolically active body mass is diminished (catabolic phase).[9] Once the patient recovers from the surgical insults, positive nitrogen balance and weight gain occur (anabolic phase). However, few body composition studies have been carried out following gastrectomy; furthermore, there is no data regarding the impact of various types of gastrectomy on body composition alterations.[10–12] The aim of this study was to compare postoperative changes in body composition in patients undergoing laparoscopic-assisted gastrectomy, distal gastrectomy, or total gastrectomy.

PATIENTS AND METHODS

The nutritional status of 108 patients with gastric cancer (72 men, 36 women) was evaluated at the Nippon Medical School Hospital between January 2002 and September 2003. Twenty-four patients underwent laparoscopy-assisted gastrectomy (LAG), 39 patients underwent distal gastrectomy (DG), and 45 patients underwent total gastrectomy (TG). LAG was indicated for the resection of T1 (mucosa or submucosa) N0 tumors and included partial gastrectomies (n = 2), segmental gastrectomies (n = 8), and distal gastrectomies (n = 14). DG with gastroduodenal or gastrojejunal anastomosis was performed for cancers located in the distal or middle third regions of the stomach. TG was carried out for lesions larger than 3 cm in diameter located in the proximal or middle third of the stomach; Roux-en-Y antecolic reconstruction was performed using a 40 to 50 cm jejunal limb. The degree of lymph node dissection varied from D0 to D2 in the surgery for stage IA and IB tumors; D2 nodal dissection was used routinely for stage II or higher stages.[13,14]

Patients were managed postoperatively according to an established clinical pathway. This included provision of drinking water (500 ml/day) on the fourth postoperative day. Food ingestion progressed every 2 days in four steps from liquid meals to solids starting on the fifth postoperative day to achieve a targeted energy intake of 1450 kcal. Hospital discharge was routinely planned for the 14th postoperative day, although earlier discharge was permitted if more than 1000 kcal/day intake had been achieved.

Body protein mass, fat mass, and the ratio of extracellular water to total body water (edema index) were measured using a segmental multifrequency bioelectrical impedance analysis performed with an inBody II machine (Biospace, Tokyo, Japan), which was developed by Cha et al. to determine the physical fitness and body shape of healthy people.[8] Patients stood upright, stepping on the foot electrodes and loosely gripping the hand electrodes, with their arms held vertically. In this manner, the eight tactile electrodes were placed in contact with the thumb and palm of each hand and the front and rear soles of each foot. The microprocessor-controlled switches and impedance analyzer were started to measure the segmental resistances of the arms, trunk, and legs without accounting for fluid redistribution. Alternating currents with a magnitude of 100 µA and frequencies of 5 to 500 kHz were used. The height and weight of each patient was measured using electric scales. The body mass index (BMI) was calculated as body weight/height^2 (kg/m^2), and the degree of obesity was calculated as body weight/ideal body weight (%). All assessments were obtained preoperatively, on the 14th postoperative day (before hospital discharge), and at 6 to 12 months after surgery in the outpatient clinic.

All data are expressed as mean ± SD. Statistical analysis employed a paired Student's *t* test for each of the patients and one-factor ANOVA with a post hoc test for the operative procedures using StatView software (SAS Institute, Cary, NC). A *P* value of <0.05 was considered to be statistically significant.

RESULTS

The clinical characteristics of the patients in each of the three study groups were comparable, although the patients allocated to the LAG group were significantly older than those in the other groups (Table 1). Coexisting diseases were present in 30% of the patients. There was no in-hospital mortality and all patients were available for follow-up examination at 6 to 12 months. Postoperative complications occurred in seven cases (6.5%): two cases of pneumonia, two wound infections, two anastomotic strictures, and one heart failure. The length of hospital stay was longest in the TG group (19.9 ± 8.5 days); the LAG and DG groups hospital stays were 13.7 ± 1.9 and 16.7 ± 5.5 days, respectively. Distribution of cases by cancer stage is shown in Table 2. The LAG group consisted of patients with only stage IA or IB tumors.

The preoperative nutritional evaluations indicated that body size and degree of obesity were similar in all groups (Table 3). The mean preoperative body weight of all subjects was 57.6 ± 10.7 kg, the mean BMI was 22.5 ± 3.4 kg/m^2, and the mean fat % was 24% ± 7%. The mean degree of obesity was 109% ± 17 %.

Table 1. Clinical status

	LAG (n = 24)	DG (n = 39)	TG (n = 45)
Age (y)	72.0 ± 6.8*	64.3 ± 9.4	63.3 ± 12.3
Male (no.)	15	25	32
Length of hospital stay (days)	13.7 ± 1.9	16.7 ± 5.5	19.9 ± 8.5†
Coexisting disease			
DM	1	6	11
Ischemic heart disease	2	3	1
CHF	1	1	1
COPD	1	0	3
Comorbid disease			
Pneumonia		1	1
Wound infection			2
Anastomotic stricture	1		1
Heart failure			1

LAG = laparoscopy-assisted gastrectomy; DG = distal gastrectomy; TG = total gastrectomy; DM = diabetes mellitus; CHF = chronic heart failure; COPD = chronic obstructive pulmonary disease.
*$P = 0.005$ vs. DG; $P = 0.001$ vs. TG.
†$P = 0.0003$ vs. LAG; $P = 0.025$ vs. DG.

In the immediate postoperative period (14 days), body weight loss was significantly lower in the LAG group compared to the DG and TG groups (2.5 ± 0.9 kg vs. 3.5 ± 1.8 kg and 4.0 ± 1.9 kg, respectively; $P < 0.05$) (Fig. 2). Body composition analysis revealed a loss of body protein mass rather than fat mass in all groups. Body protein or fat loss did not differ among the groups, although the changes in fat loss ranged from 0.6 ± 1.0 kg in the LAG group to 1.5 ± 2.7 kg in the TG group. The mean BMI had decreased in all three groups on the 14th postoperative day (Table 4). The ratio of extracellular water to total body water (edema index) was similar in the LAG and DG groups, but was higher in the TG group on the 14th postoperative day (Table 5).

Table 2. Clinical stages of gastric cancers*

	LAG (n = 24)	DG (n = 39)	TG (n = 45)
IA	21	20	5
IB	3	8	6
II	0	3	9
IIIA	0	1	6
IIIB	0	3	11
IV	0	4	8

LAG = laparoscopy-assisted gastrectomy; DG = distal gastrectomy; TG = total gastrectomy.
*According to Japanese Classification of Gastric Carcinoma.[11]

Table 3. Preoperative nutritional assessment

	LAG (n = 24)	DG (n = 39)	TG (n = 45)
Body weight (kg)	54.4 ± 9.1	57.2 ± 11.3	59.6 ± 10.1
Degree of obesity (%)	106 ± 19	108 ± 16	112 ± 17
Body protein (kg)	38.6 ± 7.3	40.8 ± 8.0	42.6 ± 8.3
Fat (kg)	13.5 ± 5.2	13.9 ± 5.5	14.5 ± 5.8
BMI (kg/m^2)	21.8 ± 3.5	22.3 ± 3.2	23.2 ± 3.4

LAG = laparoscopy-assisted gastrectomy; DG = distal gastrectomy; TG = total gastrectomy; BMI = body mass index.

Table 4. Postoperative changes in body mass index

	LAG (n = 24)	DG (n = 39)	TG (n = 45)
14 d	−0.8 ± 0.7*	−1.0 ± 0.7*	−1.4 ± 1.0*
6 mo	−0.3 ± 1.4	−0.3 ± 1.8	−3.4 ± 2.4†

LAG = laparoscopy-assisted gastrectomy; DG = distal gastrectomy; TG = total gastrectomy.
*$P < 0.0001$.
$^†P = 0.0072$.

At 6 months after surgery, mean body weight had returned to its preoperative values in the LAG and DG groups (−1.2 ± 3.8 kg and −1.8 ± 4.7 kg, respectively) (Fig. 3), but had decreased by 8.9 ± 4.9 kg in the TG group ($P = 0.0003$). A body composition analysis revealed that the mean fat mass had decreased in the DG group (−1.5 ± 2.9 kg), but both the mean body protein and the mean fat mass had decreased in the TG group (−3.6 ± 1.8 kg and −5.2 ± 4.2 kg, respectively). The mean BMI was similar to the preoperative value in the LAG and DG groups, but had decreased in the TG group (Table 4). The ratio of extracellular water to total body water (edema index) 6 months after surgery was similar to the preoperative value in the LAG group, but had increased in the DG and TG groups (Table 5).

From the 14th postoperative day to 6 to 12 months after surgery, a gain in the mean body protein mass was observed in the LAG and DG groups (1.1 ± 1.1 kg and 1.3 ± 1.5 kg, respectively) (Fig. 4). In the TG group, no difference in the mean body protein mass was observed between those two time periods, but the mean body weight and mean fat mass had decreased (−4.1 ± 3.4 kg and −3.5 ± 3.2 kg, respectively). The edema index increased in the TG group only after the patients were discharged.

DISCUSSION

This study investigated changes in the body composition of patients undergoing laparoscopy-assisted gastrectomy, distal gastrectomy, or total gastrectomy. Body weight, body protein, and fat mass decreased during the immediate postoperative period. Laparoscopy-assisted gastrectomies resulted in a smaller loss of body weight and a shorter hospital stay compared with open surgeries. Laparoscopic procedures represent a less invasive approach for the treatment of gastric cancer, similar to laparoscopic cholecystectomies.[15,16] Many organs and cells of the body use glucose, not fat, as their primary fuel.[17] Although fat is the largest deposit of energy in the body, fat cannot be effectively converted to carbohydrates in mammalian tissues. Fat is composed of fatty acid, which is used as a substrate for the synthesis of ketone bodies as fuel in the liver, and glycerol, which can be used for gluconeogenesis. Body protein constitutes the next

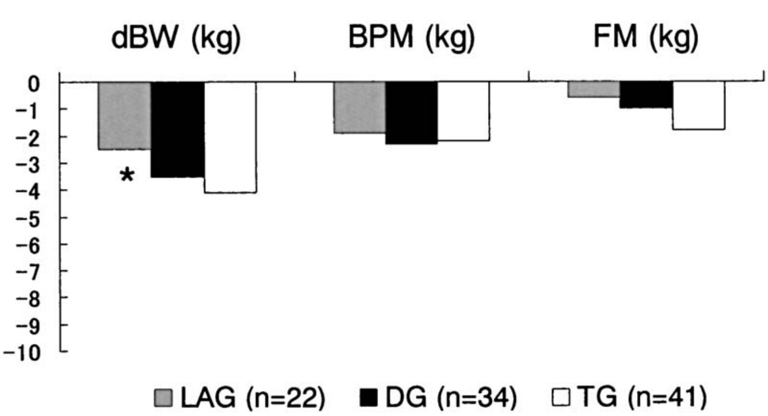

Fig. 2. Comparison of perioperative changes in the body composition of patients undergoing laparoscopy-assisted (LAG), distal (DG), and total gastrectomy (TG), from before surgery to 14th postoperative day. *$P = 0.039$ vs. DG and $P = 0.002$ vs. TG. dBW = change in body weight; BPM = body protein mass; FM = fat mass.

Table 5. Edema index

	LAG (n = 24)	DG (n = 39)	TG (n = 45)
Preoperative	0.341 ± 0.013	0.340 ± 0.016	0.336 ± 0.013 † **
14 d postoperative	0.344 ± 0.011	0.342 ± 0.012 *	0.344 ± 0.014
6 mo postoperative	0.346 ± 0.015	0.343 ± 0.010	0.355 ± 0.014 ‡

LAG = laparoscopy-assisted gastrectomy; DG = distal gastrectomy; TG = total gastrectomy; edena index = extracellular fluid/total body water.
*P = 0.0006 vs. preoperative.
†P = 0.0001 vs. preoperative.
‡P = 0.0095 vs. 14 d postoperative.
**P = 0.0003 vs. preoperative.

largest mass of usable energy. Following surgery, proteolysis is accelerated to generate amino acids for the support of gluconeogenesis and other key synthetic processes. Therefore, endogenous protein must be broken down for conversion to glucose after surgery. This results in the simultaneous, rather than sequential, depletion of body protein and fat mass.[18]

In this study, the body weight loss that occurred during the immediate postoperative period consisted mainly of body protein loss rather than fat loss. The changes in body composition after surgery were characterized by a loss of body protein and fat mass and the expansion of the extracellular fluid compartment.[7] Although no differences in body protein or fat loss were seen among the three groups, the edema index of the TG group, but not that of the LAG or DG groups, increased during the early postoperative period. Within the confines of the multicomponent model, the body protein mass includes extracellular water as well as total body water. These findings suggest that the increase in interstitial water after a total gastrectomy may result in an underestimation of the decrease in the body protein mass during this altered state, compared with the results for patients who have undergone other surgical procedures. On the other hand, the serum albumin levels were similar among the groups before surgery and 6 months after surgery (mean value of 4.1 ± 0.5 and 4.3 ± 0.3 g/dl, respectively). Only in the immediate postoperative period were the levels of the TG group (3.6 ± 0.4 g/dl) lower than the levels of the LAG (4.0 ± 0.2 g/dl) and DG (3.9 ± 0.4 g/dl) groups.

The anabolic phase starts 3 to 6 days after an operation with a high level of insult, such as gastrectomy, and often coincides with the commencement of oral feeding.[7] In this study, the length of the hospital stay was longer in the TG group because adequate food intake was often delayed in this group. After the start of the anabolic phase, the patient enters a prolonged period of early anabolism, characterized by a positive nitrogen balance and weight gain. In the postoperative period, from the time of hospital discharge until 6 months after surgery, the patients in the LAG and DG groups regained their body protein mass, but no gain in body protein mass occurred in the TG group. The edema index of the TG group also increased, so the active body protein mass was likely diminished. Moreover, losses of body weight and fat mass were recorded in the TG group during

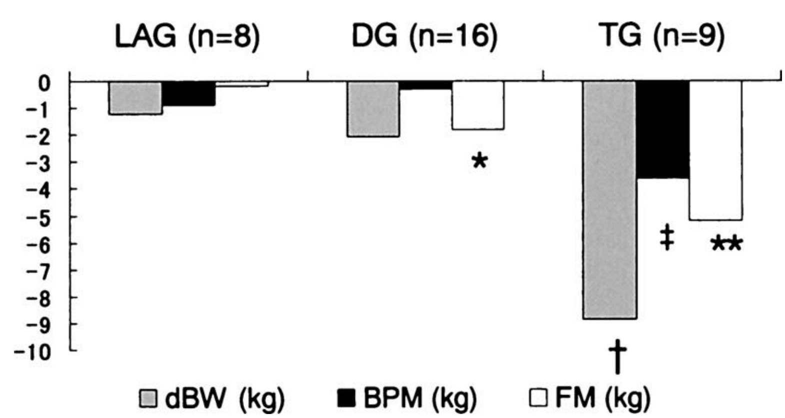

Fig. 3. Overall changes in the body composition of patients undergoing laparoscopy-assisted (LAG), distal (DG), and total gastrectomy (TG), from before surgery until 6 months after surgery. *P = 0.031, †P = 0.0003, ‡P = 0.0001, **P = 0.0038. dBW = change in body weight; BPM = body protein mass; FM = fat mass.

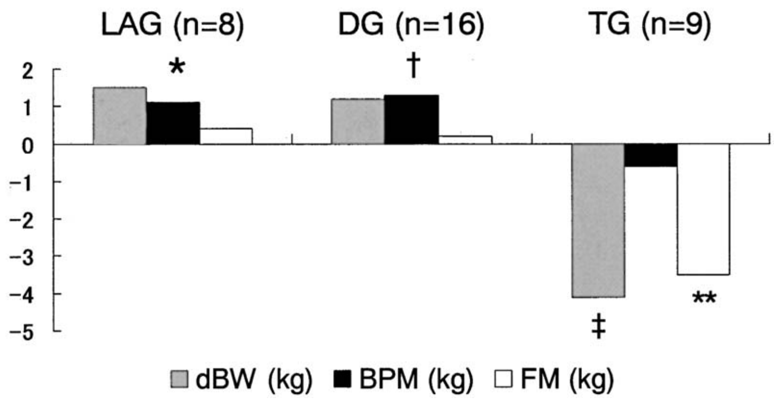

Fig. 4. Postoperative changes in body composition of patients undergoing laparoscopy-assisted (LAG), distal (DG), and total gastrectomy (TG), from the 14th postoperative day until 12 months after surgery. $^*P = 0.020$, $^\dagger P = 0.0027$, $^\ddagger P = 0.0036$, $^{**}P = 0.0077$. dBW = change in body weight; BPM = body protein mass; FM = fat mass.

this period, although protein synthesis may have been increased as a result of sustained oral feeding.

The overall changes in body composition from before surgery to 6 months after surgery showed that the body weight loss that occurred during the immediate postoperative period was recovered in the LAG and DG groups, although a loss of fat mass was recorded in the DG group. This finding may reflect the fact that patients undergoing partial and segmental gastrectomy (LAG group) had larger remnant stomach than patients who underwent a distal gastrectomy (DG group). In the TG group, overall losses of 15% body weight, 8% body protein, and 36% fat were recorded during this period. These results are consistent with the findings of previous studies in which weight loss (10% of preoperative weight) occurred early after total gastrectomy and body fat decreased by 40% during the first 6 months after gastrectomy.[19] In a long-term follow-up study, the weight loss consisted mainly of the depletion of body fat stores, whereas no significant decrease in lean body mass was observed.[10] Similar changes in body composition, including an increase in interstitial fluid (edema), were observed in the TG group during the postoperative period in the present study. Fat loss may be correlated with insufficient food intake after surgery.

Presumably, patients in the LAG and DG groups were able to regain their body protein mass during the postoperative period and return to their previous quality of life earlier after surgery.[20] The patients in the DG and TG group may have impaired nutritional intake, which seems to be associated with fat loss. Clearly, the small size of the residual gastric pouch and the absence of the stomach limit the amount of food consumed at one sitting. However, gastrectomy patients are expected to increase the frequency and caloric density of their meals postoperatively. In contrast, individuals who have undergone a Roux-en-Y gastric bypass typically eat fewer meals and voluntarily restrict their consumption of calorie-dense foods.[21,22] These alterations arise in part from a generalized loss of hunger that extends beyond postprandial satiety. One hypothesis explaining this phenomenon is that the procedure affects gut-derived factors involved in appetite regulation. Patients who have undergone a Roux-en-Y gastric bypass have markedly lower ghrelin levels and do not exhibit any of the meal-related oscillations observed in control subjects.[23] Future studies are required to define the clinical significance of ghrelin and develop nutritional interventions to prevent the depletion of body fat.

CONCLUSION

Patients who underwent a gastrectomy lost body protein during the perioperative period, and the resulting loss of body weight was significantly smaller in the LAG group than in the DG or TG groups. Six months after surgery, the body weight of the patients in the LAG and DG groups had recovered to the preoperative level, but a further decrease was observed in the TG group. The main postoperative change in body composition was a loss of fat mass in the DG and TG groups. Multifrequency bioelectrical impedance analyses can be used to assess body composition and may be useful for performing nutritional assessments in patients who have undergone a gastrectomy.

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