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REVIEW

The Importance of the Length of the Limbs for Gastric Bypass Patients—An Evidence-based Review

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Abstract The ideal length of the gastric bypass limbs is debated. Recent evidence suggests that standard limb lengths used today have a limited impact on patient weight loss. Our objective was to appraise critically the available evidence on the influence of the length of gastric bypass limbs on weight loss outcomes. We systematically reviewed MEDLINE, the Cochrane database of evidence-based reviews, and the Database of Abstracts of Reviews of Effects for articles reporting the effect of gastric bypass length on outcomes published between 1987 and 2009. Four randomized controlled trials and several retrospective studies were identified and reviewed. Longer Roux limb lengths (at least 150 cm) were associated with a very modest weight loss advantage in the short term in superobese patients. No significant impact of alimentary limb length on weight loss for patients with body mass index (BMI) <50 was seen. When the length of the common channel approaches 100 cm, a significant impact on weight loss is observed. The currently available literature supports the notion that a longer Roux limb (at least 150 cm) may be associated with a very modest weight loss advantage in the short term in superobese patients but has no significant impact on patients with BMI ≤50. To achieve weight loss benefit due to malabsorption, bariatric surgeons should focus on the length of the common channel rather than the alimentary or biliopancreatic limbs when constructing a gastric bypass especially in the superobese population where failure rates after conventional gastric bypass are higher.

Keywords Gastric bypass · Roux limb length · Weight loss

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Introduction

Roux-en-Y gastric bypass (RYGB) is the most frequently performed procedure for surgical weight loss in the US and is considered by many as the gold standard to which other procedures should be compared [1].

The procedure effectively leads to an average maximal loss of 70–80% of the excess body weight with reduction in comorbidities but is hampered by the regaining of some of this weight on long-term follow-up. This weight regain may lead to inadequate long-term weight loss in up to 40% of superobese patients (body mass index; BMI>50 kg/m^2) who seem to have overall poorer results after standard RYGB [2, 3]. As a consequence, many bariatric surgeons consider alternative surgical options for this patient population.

The mechanism by which RYGB induces weight loss includes a restrictive and a malabsorptive component; the created small gastric pouch limits the amount of food that can be ingested, and the bypass of a segment of duodenum

and small bowel provides a degree of malabsorption. With no contact between the food bolus and the biliopancreatic secretions until reaching the jejunojejunostomy, absorption of nutrients is impossible in the biliopancreatic and alimentary (Roux) limbs. Thus, the degree of malabsorption can be modified by altering the length of these limbs.

Nevertheless, 50 years after the introduction of the RYGB by Mason and Ito [4] in the late 1960s, there is no consensus on the ideal length of the gastric bypass limbs. In a recent, internet-based study on the technical preferences of 215 bariatric surgeons, all members of the American Society for Metabolic and Bariatric Surgery, the reported length of the Roux and biliopancreatic limbs ranged widely among surgeons (average 110 [range 35–250]cm and 48 [range 10–250]cm, respectively) [5]. Furthermore, the criteria used to determine the length of the limbs varied significantly. Despite most surgeons using a BMI cutoff to vary the length of their limbs, much variability existed among surgeons even for similar patient BMIs. It is also important to note that some authors believe that the limb length currently used by most bariatric surgeons makes the RYGB a mainly restrictive rather than malabsorptive procedure [6]. This argument is supported by a recent study that demonstrated that the length of the small intestine measured in 100 obese patients averaged 671 cm (range 434–990 cm) [7].

The objective of this review was to critically appraise the available evidence on the influence of the length of the gastric bypass limbs on outcomes.

Methods

We systematically searched the MEDLINE literature, limited to English language articles published between 1987 and August 2009. The search strategy is shown in Table 1. Using the same strategy, we searched the Cochrane database of evidence-based reviews and the Database of Abstracts of Reviews of Effects. Identified abstracts were reviewed and the articles of the relevant studies pulled. A critical appraisal of these articles was performed and their bibliographies were searched for additional relevant articles that were included in this review.

Appraisal of the Available Literature

A number of comparative studies have reported on the length of the limbs of gastric bypass (Table 2) [2, 3, 8–18]. The first report on lengthening the Roux limb to increase malabsorption and improve weight loss came from Torres and Oka in 1987 [19]. A few years later, Bruder et al. [12] tested this idea using an experimental design by creating a short (45 cm; the standard Roux limb length at the time) and long (90 cm) Roux limb in a nonrandomized fashion in 55 patients. The authors reported 6% more excess weight loss in the 90-cm group in the short term but did not find differences between the groups after 18 months. They also did not observe differences in nutritional deficiencies postoperatively. Nevertheless, the small sample, the short follow-up, the short "long" limb, and other methodological flaws limit the conclusions of this study.

The first randomized controlled study on this issue was published by Brolin et al. [8]. The authors compared the weight loss of two groups of superobese patients (total n= 45 patients) that received 75- vs. 150-cm Roux limbs and found a 14% greater weight loss in the 150-cm group 2–3 years after the surgery. The authors also reported no additional metabolic sequelae or diarrhea in the longer Roux group and concluded that the 150-cm Roux limb was safe and effective for the superobese patient. The same authors reported in 2002 the results of a 10-year observational study of a "distal" RYGB in which the Roux enteroenterostomy was placed 75 cm above the ileocecal junction [3]. Forty-eight superobese patients with a mean BMI of 68 who had the distal RYGB were compared retrospectively with superobese patients who had "short" (50–75 cm) and "long" (150 cm) Roux limbs. The authors found significant differences in weight loss among the three groups that began 6 months postoperatively and persisted throughout the study (follow-up >3 years). They also noted that greater weight loss was associated consistently with progressively longer Roux limb lengths. In addition, the short-limb group's weight stabilized between 12 and 18 months postoperatively, but the patients who had 150-cm limbs or distal RYGB stabilized after 24 and 36 months. Importantly, they found that the percentage of long-term weight regain was similar in patients who had short limbs and 150-cm limbs but less in those who had

Table 1 Search Strategy

Database: Ovid MEDLINE(R) <1950 to August Week 1 2009>	
1	roux$.hw,ab,ti. and limb.ti,ab,hw. and (length$ or long or longer or longest or short or shorter or shortest).ti,ab,hw. (200)
2	body weight/or body weight changes/or weight gain/or weight loss/(168763)
3	1 and 2 (41)

Table 2 Summary of Comparative Studies on the Roux Limb Length

Author	Pub. Year	Study type	*n* Patients	BMI	Roux limb (cm)	BP limb (cm)	F/U months	EWL at F/U	Patients EWL >50%	Metabolic sequelae	Other
Level I evidence											
Brolin [8]	1992	RCT	22 23	63.4 61.6	75 150	15 30	24	50%* 64%*	50%* 83%*	Similar	
Choban [10]	2002	RCT	33 34	44 44	75 150	30 30	24	59% 60%	NR NR	NR	
			33	61	150	30		49%	50%*		
			28	61	250	30		61%	80%*		
Inabnet [9]	2005	RCT	25 23	44.6 44.9	100 150	50 100	24	81% 67%	NR	Similar	More internal hernias
Pinheiro [11]	2008	RCT	57	53.4	150	50	48	70%	NR	Similar	58%*[a]
			48	54.7	250	100		74%			93% better diabetes resolution*[a]
Level III evidence											
Bruder [12]	1991	Retro	55 Total	NR	45 90	20 20	Up to 66	Long 6% better	NR	Similar	
Freeman [13]	1997	Retro	40 81	45 46	45–135 180–225	10 10	24	34%[b] 40%[b]	NR	Similar	More diarrhea[a]
Brolin [3]	2002	Retro	99 152	All >50	50–75 150	15–25 15–25	60 37	45% 51%	65% 76%	More anemia[a]	
			47		265–570	CC 75	46	60%	80%		
Feng [15]	2003	Retro	45 13	43.7 45.2	45–100 150	20–50 100	12	70% 70%	Similar	NR	
Christou [2]	2006	Retro	86–54 44–23	44–56 44–56	40 100	10 100	120	Similar	Similar	NR	Weight gain in all patients long term
Ciovica [17]	2008	Retro	102 35	61 62	100 150	30 30	12	53%* 64%*	NR	NR	
Gleysteen [16]	2009	Retro	112 132	Variable	40–60 130–160	20–30 20–30	60	*Long better	NR	NR	
			110		1/3 length	20–30					

Similar no statistical differences existed between groups, *RCT* randomized controlled trial, *Retro* retrospective study, *BMI* body mass index, *BP* biliopancreatic, *CC* common channel, *F/U* follow up (we included the follow up where meaningful%EWL data were available and not the maximum follow up of each study), *EWL* excess weight loss, *NR* not reported, *1/3 length* the size of the Roux limb was measured at one third of the total small bowel length

[a] Refers to the long limb group of each study

[b] Percentages reflect% absolute weight loss and not EWL

*$p<0.05$, results statistically significant or better

distal malabsorptive RYGB. On the other hand, this benefit of the distal RYGB came at the expense of a higher incidence of metabolic problems [3, 20]. The results of these studies are subject to some limitations. The findings are relevant to superobese patients but not to the majority of morbidly obese patients (BMI <50) who were not included. In addition, the randomized trial had few patients and short follow-up, while the reported long-term data were accrued over different time periods and in populations that were not matched at baseline, which introduces selection bias.

Choban et al. [10] randomized 133 patients to four groups based on their BMI and the length of the Roux limb (BMI ≤50: 75 cm vs. 150 cm and BMI >50: 150 cm vs. 250 cm). They found that weight loss for the BMI ≤50 patients was similar during their follow-up (up to 36 months) independent of the length of the Roux limb. On the other hand, they noticed a trend toward improved weight loss in the BMI >50 group with increasing lengths of the Roux limb. Moreover, a higher number of patients with longer Roux lengths achieved at least 50% excess weight loss (defined as successful outcome by the authors) at 18 months, but these differences dissipated during longer follow-up. The authors concluded that there was no benefit to longer Roux limb lengths for patients with BMI <50 but that superobese patients might benefit from Roux limbs at least 150 cm. Unfortunately, the limited number of patients

available at longer-term follow-up (2–3 years) was too small, limiting the power of the study and the ability of the authors to provide a more definitive and meaningful conclusion on the effect of the Roux length [10].

Inabnet et al. [9] randomized 48 patients with BMI<50 to a group with 100-cm Roux and 50-cm biliopancreatic limbs or a group with 150-cm Roux and 100-cm biliopancreatic limbs. The authors observed no weight loss or nutritional differences between the two groups up to 1 year postoperatively but noted a higher incidence of internal hernias in the longer-limb group. They concluded that increasing the Roux limb length in non-superobese patients did not improve weight loss and may increase the incidence of internal hernias. The main limitation of this good quality study was its short follow-up and its small sample [9].

More recently, a study by Pinheiro et al. [11] randomized superobese patients (BMI >50) to a group with biliopancreatic limb length of 50 cm and Roux limb of 150 cm or to a group with biliopancreatic length of 100 cm and Roux limb of 250 cm and followed them for 2 years. While the excess weight loss at 2 years was similar between the groups (70% vs. 74%, respectively; p=n.s.), the longer-limb group lost weight faster and demonstrated better control of diabetes and dyslipidemia (93% vs. 58% and 70% vs. 57%, respectively; both $p<0.05$). No significant differences were noted in metabolic sequelae between the groups [11]. While this study did not confirm the findings of previous publications on the weight loss benefits of longer Roux limbs for superobese patients, it was the first to document an improvement in comorbidities. Sample size limitations apply to this study as well.

A number of retrospective studies have also reported on the impact of the gastric bypass limb length on weight loss (Table 2). Common to these studies is that patients receiving longer Roux and biliopancreatic (BP) limbs seemed to have improved weight loss, but this benefit was limited to superobese patients (BMI >50) in most studies. Furthermore, a study by Lee et al. [21] demonstrated a linear relationship between Roux limb length and BMI reduction. Besides the retrospective nature of these studies, which introduces selection bias into their results, their main limitation is their short patient follow-up that rarely approaches 5 years.

Importantly, the study by Christou et al. [2] that has reported the longest follow-up to date (10 years) did not demonstrate a benefit to longer Roux limbs (40 vs. 100 cm) independent of BMI. Nevertheless, this study does not appear to oppose the findings of others as the length of the long limb used was less than the length suggested by other authors (150 cm) as being beneficial for superobese patients.

Interestingly, a recently published study by Savassi-Rocha et al. [7] who measured the length of the small intestine in 100 morbidly obese patients before they constructed a 110-cm Roux limb with a 56-cm (range 30–105) biliopancreatic limb for weight loss. The authors found that the small intestinal length averaged 671 cm (range 434–990 cm), and their common channel length was 505 cm (range 268–829 cm), respectively. They furthermore found that the small intestinal length was on average about 1 m longer in men and longer in taller patients, but no difference in length was seen between morbidly obese and superobese patients. The authors also noted a weak negative correlation between common channel length and percent excess weight loss 12 months after the surgery. They concluded that constructing longer Roux limbs in the range of 150 cm is unlikely to lead to better weight loss in the majority of patients when the common channel length is not considered [7]. The findings of this study may explain the limited impact of the commonly used limb lengths (100–200 cm) in most prior published studies and highlights the importance of consideration of the common channel, a concept addressed during the construction of distal bypasses.

A few publications considered the length of the common channel during the creation of the gastric bypass. Nelson et al. [21] reported results of a postoperative survey on 257 mostly superobese patients that received a distal bypass with a 100-cm common channel. At an average postoperative follow-up of 4 years, 82% of 188 responding patients had lost >50% of their excess weight and their BMI averaged around 37. Furthermore, resolution of diabetes reached 94%, hypertension 65%, sleep apnea 48%, and patient satisfaction with the surgery was 90%. Nevertheless, many patients experienced mild food intolerance and occasional loose stools (71–82%) with 4% of patients requiring reoperation with proximal relocation of the Roux limb for symptom resolution. In addition, the study by Brolin et al. [3] found that distal RYGB (75 cm common channel) was more effective than a 150-cm Roux but at the expense of higher malabsorptive complications and a small but real incidence of reoperation for reversal.

More evidence on the importance of the common channel can be found in the revisional surgery and biliopancreatic diversion literature. In 1997, Sugerman et al. [22] reported a series of 27 superobese patients who underwent reoperation for failure to lose weight following conventional RYGB. The authors lengthened the Roux limb and created a 150-cm common channel in 22 patients and a 50-cm common channel in five. All five patients developed severe protein calorie malnutrition with two late deaths secondary to hepatic failure, whereas the 150-cm common channel group had 69% mean excess weight loss at 5 years postoperatively and manageable nutritional sequelae.[22]. In their series, Brolin and Cody reoperated on 54 patients, most of which had prior failed conventional RYGB and

many were superobese, and revised the gastrojejunostomy creating a 75—100-cm common channel distal RYGB [23]. At ≥1-year follow-up, the average percent excess weight loss was 48%. However, this study failed to distinguish between the effect of the gastrojejunal anastomosis revision and that of the distal RYGB construction given that an undisclosed number of patients had gastrogastric fistulas.

In a recent study by Hamoui et al. [24], the authors compared their results in 1,001 patients according to the ratio of their BP limb to the total length of the small bowel. They found that in patients with a BMI >60, a ratio of >45% was associated with higher percent excess weight loss at 2 and 3 years. The authors also reported, however, that in patients with BMI <60, the benefits of longer biliopancreatic limbs diminished during longer term follow-up and the nutritional sequelae increased. Another group of authors made similar observations in their superobese patients who underwent biliopancreatic diversion surgery. McConnell et al. [25] found that a common channel length of ≤100 cm was associated with better weight loss 1 year after surgery compared with a common channel of 150 cm and recommended that the common channel of the biliopancreatic diversion does not exceed 100 cm. While these publications have relevance to the length of the common channel, the associated weight loss may have also been influenced by the type of surgery and may not directly translate to gastric bypass patients.

Discussion

Based on the reported studies, it appears that the length of the Roux limb as constructed currently by bariatric surgeons is of limited relevance to postoperative weight loss for the non-superobese patient (BMI ≤50) but may make a small difference for the superobese (BMI >50). Nevertheless, even for the latter group, the evidence suggests that this modest weight loss benefit does not persist long term. These findings are not surprising for a couple of reasons. First, the evidence from the distal gastric bypass and biliopancreatic diversion literature is clear that the degree of malabsorption is dependent on the length of the common channel. Second, recent literature suggests that the Roux and BP lengths used routinely by most bariatric surgeons have minimal impact on the length of the common channel. Given that the three limb lengths (Roux, BP, and common channel) are interdependent, i.e., the longer the Roux and/or BP limbs are the shorter the common channel becomes, the modest weight loss benefit described by some studies in the superobese when longer Roux and BP limbs are used are likely a reflection of the shortening common channel. This implies that if malabsorption is a primary goal of the gastric bypass, intraoperative measurements should focus on the length of the common channel rather than the Roux and the BP limbs.

Unfortunately, the majority of the available studies including all randomized controlled trials have failed to take into consideration the length of the common channel. Thus, we have a limited understanding of how long the common channel should be to achieve the best weight loss and comorbidity resolution outcomes after gastric bypass without increasing significantly the incidence of nutritional complications.

It should also be noted that no reference can be made to the effect of the ratio of the Roux to the BP limbs on weight loss and comorbidity resolution outcomes as there is no available literature that has investigated this issue. Nevertheless, the authors believe that this ratio is unlikely to have any significant impact on outcome compared to the ratio of the Roux/BP to the common channel length.

Limitations of the available literature include the lack of homogeneity and standardization making comparisons difficult. The same Roux length is considered short by some studies and long by others. In addition, differences in technique other than limb length that may account for weight loss differences make it difficult to combine results and may explain discrepancies in the findings of various studies. While several level I evidence studies exist (randomized controlled trials), their uniformly small sample size limits the ability to detect differences due to inadequate power and the lack of blindness introduces bias in the results. Furthermore, long-term weight loss data (>5 years) are not available from randomized controlled trials and are extremely limited in other poorer quality studies.

In conclusion, the currently available literature supports the notion that a longer Roux limb (at least 150 cm) may be associated with a very modest weight loss advantage in the short term in superobese patients but has no significant impact on patients with BMI ≤50. Nevertheless, there is convincing evidence that the degree of malabsorption after gastric bypass is influenced mainly by the length of the common channel rather than the lengths of the Roux or biliopancreatic limbs as constructed currently by the majority of bariatric surgeons. Consequently, bariatric surgeons should pay more attention to the length of the common channel when constructing a gastric bypass especially in the superobese population where failure rates after conventional gastric bypass are higher. Additionally, good quality studies that focus on the impact of the length of the common channel on weight loss are needed.

Conflicts of Interest Drs. Stefanidis, Kuwada, and Gersin have no conflict of interest with any institution or product that is mentioned in the manuscript and/or is important to the outcome of the work presented here.

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