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Proximal Roux-en-Y gastric bypass: Addressing the myth of limb length

Bestoun Ahmed, MD, FACS, FASMBS[a], Wendy C. King, PhD[b], William Gourash, PhD, CRNP[a,*], Amanda Hinerman, MPH[b], Steven H. Belle, PhD, MscHyg[b,c], Alfons Pomp, MD, FACS, FRCSC[d], Walter J. Pories, MD, FACS[e], Anita P. Courcoulas, MD, MPH, FACS[a]

[a] Department of Surgery, Division of Minimally Invasive Bariatric and General Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA
[b] Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA
[c] Biostatistics, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA
[d] Department of Surgery, Division of GI Metabolic and Bariatric Surgery, Weill Cornell Medicine, New York, NY
[e] Department of Surgery, Brody School of Medicine, East Carolina University, Greenville, NC

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ABSTRACT

Background: Some studies suggest that changes in weight or metabolic outcomes are affected by the lengths of the gastrointestinal limbs in the Roux-en-Y gastric bypass.
Methods: Participants ($N = 1{,}770$) underwent primary Roux-en-Y gastric bypass and were followed ≤ 7 years in the Longitudinal Assessment of Bariatric Surgery-2, a multicenter US cohort study. Alimentary limb and biliopancreatic limb lengths were measured according to research protocol; common channel was measured in a subsample ($N = 547$). Aimentary limb, biliopancreatic limb, and common channel ratio to total small bowel length were calculated.
Results: Median presurgery body mass index was 46 (25th–75th percentile: 43–51) kg/m^2. Medians (25th–75th percentiles) for alimentary limb length were 125 cm (100–150), for biliopancreatic limb length were 50 cm (50–60), and common channel length were 410 cm (322–520). Statistics for ratios to the small bowel length were 0.23 (0.18–0.27) for alimentary limb, 0.09 (0.07–0.10) for biliopancreatic limb, and 0.69 (0.63–0.73) for common length. There were no significant associations between alimentary limb, biliopancreatic limb, common channel, alimentary limb ratio, biliopancreatic limb ratio or common channel ratio, and either weight loss or improvement in cardiometabolic outcomes.
Conclusion: The common channel length in Roux-en-Y gastric bypass is highly variable between individuals. None of the limb lengths in this study, nor alimentary limb, biliopancreatic limb, or common channel ratios, seem to be related to weight loss or metabolic improvements >7 years.

Introduction

The Roux-en-Y gastric bypass (RYGB) has been one of the principal bariatric and metabolic operative procedures for the past 5 decades and has undergone many variations of aspects of the technique. Factors in the formation of the gastric pouch, the operative approach (laparoscopic or open), use of staplers or hand sewn anastomosis techniques, anastomotic testing and reinforcement, limb lengths, and limb paths (retro colic or ante colic) are some of the aspects of the operation for which variations have taken place with the goal of decreasing the operative and nutrition complications or increasing the weight loss or metabolic efficacy.[1] Many of these technical elements have not been well characterized in large, multicenter cohort reports.

Currently, there is no consensus as to the optimal lengths of the alimentary limb (AL) or Roux limb and the biliopancreatic limb (BPL) utilized in the standard, proximal gastric bypass, which has been characterized as having a long common channel (CC; Figure). The AL and BPL usually total about ≤ 200 cm, whereas the CC is usually not measured.[2] Historically, variations in limb length were motivated by the perspective that the RYGB was a both a

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* Reprint requests: William Gourash, PhD, CRNP, Department of Surgery, University of Pittsburgh Medical Center, 3380 Boulevard of the Allies, Suite 390, Pittsburgh, PA 15213.
E-mail address: gourashwf@upmc.edu (W. Gourash).

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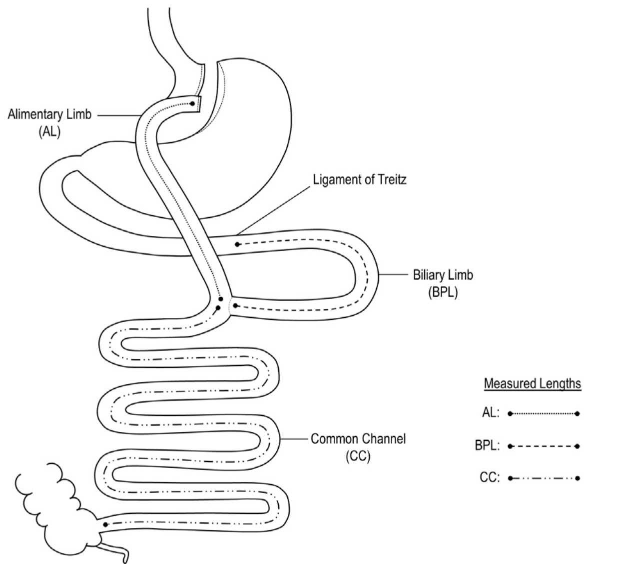

Figure. Diagram of the proximal Roux-en-Y gastric bypass with alimentary and biliopancreatic limbs, the common channel, and measured lengths indicated.

restrictive and a malabsorptive procedure. One hypothesis was that by increasing the bypassed small bowel, there would be increased weight loss and resulting metabolic improvement. Currently, however, there is general acceptance of a decreased role for malabsorption in RYGB[3] and more emphasis, though incompletely understood, on composite contributions from multiple possible sources, such as exclusion of nutrients from the proximal intestine (duodenum or proximal jejunum), rapid delivery of nutrients into the distal gut, the role of gut hormones, changes in metabolism of bile acids, metabolic intestinal reprograming, nutrient sensing and glucose utilization by the gastrointestinal tract, incretins and possible anti-incretin(s), and the intestinal microbiome.[4]

Although the literature examining small bowel limb lengths and associations with weight loss and metabolic outcomes includes several randomized controlled trials (RCT) and comparative studies, the clarity of the results is overshadowed by poor methodologic quality exemplified by small sample sizes, noncomparable populations, multiple combinations of limb length, inadequate follow-up, little standardization of outcome reporting regarding weight loss, and few studies that include metabolic outcomes.[2,5,6] In addition, there is little reference to the effect of the ratios of AL to the BPL lengths (AL/BPL) and these in relation to the CC length.[6] Only a few of these studies have measured the CC, which has been reported to be substantially variable between individuals.[2] Systematic reviews have concluded that within the aforementioned limitations, the proximal RYGB attains optimal results when the combined BPL and AL length is between 100 and 200 cm.[2] For patients with super obesity (body mass index [BMI] of 50 kg/m^2 and greater), a much longer segment of bypassed small bowel may yield improved outcomes.[2,5,6]

Using a large multicenter US cohort of 1,770 adults who underwent RYGB between 2006 and 2009 with $\leq$7 years of follow-up, the aims of this study were as follows: (1) describe the operative characteristics of RYGB, (2) identify factors related to limb length, and (3) examine associations between limb lengths and changes in weight and metabolic outcomes. A secondary aim was to evaluate whether BMI was an effect modifier, that is, whether associations with limb lengths differed for those with lesser versus greater BMI.

Methods

The Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) was a multicenter observational cohort study at 10 US hospitals in 6 geographically diverse clinical centers and a data coordinating center. Adults undergoing first-time bariatric operative procedures by participating surgeons were eligible. The institutional review boards of each center approved the protocol, and participants gave written informed consent to participate. This report is limited to the 1,770 of 2,458 LABS-2 participants who underwent RYGB. Analyses that utilized the CC length were limited to the subset of 547 participants in whom it was measured.

Descriptions of research assessments and most data collection forms and measures have been described previously.[7] Sociodemographics were self-reported. LABS-2 had a standard protocol to report uniformly the operative factors (eg, gastric pouch formation, operative approach, techniques of anastomoses, testing, reinforcement, and configurations, and limb lengths).

The BPL was defined as the length from the ligament of Treitz to the point at which the small bowel was divided (Figure). The AL (Roux limb) was defined as the length of small bowel attached from the gastrojejunostomy to the enterostomy with the BPL. The CC was defined as the total length of small intestine from the AL enterostomy to the terminal ileum. The small bowel length (TSBL) was calculated as the sum of the BPL, the AL, and the CC. The AL, BPL, and CC length ratios were calculated as the respective length divided by the TSBL.

Weight and height were measured using standard protocols.[8] BMI was calculated as weight in kilograms divided by squared height in meters. Weight change was calculated as percentage of preoperative weight. Weight regain from the nadir of weight loss postoperatively was evaluated as percentage of maximum weight lost.

At annual visits, glycated hemoglobin (HbA1c), low-density lipoprotein cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL) were determined by a central laboratory. Blood pressure was determined by a single measurement. Improvement in each cardio-metabolic outcome (diabetes, hyperlipidemia, hypertension [HTN], triglycerides, and HDL) was defined by criteria used in clinical care to manage risk of cardio-metabolic outcomes. Each postoperative outcome was evaluated among those who were above the established threshold(s) or reported taking the medication(s) for the condition at the preoperative assessment (Appendix, Supplemental Digital Content).

Analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC). All reported *P* values are 2-sided.

BPL and AL lengths were categorized as <50, 50, or >50 cm, and as <99, 99 to 100, 101 to 149, 150, or >150 cm, respectively. The category with the largest sample (150 cm for AL and 50 cm for BPL) was used as the reference. Two multivariable multinomial logistic regression models were used to evaluate associations of clinical center, surgeon, operative approach, and preoperative BMI with BPL length and AL length, respectively. In the CC length subsample, 2 multivariable linear regression models were used to evaluate associations of clinical center, operative approach, and preoperative BMI with the CC length and the TSBL, respectively.

A series of linear mixed models were used to test associations between measurements of limb length and percentage weight change across follow-up. A difference in weight change between the CC length subsample ($N = 547$) and those who were not in the subsample ($N = 1{,}223$) was assessed using a linear mixed model fit using maximum likelihood with a person-level random intercept, with a group indicator (ie, included or excluded) as a discrete fixed effect, and time since

Table I
Characteristics of adults before undergoing a proximal RYGB in the total sample and the common channel length subsample

	Total sample (N = 1,770*) No. (%)†	Common channel length subsample (N = 547*) No. (%)†
Age, y		
Median (25th–75th percentile)	45 (37–54)	44 (36–52)
Range	19–75	20–75
Female	1413 (79.8)	427 (78.1)
White	1,494/1,751 (85.3)	492/542 (90.8)
Hispanic/Latino ethnicity, No./total (%)	87/1,769 (4.9)	36 (6.6)
Married or living as married	1,019/1,633 (62.4)	319/504 (63.3)
Education	(*N* = 1635)	(*N* = 503)
High school or less	385 (23.6)	134 (26.6)
Some college	700 (42.8)	202 (40.2)
College degree	550 (33.6)	167 (33.2)
Employment	(*N* = 1,626)	(*N* = 498)
Work for pay	1,125 (69.2)	351 (70.5)
Homemaker	75 (4.6)	26 (5.2)
Disabled	250 (15.4)	56 (11.2)
Unemployed	69 (4.2)	28 (5.6)
Retired	83 (5.1)	26 (5.2)
Other	24 (1.5)	11 (2.2)
Household income, US $	(*N* = 1,589)	(*N* = 492)
<25,000	316 (19.9)	92 (18.7)
25,000–49,999	447 (28.1)	158 (32.1)
50,000–74,999	378 (23.8)	108 (22.0)
75,000–99,999	237 (14.9)	67 (13.6)
>100,000	211 (13.3)	67 (13.6)
Medical insurance	(*N* = 1,630)	(*N* = 503)
Private	1,064 (65.3)	341 (67.8)
Medicaid	171 (10.5)	59 (11.7)
Medicare	158 (9.7)	34 (6.8)
Tricare	56 (3.4)	7 (1.4)
Other/unknown type	162 (9.9)	57 (11.5)
None	19 (1.2)	3
Current or recent smoker, No./total (%)	254/1,766 (14.4)	97 (17.7)
Body mass index, kg/m^2		
Median (25th–75th percentile)	46.6 (42.4–52.0)	46.3 (42.5–51.5)
Range	33.7–81.0	33.7–72.5
Diabetes	615/1,737 (35.4)	167/534 (31.3)
Hyperlipidemia	625/1,538 (40.6)	173/469 (36.9)
Low HDL	663/1,701 (39.0)	198/536 (36.9)
High triglycerides	343/1,636 (21.0)	107/515 (20.8)
Hypertension	1,207/1,740 (69.4)	357/536 (66.7)

* Denominators shift between variables due to missing data.
† Data are reported as No. (%) unless otherwise indicated.

operation as a continuous fixed effect, controlling for preoperative factors related to missing data (ie, center, smoking status, and age). A series of Poisson mixed models with robust error variance[9] were used to test associations of limb lengths with binary cardio-metabolic outcomes across follow-up. Mixed models[10] controlled for preoperative factors related to missing follow-up data (ie, clinical center, age, and smoking status), preoperative BMI, and time since operation entered as fixed effects. Banding (ie, reinforcement of the pouch after stapling) and interactions between limb lengths and preoperative BMI were considered and retained if statistically significant. Models for cardio-metabolic outcomes also controlled for percentage weight change from the preoperative weight. The first set of models included the 3 limb lengths. The second, third, and fourth sets of models included the CC length ratio, the AL length ratio, and the BPL length ratio, respectively. Because CC length was not associated with any of the outcomes, the fifth set of models included the AL and BPL lengths in the full sample.

As a sensitivity analysis, the modeling of weight change and cardio-metabolic outcomes was repeated replacing continuous BMI with the binary variable, ≥50 kg/m^2 vs <50 kg/m^2.[2,5,6] An interaction between limb length and preoperative BMI was considered and retained if significant.

Results

Participant characteristics

Preoperative characteristics for the total sample ($N = 1{,}770$) and the CC length subsample ($N = 547$) are reported in Table I. Among the full sample, the median age was 45 years (25th–75th percentile, 37–54), 79.8% were female, 85.3% were white, and the median BMI was 46.6 kg/m^2 (25th–75th percentile, 42.4–52.0). One clinical center was much more likely than other centers to record CC length (85% vs <40% at all other centers) and accounted for 336 of 547 (61%) of the participants with this data element. There was no difference in weight change from the date of operation across all follow-up visits between the CC length subsample ($N = 547$) and those who were not in the subsample ($N = 1223$; $P = .30$).

Operative characteristics

Thirty-two surgeons contributed a median of 43 operations each (25th–75th percentile, 6–70). Twenty-three surgeons contributed a median of 6 operations each (25th–75th percentile, 2–33) to the CC subsample. A comprehensive listing of operative characteristics is reported in Table II. The majority of operations (87.6%) were

Table II
Operative characteristics of adults who underwent a proximal RYGB in the LABS-2 cohort

	Total (N = 1,770*) No. (%)†
Operative approach	
Laparoscopic	1,550 (87.6)
Open	220 (12.4)
Total length of gastric staple line, cm	(*N* = 1,409)
Median (25th–75th percentile)	8.0 (7.0, 11.0)
Range	1.5–30.0
How gastric staple line measured	(*N* = 1,409)
String	55 (3.9)
Ruler	427 (30.3)
Grasper	927 (65.8)
Type of gastric stapling line	
Partitioned	32 (1.8)
Divided	1,705 (98.1)
Both divided and part	1 (0.1)
Staple height for the gastric pouch	
2.5 mm only	13 (0.7)
3.5 mm only	1,325 (74.9)
4.5 mm only	94 (5.3)
Other heights only	111 (6.3)
Multiple heights	227 (12.8)
Manufacturer of the stapling device	
US Surgical	1,471 (83.1)
Ethicon	297 (16.8)
Other	2 (0.1)
Banding or a ring was used	102 (5.8)
Type of gastric pouch reinforcement	(*N* = 102)
Silastic ring/band	79 (77.5)
Synthetic mesh	23 (22.5)
Route of alimentary limb ascension	
Ante-colic, ante-gastric	1,104 (62.4)
Ante-colic, retro-gastric	7 (0.4)
Retro-colic, ante-gastric	157 (8.9)
Retro-colic, retro-gastric	502 (28.4)
Configuration used for the proximal (Gastro-Jejunal) anastomosis	
Side-to-side	549 (31.0)
End-to-side	1,218 (68.8)
End-to-end	3 (0.2)
Method of proximal (Gastro-Jejunal) anastomosis	
Hand sewn only	491 (27.7)
Linear stapled only	10 (0.6)
Circular stapled only	710 (40.1)
Multiple methods	559 (31.6)
Anastomoses tested	1,512 (85.4)
Additional protectant used around Gastro-Jejunum anastomosis creation	
None	859 (48.5)
Seal only	242 (13.7)
Buttress only	5 (0.3)
Sutures only	568 (32.1)
Other only	9 (0.5)
Multiple protectants	87 (4.9)
Drain placed at the Gastric-Jejunum anastomosis	332 (18.8)
Configuration used for the distal (Jejunum-Jejunum) anastomosis	
Side-to-side	1,659 (93.7)
End-to-side	111 (6.3)
Method of distal (Jejunum-Jejunum) anastomosis: hand sewn§	499 (28.2)
Method of distal (Jejunum-Jejunum) anastomosis: linear stapled§	1,757 (99.3)
Closure of Mesenteric defects	1,071 (60.5)
Closure Petersen's defect	
Entero-enterostomy	1,677 (94.7)
Trans mesenteric	650/659 (98.6)
Anti-obstruction stitch placed	1,155 (65.3)
Rating of difficulty in performing the surgical procedure‡	(*N* = 1,753)
Median (25th–75th percentile)	4.0 (3.0–6.0)
Range	1.0–10.0
Difficulty owing to intra-abdominal fat distribution	596/1,758 (33.9)
Difficulty owing to thick abdominal wall	475/1,758 (27.0)
Difficulty owing to limited exposure due to enlarged/fatty liver	391/1,758 (22.2)
Difficulty owing to adhesion from previous surgery	328/1,759 (18.6)

* Unless otherwise indicated. Denominator is lower for some variables due to missing data.
† Data are reported as No. (%) unless otherwise indicated.
‡ On a scale of 1 to 10, with 1 being easy and 10 being very difficult.
§ Some surgeons utilized a combination of both (hand sewn and a linear staple technique) methods together in the same case and this was not captured separately.

performed laparoscopically. The configuration used for the gastrojejunostomy was end-to-side in 68.8% of procedures, and the anatomic track of the AL was ante-colic or ante-gastric in 62.4%. A range of methods were used to complete the gastrojejunostomy including circular stapled only (40.1.6%), hand sewn only (27.7%), linear stapled only (0.6%), and multiple methods (31.6%), most often a combination of linear stapled and hand sewn.

Anastomotic testing of the gastrojejunostomy was completed in 85.4% of procedures and drains were placed in 18.8%. The gastric pouch was reinforced in a small percentage of procedures with a silastic ring or band or synthetic mesh (5.8%). The vast majority of jejunojejunostomies (99.3%) were completed with the use of a stapler; approximately 27% also involved hand sewing. The side-to-side configuration was used in 93.7% of procedures. The Petersen's defects were closed in 60.5% of procedures, while the entero-enterostomy defect and the trans mesenteric defect were closed in 94.7% and 98.6%, respectively.

Limb lengths are reported in Table III. The BPL was measured utilizing a grasper (74.4%), string (19.0%), or a ruler (6.5%). The AL was measured utilizing a grasper (74.4), string (19.0%) or a ruler (7.0%). The CC was measured utilizing a grasper (54.7%), string (37.1%), or a ruler (8.2%). The most common length of the BPL was 50 cm and of the AL was 150 cm, which accounted for 46.8% and 45.2% of operations, respectively. There was more variability in the CC length for which the median was 410 cm (25th–75th percentile, 322–520). The median TSBL length in the CC subsample was 600 cm (25th–75th percentile, 509–710).

Associations with limb lengths

Preoperative BMI was positively associated with the lengths of the BPL ($P = .04$) and AL ($P < .001$; Table IV). Specifically, for every 5 kg/m^2 greater BMI, the odds of having a BPL of 50 cm vs <50 cm was 1.09 (95% confidence interval [CI], 0.92–1.30), whereas the odds of having a BPL of >50 cm vs 50 cm was 1.14 (95% CI, 0.97–1.33). With regard to the AL, for every 5 kg/m^2 greater BMI , the odds of having a limb <150 cm vs 150 cm were 0.38 (95% CI, 0.31–0.47), 0.45 (95% CI, 0.39–0.53), and 0.51 (95% CI, 0.43–0.61), for categories of <99 cm, 99 to 100 cm, and 101 to 149 cm, respectively, whereas the odds of having an AL of >150 vs 150 cm was 2.03 (95% CI, 1.58–2.61). There was no independent association between operative approach with BPL ($P = .58$) or AL length ($P = .59$). In contrast, the clinical center and surgeon were both related to AL and BPL, even after accounting for preoperative BMI and operative approach (P for all <.001).

Among the CC subsample, CC length was less in those with greater BMI ($P = .005$), such that for every 5 kg/m^2 greater BMI, CC length was on average 11.7 cm (95% CI, 3.6-19.9) shorter.

Table III
Limb lengths of RYGB in the LABS-2 cohort

	Total (N = 1,770*) No. (%)†
How biliopancreatic limb was measured	(N = 1,761)
String	335 (19.0)
Ruler	115 (6.5)
Grasper	1,311 (74.4)
Length of the biliopancreatic limb, cm	(N = 1,765)
Median (25th–75th percentile)	50.0 (50.0–60.0)
Range	10.0–160.0
Length of the biliopancreatic limb, cm	(N = 1,765)
<50	293 (16.6)
50	826 (46.8)
>50	646 (36.6)
How alimentary limb was measured	(N = 1,762)
String	334 (19.0)
Ruler	124 (7.0)
Grasper	1,304 (74.0)
Length of the alimentary limb, cm	(N = 1,768)
Median (25th–75th percentile)	125.0 (100.0–150.0)
Range	30.0–230.0
Length of the alimentary limb, cm	(N = 1,736)
<99	109 (6.2)
99/100	502 (28.4)
101–149	292 (16.5)
150	799 (45.2)
>150	66 (3.7)
How common channel was measured	(N = 547)
String	203 (37.1)
Ruler	45 (8.2)
Grasper	299 (54.7)
Length of the common channel, cm	(N = 547)
Median (25th–75th percentile)	410.0 (322.0–520.0)
Range	47.0–775.0
Common channel length ratio	(N = 547)
Median (25th–75th percentile)	0.69 (0.63–0.73)
Range	0.17–0.87
Alimentary limb length ratio	(N = 547)
Median (25th–75th percentile)	0.23 (0.18–0.27)
Range	0.08–0.61
Biliopancreatic limb length ratio	(N = 547)
Median (25th–75th percentile)	0.09 (0.07–0.10)
Range	0.03–0.31
Total small bowel limb length	(N = 547)
Median (25th–75th percentile)	600.0 (509.0–710.0)
Range	225.0–1015.0

* Unless otherwise indicated. Denominator is lower for some variables due to missing data.
† Data are reported as No. (%) unless otherwise indicated.

Preoperative BMI was not related to TSBL ($P = .07$; Table V). Those undergoing an open vs laparoscopic approach had on average shorter CC lengths (105.1 cm; 95% CI, 70.0 p = .140.2; $P < .01$) and TSBL (117.2 cm; 95% CI, 80.7–153.6; $P < .002$). The clinical center was independently related to CC and TSBL (P for both <.01).

Change in weight and metabolic improvements

Data completeness of outcomes by time since operation are reported among the CC subsample and the full sample in supplemental material (Table I, Supplementary Digital Content). Among the full sample, 5 years post-RYGB, median percent weight change from preoperative weight was −29.6% (25th–75th percentile, −36.1, −22.5), median change in HbA1c was −0.4% (25th–75th percentile, −0.9, −0.1), and more than two-thirds of participants with impaired cardio-metabolic status preoperatively had clinically meaningful improvements in the cardio-metabolic outcomes (76.4% in diabetes, 73.0% in hyperlipidemia, 67.8% in HTN, 75.1% in triglycerides, and 82.2% in HDL; Table II, Supplementary Digital Content).

Table VI provides the estimated difference in percentage weight change and HbA1c, respectively, as a function of limb length. Table VII presents relative risks of cardio-metabolic outcomes by limb lengths. Among the CC subsample, with control for potential confounders, none of the individual limb length measures in this study (model 1) nor limb length ratios (models 2–4) were related to outcomes. Among the full sample, neither BPL nor AL length as used in this study (model 5) were independently related to outcomes.

Sensitivity analysis

The significance and direction of associations with weight and cardio-metabolic outcomes reported in Tables VI to VII were similar when the continuous measure of BMI was replaced with the BMI categorized as less than versus at least 50 kg/m^2 (data not shown). There were no statistically significant interactions between BMI category and limb lengths.

Discussion

This study presents in detail the technical operative characteristics of the RYGB that are not regularly reported in outcome studies from large cohorts. The vast majority of the cases in this report were proximal gastric bypasses with a laparoscopic approach and were not distal or very very long limb gastric bypasses.[11] The CC measured in approximately a third of the cases in this report had considerable variability. With control for clinical center, age, smoking status, and BMI and the exclusion of the broad category of distal gastric bypasses, there were no statistically significant associations between individual limb or CC lengths or ratios and weight change or cardio-metabolic outcomes (change in HbA1c, diabetes, hyperlipidemia, triglycerides, HDL, and HTN) across the full BMI spectrum or when categorizing people as super obese (ie, BMI at least 50 kg/m^2) or not.

Nine studies have reported on measurements of the CC and limb length effects and associations with outcomes in proximal RYGB, predominantly with a laparoscopic approach (Table VIII).[12–20] They reported on a total of 1,334 patients; all but one had 25 to 151 participants each. The mean TSBL ranged from 407.9 to 743.4 cm. The shortest reported measured lengths of the TSBL ranged between 302 cm to 550 cm and the longest measured lengths ranged between 600 and 1,060 cm. In comparison, in our sample of 547 participants, the mean TSBL was 612.6 (147.1 SD) cm and the range was 225 cm to 1,015 cm. The substantial variability among our sample and previous studies indicates measurement of the CC length is important to avoid a short CC in some individuals which can lead to unwanted, potentially nutritional complications.[2]

Preoperative variables and limb lengths

As expected, those with higher preoperative BMI had longer BPL and AL lengths and shorter CC length. In addition, independent of preoperative BMI or operative approach, the surgical center and surgeon were related to BPL and AL lengths. Likewise, surgical center was related to CC length. Thus, our results indicate that factors other than BMI (eg, personal or center-directed preferences regarding limb length or unmeasured patient-level confounders) influence limb length.

AL, BPL, and the CC length and weight loss

There is little debate that, for those patients with a BMI <50, extending the AL beyond 100 cm (within the constraints of a proximal RYGB) adds little if any substantial weight loss benefit.[2,5,6]

Table IV
Adjusted odds of longer or shorter limb lengths, by operative approach and BMI among adults who underwent RYGB*

	Biliopancreatic limb (ref = 50 cm) (N = 1,765)			Alimentary limb (ref = 150 cm) (N = 1,768)				
	<50 cm AOR (95% CI)	>50 cm AOR (95% CI)	*P* value	<99 cm AOR (95% CI)	99/100 cm AOR (95% CI)	101–149 cm AOR (95% CI)	>150 cm AOR (95% CI)	*P* value
Approach, Open vs Laparoscopic	1.56 (0.56–4.32)	0.92 (0.27–3.18)	.58	3.72 (0.73–18.93)	1.02 (0.42–2.50)	1.16 (0.41–3.30)	†	.59
BMI, per 5 kg/m^2	0.92 (0.77–1.09)	1.14 (0.97–1.33)	.04	0.38 (0.31–0.47)	0.45 (0.39–0.53)	0.51 (0.43–0.61)	2.03 (1.58–2.61)	<.001

* Both models included clinical center, surgeon, operative approach and preoperative BMI. Clinical center (*P* < .001) and surgeon (*P* < .001) were significant in the model of biliopancreatic limb length, and in the model of alimentary limb model (*P* = .01 for clinical center, *P* < .001 for surgeon).
† Model unable to produce reliable estimates for this category.

Table V
Adjusted estimates of limb lengths, by operative approach and BMI among adults who underwent RYGB*

	Common channel length, cm (N = 547)		Total small bowel limb length, cm (N = 547)	
	B (95% CI)	*P* value	*B* (95% CI)	*P* value
Operative approach, open vs laparoscopic	−105.08 (−140.16 to 70.01)	<.01	−117.16 (−153.59 to 80.73)	<.002
Body mass index, per 5 kg/m^2	−11.72 (−19.88 to 3.56)	.005	−7.80 (−16.28 to 0.68)	.07

* Both models included clinical center (majority center versus other centers), operative approach and preoperative body mass index. Clinical center was significant in both models (*P* < .001). The r^2 statistic from the common channel length and total small bowel limb length models was 0.12 and 0.13, respectively.

Table VI
Adjusted changes in weight and in HbA1c from operation by RYGB limb lengths*

	Percentage weight change			Change in HbA1c (%)		
	n	*B* (95% CI)	*P* value	n	*B* (95% CI)	*P* value
	N = 536			N = 490		
Model 1†:						
Common channel length, per 10 cm		0.02 (−0.04 to 0.07)	.56		−0.01 (−0.01 to 0.001)	.08
Model 2:						
Common channel length ratio, per 1 unit increase		−3.09 (−11.21 to 5.02)	.45		−0.56 (−1.47 to 0.35)	.23
Model 3:						
Alimentary limb length ratio, per 1 unit increase		4.94 (−5.69 to 15.58)	.36		0.64 (−0.56 to 1.83)	.30
Model 4:						
Biliopancreatic limb length ratio, per 1 unit increase		2.06 (−22.71 to 26.82)	.87		1.72 (−1.04 to 4.48)	.22
	N = 1727			N = 1484		
Model 5:						
Biliopancreatic limb (ref = 50 cm)	813		.66	738		.23
<50 cm	287	0.15 (−1.99 to 2.28)		236	0.22 (−0.04 to 0.47)	
>50 cm	631	0.69 (−0.88 to 2.25)		516	0.10 (−0.09 to 0.28)	
Alimentary limb (ref = 150 cm)	782		.07	700		.14
<99 cm	108	−0.81 (−2.87 to 1.26)		91	0.05 (−0.19 to 0.29)	
99/100 cm	493	−1.54 (−2.78 to −0.30)		425	0.11 (−0.03 to 0.26)	
101–149 cm	287	−1.70 (−3.22 to −0.19)		224	0.14 (−0.04 to 0.32)	
>150 cm	63	0.52 (−1.98 to 3.03)		52	−0.21 (−0.51 to 0.08)	

* Adjusted for preoperative factors related to missing data (ie, clinical center, age and smoking status), preoperative body mass index, and time since operation surgery entered as a continuous fixed effect. The models of change in HbA1c also adjusted for percentage weight change. Banding (yes/no) and interaction terms for limb length measures and BMI were not significant and thus not retained.
† This model also adjusted for biliopancreatic limb and alimentary limb lengths (see model 5 for associations with these limb lengths among the full sample).

Additionally, a recent meta-analysis that focused on RYGB AL limb length and weight loss concluded that in patients with a BMI <50, relatively short ALs (40–100 cm) were as efficacious as longer (130–150 cm) ALs regarding weight loss.[21] Our analysis is in agreement with this report and demonstrated that weight change did not differ significantly by individual limb or CC lengths or ratios between the lengths.

Brolin et al in 1992 was one of the first to test the hypothesis that a longer limb bypass would result in more weight loss in patients with super obesity and referred to a AL of 150 cm as a long limb RYGB.[22] They completed a prospective, randomized RYGB trial of patients with super-obesity who were randomized between the standard limb lengths and lengthening the BPL 15 to 30 cm and the AL from 75 to 150 cm. They noted that percent excess weight loss

Table VII
Adjusted relative risks for cardio-metabolic factors by RYGB limb lengths*

	Improvement in:														
	Diabetes†			Hyperlipidemia‡			Hypertension§			Triglycerides‖			HDL¶		
	n	RR (95% CI)	P value	n	RR (95% CI)	P value	n	RR (95% CI)	P value	n	RR (95% CI)	P value	n	RR (95% CI)	P value
	N = 244			N = 329			N = 451			N = 173			N = 292		
Model 1#:															
Common channel length, per 10 cm		0.99 (0.994–1.01)	.82		1.00 (0.99–1.01)	.85		1.00 (0.99–1.003)	.55		0.99 (0.98–1.003)	0.26		1.00 (0.99–1.01)	.37
Model 2:															
Common channel length ratio, per 1 unit increase		0.85 (0.41–1.80)	.68		0.80 (0.38–1.71)	.57		0.98 (0.52–1.82)	.94		0.57 (0.22–1.50)	0.25		1.26 (0.53–3.00)	.61
Model 3:															
Alimentary limb length ratio, per 1 unit increase		1.12 (0.42–3.00)	.82		1.54 (0.58–4.08)	.38		0.96 (0.42–2.17)	.92		1.88 (0.52–6.72)	0.33		0.78 (0.26–2.33)	.66
Model 4:															
Biliopancreatic limb length ratio, per 1 unit increase		2.55 (0.24–26.84)	.44		0.65 (0.05–7.81)	.74		1.55 (0.24–10.16)	.65		12.67 (0.40–402.59)	0.15		0.51 (0.04–7.25)	.62
		N = 836			N = 1043			N = 1510			N = 503			N = 866	
Model 5:															
Biliopancreatic limb (ref = 50 cm)	365		.84	519		.46	704		.91	267		0.15	437		0.32
<50 cm	158	1.03 (0.87–1.21)		178	0.93 (0.78–1.10)		252	1.02 (0.89–1.17)		90	1.41 (1.00–1.99)		139	0.94 (0.77–1.15)	
>50 cm	317	0.98 (0.87–1.12)		352	1.03 (0.89–1.19)		559	0.99 (0.89–1.10)		147	1.15 (0.86–1.55)		293	0.89 (0.77–1.03)	
Alimentary limb (ref = 150 cm)	363		.97	484		.43	667		.92	250		0.95	404		0.80
<99 cm	60	0.99 (0.84–1.17)		64	0.90 (0.75–1.09)		97	1.01 (0.88–1.16)		27	1.08 (0.78–1.49)		55	0.97 (0.80–1.18)	
99/100 cm	237	0.99 (0.89–1.10)		324	0.90 (0.81–1.00)		437	1.01 (0.93–1.10)		157	0.97 (0.82–1.16)		258	0.95 (0.86–1.06)	
101–149 cm	147	0.98 (0.86–1.11)		145	0.95 (0.83–1.09)		257	0.99 (0.90–1.10)		56	0.95 (0.75–1.20)		132	0.95 (0.82–1.09)	
>150 cm	34	1.06 (0.88–1.28)		32	1.01 (0.79–1.29)		60	1.07 (0.91–1.27)		14	1.00 (0.69–1.43)		22	1.09 (0.81–1.46)	

* Adjusted for preoperative factors related to missing data (ie, clinical center, age and smoking status), presurgery BMI (continuous), percentage weight change from surgery and time since surgery entered as a continuous fixed effect. Banding (yes/no) and interaction terms for limb length measures with BMI were not significant and thus not retained.
† A change from taking diabetes medication to not taking diabetes medication, change from taking insulin to not taking insulin, or a decrease of glycated hemoglobin (HbA1c) by at least 0.5% plus a postsurgery value of ≤5.7%.
‡ A change from taking hyperlipidemia medication to not taking hyperlipidemia medication, or a decrease of low-density lipoprotein (LDL) by at least 10 plus a postsurgery value of ≤100.
§ A change from taking hypertension medication to not taking hypertension medication, a decrease of systolic blood pressure (SBP) by at least 5 plus a postsurgery value of ≤120, or a decrease of diastolic blood pressure (DBP) by at least 5 plus a postsurgery value of 80 or lower.
‖ Improvement of triglycerides was defined as: a decrease by at least 15 mg/dL to lower than 150 mg/dL.
¶ Improvement of HDL was defined as: an increase by at least 5 mg/dL to higher than 40 mg/dL.
# Model also adjusted for biliopancreatic limb and alimentary limb (see model 4 for associations with these limb lengths among the full sample).

was greater at 24 and 36 months with this longer limb length. Subsequently, a number of other similar studies have demonstrated mixed results (Table IX).[14,22–30] The conclusion that a longer AL (at least 150 cm) may lead to a modest weight loss advantage in the short-term in patients with super obesity, without having significant impact on those with a BMI <50, was supported by 3 different systematic reviews of the data during the past 25 years[2,5,6] and has influenced the limb length preferences of bariatric surgeons.

Ten studies (Table IX) have focused on limb length among patients with super obesity. Across studies, there is substantial heterogeneity in study design, limb lengths tested, outcome variables, and units, and in general, sample sizes are small, patient follow-up is short term (<5 years), and the completeness of the data is low in studies that have greater than 3-year duration.[2,5,6] In a subgroup meta-analysis of super obese patients based on only 2 of the 10 studies in Table IX and representing data from only 388 patients, Gan et al[21] concluded that AL lengths 40 to 100 cm decreased weight but not as efficaciously as AL lengths of 130 to 150 cm.

In proximal RYGB studies where the CC length was measured and associations with outcomes were evaluated,[13,15,18] CC length and %CC (CC length divided by the TSBL multiplied by 100) demonstrated no effect on weight loss through 2 years. In contrast, a lesser CC ratio was related to greater nutritional deficiencies. Savassi-Rocha et al in a subgroup of 21 patients with super obesity detected a weak correlation between CC and percent excess weight loss.[13] In our cohort of 547 patients with a proximal RYGB, we have measured and analyzed the ratio of all 3 limbs to the TSBL separately. There were no statistically significant differences in weight loss regarding the limb lengths or ratios of the limbs to the CC.

Intestinal limbs and cardiometabolic outcomes

LABS-2 and many large cohort studies have described significant cardio-metabolic improvements after RYGB.[31,32] In the present study, the majority of participants with impaired cardio-metabolic status preoperatively had clinically meaningful improvements in diabetes, HTN, and lipid-related metrics as determined using established objective criteria throughout 7 years of follow-up. In contrast, limb lengths or ratios of the limbs were not related to chance of improvement of these outcomes. Comparative studies of

Table VIII
Proximal RYGB studies which included limb length analysis and measurement of total small bowel*

Study	Year	N	Surgical approach L = laparoscopic, O = open, B = both	Measurement method G = grasper T = thread NS = not stated	Mean Small bowel length, cm (SD)	Shortest bowel length (cm)	Longest bowel length (cm)	Follow-up (y)
Leifsson et al[12]	2005	25	L	NS	540 (median)	450	600	1.5
Savassi-Rocha et al[13]	2008	100	O	T	671.4	434	990	1
Gleysteen et al[14]	2009	110	O	T	498	302	792	5
Abellan et al[15]	2014	151	L	G	573	335	860	2
Kaska et al[16]	2014	93	B	NS	407.9 (108.2)	325	650	2
Nergaard et al[17]	2014	650	L	G	620	420	870	7
Navez et al[18]	2016	90	L	G	585.1 (94.6)	380	815	1
Schiavon et al[19]	2018	45	L	G	716.3	550	930	1
Kakela et al[20]	2018	70	L	G	743.4 (113.6)	530	1,060	1

* Total small bowel length was considered the measurement from the ligament of Trietz to the ileocecal valve or the addition of the biliopancreatic and alimentary limbs and the common channel.

Table IX
Proximal RYGB studies where weight loss outcomes were compared in the super obese (BMI >50) population.

Author	Year	Study type	N	Limb lengths group 1			Limb lengths group 2			Limb lengths group 3			Weight loss findings	FU mo
				BPL cm	AL cm	CC cm	BPL cm	AL cm	CC cm	BPL cm	AL cm	CC cm		
Brolin et al[22]	1992	RCT	45	15	75	NM	30	150	NM				Group 2 > mean weight loss at 24 and 36 mo. ($P < .02$); mean BMI < at 24 mo. ($P < .01$)	48
MacLean et al[23]	2001	RCT	96	10	40	NM	100	100	NM				Group 2 < final BMI, mean % EWL NSS	46.3
Choban et al[24]	2002	RCT	64	30	150	NM	30	250	NM				Group 2 with > # with 50 %EWL but mean %EWL NSS	36
Brolin et al[25,*]	2002	Comparative	251	15	75	NM	30	150	NM				Group 2 with significant weight loss differences at 1, 2, 3, 4 y. FU of group 2 at 4 and % yr., 68% and 64%	60
Christou et al[26]	2006	Comparative	100	10	40	NM	100	100	NM				Group 2 slight > in weight loss at 5 and 10 y, but NSS	120
Ciovica et al[27]	2008	Comparative	161	30	100	NM	30	150	NM				Group 2 > change in BMI ($P <$ .01) and > %EWL ($P < .01$)	12
Pinheiro et al[28]	2008	RCT	105	50	150	NM	100	250	NM				Group 2 with faster weight loss but NSS mean %EWL at 48 mo.	48
Gleysteen et al[14]	2009	Comparative	227	18–30	41–61	NM	18–30	160	NM	10–30	115–250	M	Group 2 with > BMI change and pounds lost at all annual time points ($P < .01$ at all annual points but % FU at 5 y was 44%.	60
Sarhan et al[29]	2011	Comparative	120	50–80	120–150	NM	50–80	170–200	NM				Group 2 NSS in %EWL	36
Risstad et al[30]	2016	RCT	113	50	150	NM	50	V	150				Group 2 without > BMI reduction	24

FU, follow-up; *GLP-1*, glucagon-like peptide 1; *NM*, not measured; *NSS*, not statistically significant.; *%EWL*, percent excess weight loss.
* Patient data from 1992 RCT was included in this comparative study.

cardio-metabolic outcomes by intestinal limb lengths have not commonly been performed with proximal RYG perhaps owing to the low power for sub analysis of cardio-metabolic medical conditions in the relatively small sample RCTs and comparative studies of limb length.

Several RYGB studies[16,28,33] demonstrated a higher type 2 diabetes mellitus remission rate in the longer limb combination which included a BPL longer than 100 cm and an overall BLP and AL combination >300 cm. Kaska et al[16] additionally observed a more substantial metabolic effect in patients with a shorter CC in both groups. They hypothesized that the length of the CC rather than the BPL influences the laboratory criteria for T2DM remission. The AL and BPL lengths in our data contain very few that would be similar to any of longer limbs of these 3 studies. Consistent with our findings and our intestinal limb lengths is a comparative study by Ramos et al[34] of 53 patients with T2DM with a BMI ≥35 where the long limb group utilized a BPL of 100 cm and an AL of 50 cm. They reported no difference in improvement of metabolic syndrome. Schiavon et al[19] in an RCT focused on HTN outcomes and demonstrated that the CC length did not influence remission of HTN and other cardio-metabolic risk factors.

The distal RYGB, similar to the proximal RYGB, consists of a relatively small gastric pouch, but includes either a long (150–570 cm) BPL or AL together with a short CC (75–150 cm).[25,30] Results have been mixed regarding the magnitude of improvement of cardio-metabolic outcomes as compared with proximal RYGB. Similarly, the so-called very, very long limb RYGB used a short BPL (50 cm), a very long AL, and a CC of only 50 to 100 cm.[11] A 2018 systematic review explored the importance of the BPL length in gastric bypass results identifying 13 studies addressing the BPL in proximal and distal RYGB.[35] They concluded that there are few rigorous studies available delineating the metabolic effects of different BPL lengths. There was some evidence suggesting that longer over shorter BPL length may affect the metabolic effects of RYGB. The longer BPL lengths were those typically used in distal RYGB. But owing to a greater risk for long-term severe complications (eg, protein malnutrition, and fat-soluble vitamin deficiency), the distal and very, very long limb RYGB is no longer utilized routinely as a primary bariatric surgery procedure.[11,25,30]

In proximal gastric bypass by definition, the BPL and AL lengths would add up to less than the 200 cm limit.[2] A safe range is 90 to 200 cm. This calculation is based on a BPL of 30 to 50 cm and the AL of 60 to 150 cm. This would be a safe range for the majority of our patients to avoid the possibility of bile reflux, fat soluble vitamin deficiencies, and protein malnutrition. Measurement of TSBL can avoid the possibility of these complications.

There are limitations to this study. First, the focus of this report was on proximal RYGB and BPL and AL lengths generally found in clinical practice and not on the effects in distal gastric bypasses. Thus, the distribution of lengths did not allow for groupings of all potential lengths of interest. Second, the CC was not measured in all participants, although the subsample of 547 participants allowed for evaluation. Third, the measurement of the small bowel particularly by the laparoscopic approach has inherent limitations[36] that were hoped to be overcome by a detailed protocol of data collection. Additionally, almost half (45.3%) of the CC measurements in this cohort utilized a silk suture (thread) or a ruler. These methods are thought to be the best measure because of the flexible nature of the bowel; rigid instruments may not have as accurate a result depending on technique.[36] Of the proximal RGYB studies that measured the CC, the majority utilized the grasper technique only. Finally, this was an observational study and lacked controlled comparison groups. The strengths of this study are the inclusion of AL and BPL lengths used commonly in clinical practice, evaluation of the CC in thee proximal RYGBs, rigorous data collection, a large sample, a multi-centered design, and 7 years of follow-up with relatively high retention (Table I, Supplemental Digital Content).[32]

The CC length in proximal RYGB is highly variable between patients with severe obesity. None of the limb lengths, nor their ratios to TSBL lengths, even in patients with super obesity seem to be related to weight change or cardio-metabolic improvements over 7 years. These findings point to the need for more research into factors that affect weight loss and mechanisms other than weight loss and limb length to explain cardio-metabolic improvements after RYGB.

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Conflict of interest/Disclosures

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Supplementary materials

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References

1. Berbiglia L, Zografakis JG, Dan AG. Laparoscopic Roux-en-Y gastric bypass: Surgical technique and perioperative care. *Surg Clin North Am*. 2016;96:773–794.
2. Mahawar KK, Kumar P, Parmar C, Graham Y, Carr WR, Jennings N, et al. Small bowel limb lengths and Roux-en-y gastric Bypass: A systematic review. *Obes Surg*. 2016;26:660–671.
3. Mahawar KK, Sharples AJ. Contribution of malabsorption to weight loss after Roux-en-Y gastric bypass: A systematic review. *Obes Surg*. 2017;27:2194–2206.
4. Batterham RL, Cummings DE. Mechanisms of diabetes Improvement following bariatric/metabolic surgery. *Diabetes Care*. 2016;39:893–901.
5. Orci L, Chilcott M, Huber O. Short versus long roux-limb length in Roux-en-y gastric bypass surgery for the treatment of morbid and super obesity: A systematic review of the literature. *Obes Surg*. 2011;21:797–804.
6. Stefanidis D, Kuwada TS, Gersin KS. The importance of the length of the limbs for gastric bypass patients: An evidence-based review. *Obes Surg*. 2011;21:119–124.
7. Belle, Berk PD, Courcoulas AP, et al. Safety and efficacy of bariatric surgery: Longitudinal assessment of bariatric surgery. *Surg Obes Relat Dis*. 2007;3:116–126.
8. Christian NJ, King WC, Yanovski SZ, Belle SH. Validity of self-reported weights following bariatric surgery. *JAMA*. 2013;310:2454–2456.
9. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159:702–706.

10. King WC, Chen JY, Belle SH, et al. Change in pain and physical function following bariatric surgery for severe obesity. *JAMA*. 2016;315:1362–1371.
11. Nelson WK, Fatima J, Houghton SG, et al. The malabsorptive very, very long limb Roux-en-Y gastric bypass for super obesity: Results in 257 patients. *Surgery*. 2006;140:517–523.
12. Leifsson BG, Gislason HG. Laparoscopic Roux-en-Y gastric bypass with 2-metre long biliopancreatic limb for morbid obesity: Technique and experience with the first 150 patients. *Obes Surg*. 2005;15:35–42.
13. Savassi-Rocha PR, Costa Diniz MT, Savassi-Rocha PR, et al. Influence of Jejunoileal and common limb length on weight loss following Roux-en-Y gastric bypass. *Obes Surg*. 2008;18:1364–1368.
14. Gleysteen JJ. Five-year outcome with gastric bypass: Roux limb length makes a difference. *Surg Obes Relat Dis*. 2009;5:242–247; discussion 247–249.
15. Abellan I, Lujan J, Frutos MD, et al. The influence of the percentage of the common limb in weight loss and nutritional alterations after laparoscopic gastric bypass. *Surg Obes Relat Dis*. 2014;10:829–833.
16. Kaska T, Kobiela J, Proczko M, Stefaniak T, Sledzinski Z. Does the length of the biliary limb influence medium-term laboratory remission of type 2 diabetes mellitus after Roux-en-Y gastric bypass in morbidly obese patients? *Wideochir Inne Tech Maloinwazyjne*. 2014;9:31–39.
17. Nergaard BJ, Leifsson BG, Hedenbro J, Gislason H. Gastric bypass with long alimentary limb or long pancreato-biliary limb: Long-term results on weight loss, resolution of co-morbidities and metabolic parameters. *Obes Surg*. 2014;24:1595–1602.
18. Navez B, Thomopoulos T, Stefanescu I, Coubeau C. Common limb length does not influence weight loss after standard laparoscopic Roux-en-Y gastric bypass. *Obes Surg*. 2016;26:1705–1709.
19. Schiavon CA, Santos RN, Santucci EV, Noujaim PM, Cavalcanti AB, Drager LF. Does the RYGB common limb length influence hypertension remission and cardiometabolic risk factors? Data from the GATEWAY trial. *Surg Obes Relat Dis*. 2019;15:211–217.
20. Kakela P, Mannisto V, Vaittinen M, et al. Small intestinal length associates with serum triglycerides before and after LRYGB. *Obes Surg*. 2018;28:3969–3975.
21. Gan J, Wang Y, Zhou X. Whether a short or long alimentary limb influences weight loss in gastric bypass: A systematic review and meta-analysis. *Obes Surg*. 2018;28:3701–3710.
22. Brolin RE, Kenler HA, Gorman JH, Cody RP. Long-limb gastric bypass in the superobese. A prospective randomized study. *Ann Surg*. 1992;215:387–395.
23. MacLean LD, Rhode BM, Nohr CW. Long- or short-limb gastric bypass? *J Gastrointest Surg*. 2001;5:525–530.
24. Choban PS, Flancbaum L. The effect of Roux limb lengths on outcome after Roux-en-Y gastric bypass: A prospective, randomized clinical trial. *Obes Surg*. 2002;12:540–545.
25. Brolin RE, LaMarca LB, Kenler HA, Cody RP. Malabsorptive gastric bypass in patients with superobesity. *J Gastrointest Surg*. 2002;6:195–203; discussion 204–205.
26. Christou NV, Look D, Maclean LD. Weight gain after short- and long-limb gastric bypass in patients followed for longer than 10 years. *Ann Surg*. 2006;244:734–740.
27. Ciovica R, Takata M, Vittinghoff E, et al. The impact of roux limb length on weight loss after gastric bypass. *Obes Surg*. 2008;18:5–10.
28. Pinheiro JS, Schiavon CA, Pereira PB, Correa JL, Noujaim P, Cohen R. Long-limb Roux-en-Y gastric bypass is more efficacious in treatment of type 2 diabetes and lipid disorders in super-obese patients. *Surg Obes Relat Dis*. 2008;4:521–525; discussion 526–527.
29. Sarhan M, Choi JJ, Al Sawwaf M, Murtaza G, Getty JL, Ahmed L. Is weight loss better sustained with long-limb gastric bypass in the super-obese? *Obes Surg*. 2011;21:1337–1343.
30. Risstad H, Svanevik M, Kristinsson JA, et al. Standard vs distal Roux-en-Y gastric bypass in patients with body mass index 50 to 60. *JAMA Surg*. 2016;151:1146–1155.
31. Sjöström L, Lindroos A-K, Peltonen M, et al. Lifestyle, diabetes, and cardiovascular risk factors 10 years after bariatric surgery. *N Engl J Med*. 2004;351:2683–2693.
32. Courcoulas AP, King WC, Belle SH, et al. Seven-year weight trajectories and health outcomes in the longitudinal assessment of bariatric surgery (LABS) study. *JAMA Surg*. 2017;153:427–434.
33. Nora M, Morais T, Almeida R, Guimaraes M, Monteriro MP. Should Roux-en-Y gastric bypass biliopancreatic limb length be tailored to achieve improved diabetes outcomes? *Medicine*. 2017;96:e8859.
34. Ramos RJ, Mottin CC, Alves LB, Benzano D, Padoin AV. Effect of size of intestinal diversions in obese patients with metabolic syndrome submitted to gastric bypass. *ABCD Arq Bras Cir Dig*. 2016;29(Supl. 1):15–19.
35. Zorrilla-Nunez LF, Campbell A, Giambartolomei G, et al. The importance of the biliopancreatic limb length in gastric bypass: A systematic review. *Surg Obes Relat Dis*. 2018;7:43–49.
36. Muise ED, Tackett JJ, Callender KA, Gandotra N, Bamdad MC, Cowles RA. Accurate assessment of bowel length: The method of measurement matters. *J Surg Res*. 2016;206:146–150.

Discussion

Dr Peter Hallowell (Charlottesville, VA): I would like to thank President Shoup and the members of the Central Surgical Association for the opportunity to comment on this paper.

Dr Ahmed and the LABS consortium have produced another fine study looking at the outcomes of gastric bypass using their lab's database. They have 3 aims to the study presented today to describe the surgical characteristics which we saw to identify factors related to limb length and to exam the Association between the limb length and changes in weight loss and metabolic outcomes. The manuscript itself is very data rich and has extensive statistical evaluation, and from that I have a few questions.

In considering the data that you examined, is there an ideal procedure in terms of limb length, alimentary, BP, common channel, or anastomotics techniques that your group would recommend as the best way to perform the laparoscopic gastric bypass? Put it another way, if I have a BMI of 70, should I be doing a 50-cm BP limb, or a 75-cm alimentary limb?

Proximal gastric bypass appears to work well for roughly 65% to 85% of patients, but up to 35% patients may fail. Recently, a paper from Higa and DeMaria have looked at a distal gastric bypass type 1 with an alimentary limb of 100 cm and a common channel of 300 cm. This seemed to produce improved weight loss without severe metabolic disarray. Did you have any patients in your cohort that had this type of anatomy? And, if so, were you able to be see any improvement?

Interestingly, you didn't mention this in the paper, so does the LABS group track nutrient deficiency or malnutrition? I think this would add to the manuscript. Do you recommend measuring the common channel routinely?

Dr Bestoun Ahmed: Thank you, Dr Hallowell, for your questions and kind review of our manuscript. Proximal gastric bypass is the commonest gastric bypass procedure done in the United States. It has good results. Its failure rate is most probably unrelated to the length of the bypassed bowels segments, but to the patient's life style, in addition to other reasons for postoperative weight regain. Our group has another paper published about postoperative weight regain from LABS study data.

In super obese patients like BMI of 70 and above, extending the intestinal limbs might give some weight loss benefit, but at the expense of other complications, as you mentioned, like malnutrition and nutritional deficiencies. The ideal Gastric bypass is still the proximal one with combination of BPL and AL of 200 cm or less.

Distal gastric bypass, as you mentioned in the study by Dr Higa and his coauthors; yes, some of our patients might get into that category. It wasn't meant to be. However, as you know, total small bowel length may be short because of the wide range we have. If we use 200 cm for both BPL and AL, what may leave us with just 100 cm for the common channel, and that just goes into the category of distal bypass. This may account for <5% of our patients and it didn't change the statistics. It will show up if there is something abnormal. This did not change any of our weight loss and metabolic outcomes.

LABS study was not concentrating on long-term complications. Thirty-day outcome was the main thing, and they were very stringent on that. We have the samples, and now one of our researchers is working on iron-deficiency anemia, on the saved samples. Therefore, we can answer some of these long-term complications by studying blood samples.

As I mentioned, I would suggest measurement of the common channel to avoid malabsorptive complications, which can occur in 4% to 5% of these patients from development of short bowel syndrome.