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Protein deficiency after gastric bypass: The role of common limb length in revision surgery

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Abstract

Background: Bariatric surgery, especially the gastric bypass procedure, is an effective therapy for morbid obesity, but may reduce protein absorption and induce protein deficiency (PD). A recent study reported an issue about common limb length for PD.

Objective: This study aimed to examine the prevalence of PD after gastric bypass surgery and investigate the role of common limb length in PD-related revision surgery.

Setting: Hospital-based bariatric center.

Methods: From 2001 to 2016, 2397 patients with morbid obesity who underwent bariatric/metabolic surgery with 1-year follow-up were recruited. Serum albumin and total protein were measured before and 1 year after surgery. Medical records of patients who underwent revision surgery due to PD were reviewed.

Results: The overall prevalence of PD was .5% preoperatively. The prevalence of PD increased to 2.0% at 1 year after surgery. The incidence was highest in one-anastomosis gastric bypass (2.8%) followed by Roux-en-Y gastric bypass (1.8%). Until the end of follow-up, all 19 patients who underwent revision surgery for intractable PD had a relatively short common limb length of <400 cm. After elongation of the common limb length to >400 cm in revision surgery, PD improved in all patients.

Conclusions: A subset of patients can develop PD after gastric bypass surgery when the common limb length is <400 cm. In patients with intractable PD after gastric bypass surgery, revision surgery for elongation of common limb length to >400 cm is mandatory to avoid PD-related complications. (Surg Obes Relat Dis 2019;15:441–446.) © 2019 Published by Elsevier Inc. on behalf of American Society for Bariatric Surgery.

Keywords: Bariatric surgery; Protein deficiency; Morbid obesity; Hypoalbuminemia

Bariatric surgery is an effective treatment for patients with morbid obesity and results in sustained weight loss [1,2]. However, the numbers of nonresponders to surgical treatment and late complications have also increased with the growing number of bariatric procedures and the increase in follow-up duration [3]. Among various bariatric procedures, gastric bypass is one of the commonly

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performed malabsorptive procedures, with sustained long-term weight loss and a high rate of resolution of co-morbidities [1–4]. Nevertheless, patients who have undergone gastric bypass surgery may experience long-term complications, including weight regain, inadequate weight loss, malnutrition, dumping syndrome, hypoglycemia, marginal ulcer, and self-intolerance (aversion to protein-rich foods due to smell and olfactory changes [5]). Revision surgery is occasionally required [6,7]. Among malnutrition-related complications, protein deficiency (PD) is a rare but serious diagnosis requiring prompt treatment [8]. However, data on PD after gastric bypass are sparse, especially in Asian populations. This study examined the prevalence of PD in Asian patients with morbid obesity after gastric bypass surgery. In addition, we specifically investigated the role of common limb length in revision surgery.

Methods

The study was conducted in Min-Sheng General Hospital of the National Taiwan University and was approved by the human research review board of Min-Sheng General Hospital. Between 1998 and 2016, 5741 consecutive patients with obesity who underwent laparoscopic bariatric/metabolic surgery were enrolled in the database of our center. Outcomes of 2397 patients (1612 females and 785 males) with 1-year follow-up data were recruited and analyzed, including 377 patients treated with Roux-en-Y gastric bypass (RYGB), 1022 treated with one- anastomosis (mini-) gastric bypass (OAGB), 169 treated with laparoscopic adjustable gastric banding, 649 treated with laparoscopic sleeve gastrectomy, 92 treated with sleeve gastrectomy with duodenal jejunal bypass, and 88 treated with laparoscopic vertical banded gastroplasty. Demographic data, including age, sex, body mass index (BMI), and laboratory data were collected and analyzed from a prospectively collected database. Serum albumin and total protein were measured preoperatively and at 1 year postoperatively. Protein deficiency was defined as serum albumin <3.5 g/dL. Medical records of patients who underwent revision surgery due to PD or other reasons were reviewed.

Patients were divided into the following 2 groups for evaluation of bowel length measurements: 19 patients (12 OAGB and 7 RYGB) underwent revision surgery for intractable PD; 54 patients (42 OAGB and 12 RYGB) underwent revision surgery for reasons other than PD in the same period (most commonly owing to intractable anemia or weight regain) and were included in a control group.

Statement of human and animal rights

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Operative technique

All procedures were performed laparoscopically. The performed surgical procedures included 2 types of gastric bypass procedures, RYGB and OAGB, which have been published previously [9]. In brief, RYGB was performed by the antecolic and antegastric route with a 100-cm biliopancreatic (BP) limb and 150- to 350-cm alimentary limb. The gastric pouch was approximately 20 mL and the gastrojejunostomy was created by a linear stapler with an anastomosis measuring 1.2 cm in diameter. The same technique was used to construct jejuno-jejunostomy. OAGB was performed first by creating a long-sleeved gastric tube along the lesser curvature from the antrum to the angle of His guided by an orogastric tube (size 36 Fr) for calibration. Then, a Billroth II type loop gastroenterostomy was created with the intestine approximately 200 cm (150–400) distal to the ligament of Treitz (BP limb). The length of the BP limb was tailored according to BMI, with an increase of 10 cm for each BMI point >40 kg/m^2 [10]. Techniques for other procedures have been described elsewhere [11–13].

The type of operation was usually co-determined by the patient themselves and the surgeon after several comprehensive discussions with the multidisciplinary team. The surgical team had experience performing various types of surgical procedures and had broad experience in bariatric/metabolic surgeries.

All revision surgeries for PD consisted of conversion to sleeve gastrectomy (SG), with the exception of 1 patient who was converted to normal anatomy. The technique of converting gastric bypass to SG was described elsewhere [14]. The whole bowel length was measured and recorded. In OAGB, the BP limb and common channel length were recorded. In RYGB, the BP limb, alimentary or Roux limb, and common channel length were recorded.

Statistical analysis

All statistical analyses were performed using SPSS version 18.0.0 (SPSS Inc., Chicago, IL, USA), and the baseline comparisons were performed using analyses of variance and 2-sample *t* tests. Continuous variables are expressed as means and standard deviations. The differences in pertinent characteristics were established via *t* tests for independent samples. A 2-sided *P* value of .05 was considered statistically significant.

Results

The characteristics of patients with severe obesity undergoing different bariatric procedures before and 1 year after the operation are shown in Table 1. The overall prevalence

Table 1
Clinical characteristics of patients with morbidly obesity before and 1 year after surgery.

	All ($n=2397$)	RYGB ($n=377$)	OAGB ($n=1022$)	AGB ($n=169$)	SG ($n=649$)	SG-DJB ($n=92$)	VBG ($n=88$)
Age, yr	34.8 (10.7)	35.9 (10.6)	34.4 (10.9)	32.1 (9.7)	35.1 (10.1)	42.0 (10.7)	30.2 (10.3)
Female (%)	1612 (67)	268 (71)	696 (68)	96 (56)	436 (67)	58 (63)	58 (65)
BMI, kg/m^2 preop	39.9 (7.5)	38.6 (6.7)	41.2 (7.7)	39.3 (7.1)	39.3 (7.1)	34.2 (6.1)	42.1 (7.8)
1-yr after op	27.7 (5.0)*	29.2 (4.7)*	27.3 (4.7)*	32.8 (6.1)*	27.4 (4.9)*	25.0 (3.7)*	29.0 (5.8)*
Total weight loss %	30.1 (9.5)	28.5 (9.2)	33.1 (8.5)	16.6 (9.4)	25.1 (7.1)	25.9 (9.0)	29.0 (5.8)
Albumin, mg/dL preop	4.4 (.3)	4.4 (.3)	4.4 (.3)	4.4 (.3)	4.4 (.3)	4.4 (.3)	4.5 (.3)
1 yr after op	4.3 (.4)	4.2 (.4)*	4.2 (.4)*	4.4 (.3)	4.3 (.3)	4.2 (.3)*	4.5 (.3)
Total protein, mg/dL preop	7.5 (.5)	7.5 (.5)	7.5 (.5)	7.4 (.8)	7.5 (.5)	7.6 (.5)	7.5 (.5)
1 yr after op	7.2 (.5)	7.1 (.5)*	7.1 (.5)*	7.4 (.5)	7.2 (.5)*	7.1 (.5)*	7.5 (.5)
Protein deficiency[†] n (%) preop	13 (.5)	1 (.3)	6 (.6)	3 (1.8)	3 (.5)	0 (0)	0 (0)
1 yr after op	46 (2.0%)*	7 (1.8%)*	29 (2.8%)*	1 (.6%)	8 (1.2%)	1 (1.1%)	0 (0%)

RYGB = Roux-en-Y gastric bypass; OAGB = one-anastomosis gastric bypass; AGB = adjustable gastric band; SG = sleeve gastrectomy; DJB = duodeno-jejunal bypass; VBG = vertical gastric banding; BMI = body mass index; Preop = preoperation; Op: operation.

Data are presented as the mean (standard deviation).

* Significantly different from preoperative data ($P<.05$).

† Protein deficiency: albumin <3.5 gm/dL.

of PD was .5% preoperatively; there was no significant difference between groups (Table 1). Etiologies of preoperative PD were nephrotic syndrome or hepatic cirrhosis. One year after surgery, with a mean weight loss of 30.1% and BMI reduction of 12.2 kg/m^2, the prevalence of PD increased to 2.0%. The incidence was highest (2.8%) in OAGB, followed by 1.8% in RYGB, 1.2% in laparoscopic SG, 1.1% in SG with duodenal jejunal bypass, .6% in laparoscopic adjustable gastric banding, and 0% in laparoscopic vertical banded gastroplasty. There was no difference in the incidence of PD between OAGB and RYGB. Most patients with PD after surgery could be managed with dietary instruction and high protein supplementation.

Up to now, 19 patients (12 OAGB and 7 RYGB) have undergone revision surgery for intractable PD. An additional 54 patients (42 OAGB and 12 RYGB) underwent revision surgery for reasons other than PD in the same period, most commonly intractable anemia or weight regain. Patients undergoing revision surgery due to PD had significantly different clinical profiles than patients undergoing revision surgery due to reasons other than PD (Table 2). Patients with PD were more likely to be male and have a higher initial BMI, lower albumin level at revision, shorter total bowel length, longer Roux limb, and shorter common limb length than patients without PD (Table 2). Although the BP limb length was similar between the 2 groups (222.1 ± 104.3 versus 203.7 ± 138.2 cm; $P=.599$), patients with PD had a shorter total length of bowel (609.5 ± 48.1 versus 702.8 ± 131.2 cm; $P<.001$) than patients without PD. Thus, patients with PD had a shorter common limb length than patients without PD (294.7 ± 71.3 versus

Table 2
Clinical characteristics of patients undergoing revision surgery due to protein deficiency or other reasons.

	PD ($n=19$)	Other reasons ($n=54$)	P value
Age, yr	32.6 ± 7.7 (20–48)	36.9 ± 9.2 (18–61)	.077
Female (%)	14 (73.3)	51 (94.4)	.013*
Years to revision, yr	3.4 ± 2.0 (1–7)	7.3 ± 2.6 (3–14)	<.001*
OAGB/RYGB	12/7	42/12	.212
BMI at baseline, kg/m^2	47.6 ± 7.1 (38–60)	38.8 ± 7.5 (25–55)	<.001*
BMI at revision, kg/m^2	26.0 ± 4.8 (17–37)	27.8 ± 7.1 (18–41)	.300
Albumin at baseline, gm/dL	4.3 ± .3 (3.6–4.9)	4.2 ± .4 (3.7–5.5)	.26
Albumin at revision, gm/dL	2.1 ± .3 (1.7–2.9)	4.1 ± .3 (3.7–4.9)	<.001*
Hemoglobin at baseline, gm/dL	13.7 ± 1.2 (12.3–16.9)	15.4 ± 1.5 (10.1–15.6)	.64
Hemoglobin at revision, gm/dL	10.2 ± 1.2 (8.3–12.2)	9.9 ± 2.0 (5.3–12.9)	.497
Total length of small bowel	609.5 ± 48.1 (490–700)	702.8 ± 131.2 (590–1320)	<.001*
BP limb length	222.1 ± 104.3 (80–390)	203.7 ± 138.2 (50–360)	.599
RY (alimentary) limb length	251.4 ± 71.7 (180–350)	160.0 ± 138.2 (150–230)	.004*
Common channel length	294.7 ± 71.3 (100–380)	480.7 ± 114.8 (290–1020)	<.001*

PD = protein deficiency; OAGB = one-anastomosis gastric bypass; RYGB = Roux-en-Y gastric bypass; BMI = body mass index; BP = biliopancreatic.
Data presented as the mean ± standard deviation (range).
* $P<.05$.

Table 3
Clinical characteristics of patients with intractable protein deficiency at baseline (before primary gastric bypass), before revision surgery, and after revision surgery.

	Baseline (N = 19)	At revision (N = 19)	1 yr (N = 14)	2 yr (N = 11)	3 yr (N = 8)
BMI	47.6 (7.1)	26.0 (4.8)*	28.0 (3.7)	28.8 (3.6)	29.9 (5.6)
Hemoglobin, g/dL	13.7 (1.2)	10.2 (1.2)*	13.2 (.3)†	13.2 (1.2)	13.7 (1.2)
Albumin, g/dL	4.3 (.3)	2.1 (.3)*	4.1 (.4)†	4.1 (.3)	4.3 (.2)†
Total protein, g/dL	7.4 (.4)	3.8 (1.1)*	6.9 (.3)	7.0 (.5)	7.2 (.3)

BMI = body mass index.
The data are presented as the mean (standard deviation).
* P value <.05 compared with baseline data.
† P value <.05 compared with data at revision.

480.7 ± 114.8 cm; $P < .001$). All patients with PD had a common limb length <400 cm.

Table 3 reports the preoperative and follow-up laboratory data for 19 patients undergoing revision surgery for PD. Mean BMI at revision surgery was significantly lower than that at initial gastric bypass surgery (26.0 ± 4.8 versus 47.6 ± 7.1 kg/m^2, $P < .001$). Mean albumin and total protein levels recovered after conversion to SG. After revision, mean albumin level increased from 2.1 ± .3 to 4.1 ± .3 g/dL. At follow-up, mean BMI remained stable for up to 3 years after conversion to SG despite a slight increase in BMI with time (from 26.0–29.9 kg/m^2). In these patients, mean hemoglobin significantly decreased from 13.3 to 10.7 g/dL after gastric bypass surgery, but this value increased significantly after conversion to SG.

Discussion

Protein malnutrition is a late complication of malabsorptive procedures [5,8] and appears to be associated with the length of the common limb in the present study. The incidence of PD after gastric bypass has been reported to be in the range of 1.3% to 4.7% [15,16]. The present study found that the rate of PD increased from .6% to 2.0% after bariatric surgery and 2.4% after gastric bypass procedures, compatible with previous reports. The incidence of PD was higher in OAGB than in RYGB (2.8% versus 1.8%), which might be attributed to increased BP limb length and shorter common limb length. In this study, the BP limb of RYGB was approximately 100 cm and the alimentary limb varied from 150 to 350 cm. In OAGB, Billroth II type loop gastroenterostomy was created with the intestine approximately 200 cm (range, 150–400 cm) distal to the ligament of Treitz. The BP limb length of OAGB was at least 2 times longer than that of RYGB. Thus, the common limb length was much shorter in OAGB than in RYGB.

The most important finding of this study is that patients with short total length of bowel were at high risk of PD after gastric bypass. These patients usually had a shorter common limb length than those with longer total length of bowel when we used a fixed or experienced bypass limb. All patients with severe PD requiring revision surgery had a common limb length <400 cm. In OAGB surgery, some authors use a 250-cm BP length, with a reported 7% incidence of PD [17]. A recent OAGB related study found a 6.45% incidence of PD even with a 150-cm BP limb, and a 45% incidence of PD with a 250-cm BP limb [18]. This PD incidence is much higher than our experience (2.8%, Table 1), at least at 1-year follow-up. We usually incorporated a BP limb length >200 cm in OAGB, but did not show a similarly high incidence of PD.

Some authors now advocate a 150-cm BP limb for OAGB to avoid postoperative PD [19–21]. In contrast, the bowel length in malabsorptive procedures is measured from the ileocecal valve rather than the Treitz ligament in gastric bypass. In malabsorptive procedures, such as biliopancreatic diversion with or without duodenal switch, a minimal common limb length (absorption bowel length) of 250 cm is designed [22]. However, 20% of the patients undergoing biliopancreatic diversion might develop PD [23]. A recent study reported that a common limb length of 400 cm was essential in gastric bypass to avoid PD [24]. This recommendation was corroborated by our finding and should be recommended for gastric bypass procedures.

Although a shorter BP limb (150 cm) in OAGB may avoid the development of PD, this strategy may decrease the efficacy of OAGB in terms of weight loss and resolution of type 2 diabetes [25]. There is evidence that a longer BP limb may produce better weight loss and improved metabolic effect compared with that with a short BP limb in conventional RYGB, as used in this study [26–30]. Miyachi et al. [26] demonstrated that both the presence of a BP limb and the length of the BP limb were important for bariatric/metabolic surgery in an animal model. Clinical observations also support the concept of a longer BP limb for the resolution of metabolic disorders [25,27,28]. It was hypothesized that resolution of metabolic disorders might be related to serum bile acid level [27], which correlates with BP limb length [30]. Therefore, we recommend that the whole length of the small bowel should be measured when designing a gastric bypass procedure if possible. A long BP limb with a common limb length measuring at least 400 cm is required to maximize the antimetabolic disorder effect and minimize the risk of PD.

The management of PD after gastric bypass is a challenge to all bariatric surgeons and remains controversial. Most patients with PD after bariatric surgery can be managed with dietary counseling and high-protein supplementation [5,8]. However, those with severe PD that remains intractable to conservative treatment might require revision surgery to increase the length of common limb for absorption or conversion to normal anatomy. However, conversion to normal anatomy will usually lead to the redevelopment of morbid obesity. In our experience, conversion to SG is one of the reasonable options. The conversions of gastric bypasses to SG not only improved PD but also maintained the weight loss effect.

Revision of gastrojejunal anastomosis and elongation of common limb length might be a simpler procedure. However, we did not have access to adequate techniques and experience for modification of the BP limb length and common limb length. Patients with severe and intractable PD require revision surgery. Protein digestion and absorption are delayed after gastric bypass surgery until the relevant digestive enzymes can interact with the ingested protein [5]. This mechanism would not be changed if the malabsorptive procedures were maintained. We tried to restore common and natural digestive continuity first, to see if the albumin level could be elevated in a short period. Revision surgery is difficult due to micro- and macroscopic structural changes after initial bariatric surgery [31]. The internal tissues may not be in optimal states of health [30]. Based on the literature, different bariatric procedures lead to various histologic modifications [32,33]. Shifting of malabsorptive with restrictive surgery might provide the chance to induce different histologic modifications leading to faster recovery of PD. We aim to maintain the bariatric effect if possible. For these reasons, we used SG as revision surgery for patients with intractable PD after gastric bypass surgery. Fortunately, results have been satisfactory up to now. There were no cases of perioperative morbidity or mortality. Based on our results, other procedures for elongation of common limb length to >400 cm may also resolve PD.

Anemia is the most common presentation of malnutrition after gastric bypass surgery. It is related to the duodenal exclusion effect rather than being the result of a short common limb length. Anemia after gastric bypass surgery is related to iron and vitamin B12 deficiencies resulting from iron and vitamin B12 malabsorption secondary to exclusion of the duodenum and the proximal jejunum, decreased gastric acidity, and dietary modification [5,8,34,35]. In this study, patients undergoing revision surgery due to intractable anemia usually had an adequate length of the common limb. The present study also demonstrated significant improvement in anemia in patients treated with gastric bypass after conversion to SG. This might be due to the restoration of natural digestive continuity.

The limitations of this study include its retrospective nature, the small sample size, selection bias, and the lack of long-term data. Data related to daily protein intake and patient compliance, such as the use of high-protein supplementation or vitamin supplementation, were also not evaluated. However, to the best of our knowledge, this study was the largest case series of patients who underwent revision surgery for PD after gastric bypass and provides evidence of the importance of common limb length.

Conclusion

In conclusion, patients with short total length of bowel might develop PD after gastric bypass surgery when their common limb length measures <400 cm. A longer BP limb is recommended for metabolic surgery, but the entire bowel length should be measured if possible. Revision surgery was needed in those with intractable PD with a short common limb length. Procedures that elongate the common limb length to >400 cm may be suitable for improvement of PD. Conversion to SG is more complex but remains an option for improving malnutrition and maintaining the weight loss effect, when performed by experienced bariatric surgeons.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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