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A short or a long Roux limb in gastric bypass surgery: does it matter?

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Abstract
Background The Roux-en-Y gastric bypass (RYGB) still remains the gold standard in bariatric surgery. However, no consensus exists on the optimal limb lengths to induce maximum weight reduction. The aim of the present study was to assess the effect of a longer alimentary limb (AL) length on weight reduction after RYGB.
Methods A retrospective analysis of a prospectively collected database of patients who underwent a primary laparoscopic RYGB between January 2001 and March 2011 was performed. Patients received a short AL (SAL; 100 cm) or a long AL (LAL; 150 cm). Primary outcome was weight loss, and secondary outcomes were short- and long-term complication rates.
Results A total of 768 patients received a RYGB during the study period. Of these, 730 consecutive patients were included for long-term analysis and had a mean follow-up (FU) of 37 ± 26 [range 0–120] months; 360 (47 %) patients received a SAL RYGB. Overall %TBWL was 33 ± 9 % after 2 years (FU 74 %) and 28 ± 12 % after 5 years (FU 20 %). No significant differences in %TBWL were found between SAL RYGB and LAL RYGB during the study period. The 30-day mortality rate was 0.13, 9 % overall short-term complication rate and 19 % cumulative long-term complication rate. No differences in complications were found between SAL and LAL RYGB patients.
Conclusion Lengthening of the alimentary limb from 100 to 150 cm did not affect post-RYGB weight loss. Overall complication rates were low and comparable in this series of RYGB patients.

Keywords Morbid obesity · Roux-en-Y gastric bypass · Laparoscopy · Weight loss · Complication · Alimentary limb

The Roux-en-Y gastric bypass (RYGB) is currently still the most performed surgical intervention to treat morbid obesity and its related co-morbidities. The total number of bariatric procedures was approximately 470.000 annually worldwide in 2013 of which 45 % were RYGB procedures [1]. Sustained adequate weight reduction in the short and long term has made the RYGB a well-accepted treatment modality for morbid obesity [2].

Several technical modifications of the RYGB procedure have been introduced over the past decades, such as variations in pouch size and limb length. Currently, no consensus exists for the optimal limb length required to induce maximum weight reduction. Studies in the early 1990s suggested that the amount of post-RYGB weight loss depended on the length of the alimentary limb (AL or Roux limb) [3, 4]. Since then, conflicting reports have been published regarding the effect of the AL length (varying between 40 and 250 cm) [5–19].

The purpose of the present study was to assess the effect of a longer AL length on weight reduction in patients undergoing a primary laparoscopic RYGB procedure. In addition, we reviewed the short- and long-term complication rates.

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Materials and methods

Patient selection

Consecutive morbidly obese patients who underwent a primary laparoscopic RYGB surgery in accordance with international guidelines [20] were included for analysis. Patients were operated in the Rijnstate Hospital Arnhem (RHA), the Netherlands between January 2001 and March 2011. The study protocol was approved by the local board of ethics of the RHA.

Inclusion criteria were age >18 years, BMI above 40 kg/m^2, or BMI above 35 kg/m^2 with an obesity-related co-morbidity, and minimal follow-up of 12 months. Exclusion criteria were other primary bariatric procedures or a revisional RYGB procedure. Patients were selected from our prospectively collected computerized database which is filled out since 2000. Pre-, intra- and postoperative data were collected by specialized nurses. Postoperative follow-up visits were offered to all patients after 3, 6, 9, 12, 18, and 24 months, and annually thereafter.

The primary end point was weight reduction expressed as percentage Total Body Weight Loss (%TBWL; defined as weight loss divided by preoperative body weight), and percentage Excess Weight Loss (%EWL; defined as weight loss divided by excess weight based on BMI 25 kg/m^2). Secondary end points were short- ($\leq$30 days) and long-term (>30 days) complications, and perioperative mortality rate.

Surgical procedure

All patients underwent a laparoscopic antecolic antegastric RYGB procedure. A small gastric pouch of approximately 40 ml was constructed using a linear stapler (Echelon, Ethicon, Johnson & Johnson, New Brunswick, NJ, USA), and a fixed biliopancreatic limb (BPL) of approximately 50 cm was measured using the hand-over-hand technique without stretch along the mesenteric border. Until 2010, patients with BMI < 50 kg/m^2 received a short AL of 100 cm (SAL) and patients with BMI > 50 kg/m^2 received a long AL of 150 cm (LAL) using the same technique. From 2010, all patients received a LAL RYGB. In all patients, the gastro-jejunostomy and entero-enterostomy were performed using a linear stapler combined with a running Vicryl suture (Endo Stitch^{TM}, Covidien, Dublin, Ireland). The integrity of the gastro-jejunostomy and gastric pouch staple-line was tested intra-operatively for anastomotic leak via a burst test.

Multidisciplinary treatment program

Prior to the operation, a screening by a multidisciplinary team, including a surgeon, endocrinologist, obesity coach, dietitian, physiotherapist, and psychologist/psychiatrist, was performed. Patients who were eligible for a surgery according to the international guidelines [20] were enrolled in a multidisciplinary coaching program. Preoperatively, patients followed multiple sessions at the Dutch Obesity Clinic, Velp, the Netherlands. During these sessions, patients received nutritional, psychological, and fitness training. Postoperatively, these sessions continued during the first 2 years, with a total frequency of 15 follow-up moments.

Statistical analysis

Patients with a follow-up of less than 12 months were excluded from long-term analysis for %EWL and %TBWL. The short- and long-term complication rate is based on the total study population. The results are presented as mean values ± standard deviation (SD), unless otherwise specified. Variance between groups was analyzed using the Mann–Whitney test for continuous data and χ^2 test for categorical data. Data were analyzed using IBM® SPSS® (version 20.0 for Windows) statistical software, and all figures were created using Graph Path Prism® (version 5.01). A p value <0.05 was considered significant.

Results

In total, 768 patients underwent a primary RYGB in the studied period, of which 360 (46.9 %) patients received a SAL RYGB. Baseline patient characteristics are shown in Table 1.

Thirty-eight patients were excluded from analysis because they were lost to follow-up; they completed their follow-up in another hospital ($n = 32$) or died within one year after surgery ($n = 6$). The mean follow-up period of the remaining 730 patients was 37 ± 26 [range 0–120] months. The number of patients followed-up during the postoperative period was 708 (97 %) at 6 months, 687 (94 %) at 1 year, 620 (85 %) at 18 months, 541 (74 %) at 2 years, 327 (45 %) at 3 years, 203 (28 %) at 4 years, and 147 (20 %) at 5 years. There was a significant difference in follow-up between the SAL (43.3 ± 31.2 [range 0–120] months) and LAL (26.8 ± 17.5 [range 0–120] months) groups ($p < 0.0001$).

Table 1 Baseline characteristics for overall study population ($n = 768$)

Demographic data		
Female gender	533	69.4 %
Age (years)	44.2	±10.6
BMI (kg/m^2)	47.3	±6.1
Weight (kg)	139.6	±22.3
Excess weight (kg)	65.7	±18.5
Perioperative data		
Roux limb of 100 cm	360	46.9 %
Surgery time (min)	98.0	±39.7
Hospitalization (days)	5.6	±8.9
Co-morbidities		
T2DM	302	39.3 %
Hypertension	380	49.5 %
Dyslipidemia	191	24.9 %
OSAS	142	18.5 %
Joint pain	266	34.6 %

Values are mean ± standard deviation or numbers (%)

T2DM type 2 diabetes mellitus, *OSAS* obstructive sleep apnea syndrome

Weight loss

Overall %EWL was 69.6 ± 19.7 % at one year, 72.9 ± 22.6 % at 2 years, 69.1 ± 25.4 % at 3 years, and 60.8 ± 27.2 % at 5 years. Overall %TBWL was 31.5 ± 7.6 % at 1 year, 33.1 ± 9.3 % at 2 years, 31.4 ± 10.8 % at 3 years, and 27.8 ± 12.3 % at 5 years.

Baseline weight and BMI were significantly lower for the SAL group compared to the LAL group, as expected given that a long limb was chosen for patients with a BMI > 50 kg/m^2. %EWL for the first 18 months postoperatively was significantly higher for the SAL compared to the LAL group; however, after 24 months, no significant differences were found. %TBWL was similar during each follow-up visit in the two groups. Weight, %EWL, and %TBWL during follow-up are presented in Table 2 and Fig. 1.

Complications

In total, six (0.8 %) patients died within the first year after surgery. Only one (0.13 %) patient died within 30 days, because of abdominal sepsis after an anastomotic leak. The other five (0.65 %) patients died after 30 days, of which only one might have been related to surgery. This patient suffered from a pulmonary embolism 6 weeks after surgery.

The short-term complication rate (<30 days) was similar in the SAL group ($n = 32$; 8.9 %) and LAL group ($n = 33$; 8.3 %; $p = 0.745$). Overall short- and long-term complications are presented in Table 3. In addition, one patient underwent with a LAL an undo-operation (restoration of the gastrointestinal tract) because of persistent abdominal pain and dysphagia.

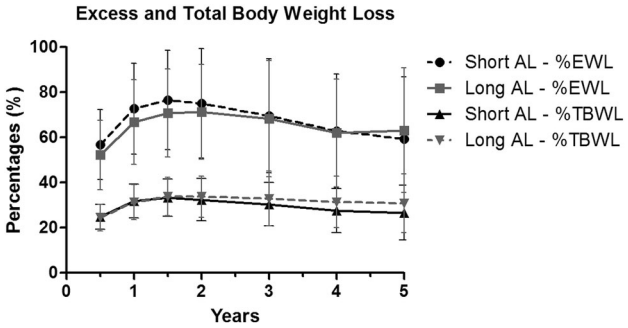

Fig. 1 Percentage excess weight loss (%EWL) and total body weight loss (%TBWL) for short and long alimentary limb (AL) during follow-up

Discussion

Weight loss

Laparoscopic RYGB surgery still remains the gold standard in bariatric surgery, with an %EWL of 63–80 % during the first 5 years, and an %EWL of 57–75 % in the long-term (5–10 years) [2, 12, 15, 21, 22]. RYGB surgery induces weight loss by reducing the gastric volume (restriction) and inducing metabolic changes through adaptations in gastrointestinal anatomy (bypass of the majority of the stomach, duodenum and proximal part of the small intestine). Given the lack of uniformity regarding the length of the bypassed small intestine, clinical heterogeneity exists in the published data. An overview of the studies comparing short versus long Roux limb Roux-en-Y gastric bypass is presented in Table 4. Orci et al. [23]. reviewed eight studies, including five randomized controlled trials (RCTs) and three prospective cohort studies, and found much variation in design and outcome, making the results difficult to interpret. Additionally, most studies of limb length had a limited follow-up of only 3 years. Furthermore, %EWL is widely used as an outcome parameter, whereas it is a relative measure that varies with initial BMI. The %TBWL allows for better comparison, but is only used in the literature in recent years [24]. In the present study, the long-term effects of the primary laparoscopic RYGB were analyzed. Additionally, a comparative study with a study population group of 768 patients is the largest available in the literature. No difference in %TBWL was found between SAL and LAL RYGB in the follow-up period of 5 years. After 10-year

Table 2 Follow-up of weight, BMI, %EWL and %TBWL up to 5 postoperative years

	SAL RYGB		LAL RYGB		*p*
Weight (kg)					
Baseline (T0)	135.6	±22.8	143.0	±21.2	**<0.0001**
12 months (T1)	92.2	±18.7	97.5	±18.7	**0.001**
18 months (T2)	89.8	±17.8	95.2	±17.8	**0.003**
24 months (T3)	89.5	±17.4	94.8	±19.3	**0.006**
36 months (T4)	93.3	±19.9	99.1	±24.5	0.160
60 months (T5)	102.5	±22.6	101.9	±26.1	0.819
BMI (kg/m^2)					
Baseline (T0)	45.8	±5.9	48.6	±5.8	**<0.0001**
12 months (T1)	31.3	±5.1	33.3	±5.4	**<0.0001**
18 months (T2)	26.1	±4.5	27.8	±4.7	**<0.0001**
24 months (T3)	30.6	±5.3	32.3	±5.8	**0.001**
36 months (T4)	32.1	±6.2	33.3	±7.3	0.315
60 months (T5)	34.1	±6.8	34.9	±8.5	0.662
%EWL					
12 months (T1)	72.7	±20.2	66.8	±18.8	**0.001**
18 months (T2)	76.5	±22.0	70.8	±19.6	**0.012**
24 months (T3)	75.0	±24.3	71.2	±21.0	0.123
36 months (T4)	69.5	±25.2	68.3	±25.8	0.939
60 months (T5)	59.3	±27.4	63.1	±27.6	0.826
%TBWL					
12 months (T1)	31.8	±7.4	31.3	±7.7	0.509
18 months (T2)	33.3	±8.3	33.7	±8.5	0.569
24 months (T3)	32.4	±9.4	33.6	±9.2	0.187
36 months (T4)	30.4	±9.7	32.9	±12.2	0.071
60 months (T5)	26.6	±12.1	30.8	±13.1	0.400

Bold values indicate statistical significance ($p < 0.05$)

Values are mean ± standard deviation

No. of patients in follow-up (%) at T0 = 730 (100), T1 = 687 (94), T2 = 620 (85), T3 = 541 (74), T4 = 327 (45), T5 = 147 (20)

SAL short alimentary limb, *LAL* long alimentary limb, *RYGB* Roux-en-Y gastric bypass, *BMI* body mass index, *%EWL* percentage excess weight loss, *%TBWL* percentage total body weight loss

follow-up, mean %TBWL was at least 24 % (data not shown).

Some studies claim significantly more weight loss after lengthening of the AL in super obese patients and a BMI of ≥50 kg/m^2, while patients with BMI < 50 kg/m^2 may not demonstrate a benefit of a longer AL [3, 6, 7, 9, 10, 12, 25]. The first published RCT comparing LAL RYGB (150 cm) with SAL RYGB (75 cm), in patients with a BMI > 50 kg/m^2, reported a difference in %EWL after 24 months of 64 and 50 %, respectively ($p < 0.01$) [3]. Another RCT also showed higher weight loss for LAL (250 cm) compared to SAL (150 cm) in RYGB patients after 18 months [6]. This suggests that patients with a BMI > 50 kg/m^2 might benefit from lengthening of the AL. However, an RCT conducted by Pinheiro et al. reported no difference in outcome for SAL (150 cm) and LAL (250 cm) RYGB in super obese patients after 4 years [14]. This is consistent with the present study, in which no difference was found between the groups of super obese patients (data not shown). Reports comparing the effect of AL lengths in patients with a BMI lower than 50 kg/m^2 also showed nonsignificant differences [6, 9, 10]. Inabnet et al. [10] randomized 48 patients with a BMI < 50 kg/m^2 between SAL (100 cm) and LAL (150 cm), and found no difference during 24 months of follow-up. Choban and Flancbaum [6] randomized 67 patients with a BMI < 50 kg/m^2 between SAL (75 cm) and LAL (150 cm), and reported similar weight loss in the two groups during a follow-up of 36 months. The most recent RCT by Valezi et al. [19] reported no significant difference in percentage weight loss among four

Table 3 Overall short- (<30 days) and long-term (>30 days) complications

<30 days	*n*	%	>30 days	*n*	%
Bleeding	17	2.2	Cholecystolithiasis (symptomatic)	57	7.4
Pneumonia	11	1.4	Unexplained abdominal complaints	44	5.7
Wound infection	6	0.8	Marginal ulcer	20	2.6
Iatrogenic*	6	0.8	Internal hernia	17	2.2
Anastomotic leakage	4	0.5	Incisional hernia	18	2.3
Intra-abdominal abscess	5	0.7	Constipation	6	0.8
Thrombo-embolism	1	0.1	Anastomotic stricture	4	0.5
Anastomotic stricture	1	0.1	Anastomotic leakage	4	0.5
Small bowel obstruction	1	0.1	Small bowel obstruction	3	0.4
Re-operation	31	4.0	Pulmonary embolism	4	0.5
Readmission	5	0.7	Bleeding	1	0.1
			Re-operation**	92	12.0
Total N of complications	65	8.5	Total N of complications	145	18.9

Values are numbers (%)

* Specified: anastomotic lesion due to nasogastric tube ($n = 1$), small/large bowel lesion ($n = 4$), spleen lesion ($n = 1$)

** Re-operation (definition): operation due to a complication

groups with different AL (100 and 150 cm) en BPL (50 and 100 cm) lengths after a limited follow-up of 12 months. These findings are comparable to those of the current study, which implies that the length of AL does not influence weight reduction in morbidly obese patients with a BMI up to 50 kg/m^2. In line with these previous studies, Mahawar et al. [25] propose a bypass with a total length of 100–200 cm (BPL and AL combined), since minor alterations in AL and BPL lengths showed no differences in outcome based on their review of the available literature.

Besides reduction in gastric volume and inducing metabolic changes by adapting the gastrointestinal anatomy, there is a third component that can be added to achieve weight loss. This component is true malabsorption for macronutrients and might be added in specific patients. In our opinion, these malabsorptive procedures should not be the first choice due to their side-effects, such as malnutrition for micronutrients and severe diarrhea [26, 27]. However, in patients with a BMI over 60 kg/m^2, a two-step procedure toward a duodenal switch might be an excellent technique to induce long-term weight loss [28]. Another group of patients that might benefit from malabsorption are patients who have in terms of weight loss a failed a primary RYGB [29].

Next to the technical aspects of the operation, changes in dietary habits and lifestyle are important in treating obesity. This part of the treatment should be a multidisciplinary approach, including surgeon, endocrinologist, dietitian, physiotherapist, and psychologist, with an intensive coaching program (before and after the operation). Patients with a lifestyle program may have better sustained weight loss, less weight regain, and improved metabolic outcomes [30–32].

Hormonal changes

Previous studies focused their attention on the length of the AL and may underestimated the effect of the BPL, probably due to the significant advantage of a longer AL reported in the first published RCT by Brolin et al. [3]. Several gastrointestinal hormonal changes have been proposed as mediators of weight loss after RYGB surgery. Alterations in the blood serum levels of upper gastrointestinal peptides (ghrelin and glucose-dependent insulinotropic polypeptide (GIP)) may contribute to this effect by bypassing the stomach, duodenum and proximal part of the jejunum (foregut theory) [33–36]. However, it is plausible that other mechanisms are more crucial since patients with longer BPL had more weight loss compared to patients with standard gastric bypass [12, 14, 37]. Rapid exposure of nutrients to distal small intestine as a result of the Roux-en-Y construction induce enlarged secretion of L-cell derived hormones glucagon-like peptide 1 (GLP-1) and peptide YY (PYY) (hindgut theory) [38]. A study group in Iceland demonstrated a significantly higher weight loss with a long BPL of two meters and a short AL of 50 cm compared to short BPL and long AL [37, 39]. Additionally, the mini-gastric bypass operation is another example with a long BPL (without Roux limb), which resulted in similar or even greater weight loss than a standard RYGB operation [34]. Therefore, the BPL may be the essential component for weight loss (and metabolic effects) in RYGB surgery.

Table 4 Review of previous studies comparing short versus long Roux limb in primary Roux-en-Y gastric bypass

Study	Type of study Date of publication	Total no. patients	Study group 1				Study group 2				Outcome (summary)
			No. patients	BMI (kg/m^2)	Roux (cm)	BPL (cm)	No. patients	BMI (kg/m^2)	Roux (cm)	BPL (cm)	
Bruder (4)	Retrospective 1991	55	32	NA	45	15–20	23	NA	90	15–20	%EWL 66 months 57 % versus 55.3 % (p = NA)
Brolin (3)	Randomized trial 1992	45	22	63.4	75	15	23	61.6	150	30	%EWL 24 months 50 % versus 64 % (p = NA) %EWL > 50 % 24 months 50 % versus 83 % ($p < 0.03$)
Freeman* (17)	Retrospective 1997	121	40	45	45–135	5–8	81	46	180–225	5–8	%EWL 60 months 53 % versus 71 % ($p < 0.05$) % weight loss 60 months 30 % versus 41 % ($p < 0.05$)
MacLean* (12)	Retrospective 2001	242	66	44	40	10	30	56	100	100	Final BMI 76 months 35.8 kg/m^2 versus 46 months 33 kg/m^2 ($p = 0.049$)
Choban (6)	Randomized trial 2002	118	33	44	75	30	34	44	150	30	%EWL 36 months 52 % versus 62 % (NS)
Brolin* (5)	Retrospective 2002	174	75	55.3	150	15–25	99	56.9	50–75	15–25	%EWL 60 months 51 % versus 45 % (p = NA)
Feng (8)	Retrospective 2003	58	45	43.6	45–100	20–50	13	45.3	150	100	%EWL 12 months 69 % versus 66.3 % (NS)
Inabnet (10)	RCT 2005	48	25	44.6	100	50	23	44.9	150	100	%EWL 24 months 82 % versus 65 % (NS)
Christou (21)	Retrospective 2006	228	86	44.4	40	10	46	44.0	100	100	Final BMI 12.3 years 30.5 kg/m^2 versus 9.5 years 31.8 kg/m^2 ($p = 0.17$)
			54	56.4	40	10	23	55.8	100	100	Final BMI 12.3 years 38.6 kg/m^2 versus 9.5 years 37.7 kg/m^2 ($p = 0.59$)
Suter (16)	Prospective 2006	466	359	43.2	100	30–50	107	55.3	150	30–50	%EWL > 50 % 48 months 71.4 % and 65.2 % (p = NA)
Pinheiro (14)	Randomized trial 2008	105	57	53.4	150	50	48	54.7	250	100	%EWL 48 months 70 % versus 74 % ($p < 0.05$)
Ciovica (7)	Prospective 2008	137	102	61.1	100	30	35	60.9	150	30	%EWL 12 months 53 % versus 64 % ($p = 0.02$)
Gleysteen* (9)	Retrospective 2009	344	54	<50	41–61	18–30	39	>50	130–160	18–30	BMI lost 60 months 12.7 kg/m^2 versus 13.9 kg/m^2 ($p < 0.01$)

Table 4 continued

Study	Type of study Date of publication	Total no. patients	Study group 1				Study group 2				Outcome (summary)
			No. patients	BMI (kg/m^2)	Roux (cm)	BPL (cm)	No. patients	BMI (kg/m^2)	Roux (cm)	BPL (cm)	
Sarhan (18)	Retrospective 2011	120	65	56.1	120–150	50–80	55	57.5	50–80	170–200	%EWL 36 months 60.2 % versus 60.1 % ($p = 0.986$) Weight regain 36 months 56 % versus 61 % ($p = 0.13$)
Valezi (19)	Randomized trial 2014	94	24	46.9	100	50	25	47.6	150	50	% weight loss 12 months 33.3 % versus 34.07 (NS)
			23	46.8	100	100	22	46.1	150	100	% weight loss 12 months 34.0 % versus 34.0 (NS)

NA not available, *NS* not significant, *%EWL* percentage excess weight loss, *BMI* body mass index, *BPL* biliopancreatic limb

*Part of the study cohort is presented

RYGB technique is evolving; this could be one of the future changes.

Complications

It is known that the outcome of bariatric surgery is correlated with the experience of the bariatric surgeon/team. The learning curve for laparoscopic RYGB surgery is considered to be 75–150 cases [40]. In the present study, with increasing experience and refinement of the technique, the operative 30-day complication rate decreased over time to approximately 6 % in 2011, with a mean overall complication rate of 8.5 % over all study years. This is similar to large series in the literature, which reported an overall early complication rate of 5–19 % and a mortality rate up to 0.2 % [15, 41, 42]. The early complication rate was similar in SAL and LAL RYGB. Frequently reported complications in the literature are marginal (anastomotic) ulcer and internal hernias [15]. In the present study, these complications were diagnosed in 3 and 2 % of patients, respectively. Elongation of the limb length may be accompanied by higher complication rates. Internal hernias are a result of the Roux-en-Y construction associated with newly created mesenteric defects. A previous study reported a higher internal hernia rate in patients with a longer limb length [10]. Nowadays, the mesenteric defects in our hospital are closed with staples (Endopath® EMS Endoscopic Multifeed Stapler, Johnson and Johnson Medical Ltd.), by only clipping the peritoneum, to prevent these hernias [43]. Leifsson et al. reported a high anastomotic ulcer rate of 17 % in patients after a long BPL RYGB [39]. Postoperative prescription of proton pump inhibitor (PPI) is advised to prevent these ulcers; however, this was only the case during the first postoperative period in this study. In our hospital, PPIs are prescribed for 6 months.

Limitations

Certain limitations of this study must be pointed out. In this study, we observed the effects of a 100 and 150 cm AL RYGB; however, this relative minor change in bypassed small intestine may had limited contribution to weight loss. On the other hand, we assume that other mechanisms, like additional changes in incretins may have more effects than the length of the alimentary limb. Additionally, follow-up after 5 years was limited. Therefore, difference between the groups on the long term could not be pointed out. Furthermore, the observational aspect of the study had some restrictions, such as difference in baseline weight and BMI between the groups.

Conclusion

Primary laparoscopic RYGB surgery is an effective treatment modality in morbidly obese patients in the long term. Outcomes were not affected by lengthening of the alimentary limb from 100 to 150 cm. Overall complication rates were low and decreased over time.

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Compliance with ethical standards

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References

1. Angrisani L, Santonicola A, Iovino P, Formisano G, Buchwald H, Scopinaro N (2015) Bariatric surgery worldwide 2013. Obes Surg 25:1822–1832
2. Sjostrom L (2013) Review of the key results from the Swedish Obese Subjects (SOS) trial—a prospective controlled intervention study of bariatric surgery. J Intern Med 273:219–234
3. Brolin RE, Kenler HA, Gorman JH, Cody RP (1992) Long-limb gastric bypass in the superobese. A prospective randomized study. Ann Surg 215:387–395
4. Bruder SJ, Freeman JB, Brazeau-Gravelle P (1991) Lengthening the Roux-Y limb increases weight loss after gastric bypass: a preliminary report. Obes Surg 1:73–77
5. Brolin RE, LaMarca LB, Kenler HA, Cody RP (2002) Malabsorptive gastric bypass in patients with superobesity. J Gastrointest Surg Off J Soc Surg Alimentary Tract 6:195–203 **Discussion 204–195**
6. Choban PS, Flancbaum L (2002) The effect of Roux limb lengths on outcome after Roux-en-Y gastric bypass: a prospective, randomized clinical trial. Obes Surg 12:540–545
7. Ciovica R, Takata M, Vittinghoff E, Lin F, Posselt AM, Rabl C, Stein HJ, Campos GM (2008) The impact of Roux limb length on weight loss after gastric bypass. Obes Surg 18:5–10
8. Feng JJ, Gagner M, Pomp A, Korgaonkar NM, Jacob BP, Chu CA, Voellinger DC, Quinn T, Herron DM, Inabnet WB (2003) Effect of standard versus extended Roux limb length on weight loss outcomes after laparoscopic Roux-en-Y gastric bypass. Surg Endosc 17:1055–1060
9. Gleysteen JJ (2009) Five-year outcome with gastric bypass: Roux limb length makes a difference. Surg Obes Relat Dis Off J Am Soc Bariatr Surg 5:242–247 **Discussion 247–249**
10. Inabnet WB, Quinn T, Gagner M, Urban M, Pomp A (2005) Laparoscopic Roux-en-Y gastric bypass in patients with BMI < 50: a prospective randomized trial comparing short and long limb lengths. Obes Surg 15:51–57
11. Lee S, Sahagian KG, Schriver JP (2006) Relationship between varying Roux limb lengths and weight loss in gastric bypass. Curr Surgery 63:259–263
12. MacLean LD, Rhode BM, Nohr CW (2001) Long- or short-limb gastric bypass? J Gastrointest Surg Off J Soc Surg Alimentary Tract 5:525–530
13. Murr MM, Balsiger BM, Kennedy FP, Mai JL, Sarr MG (1999) Malabsorptive procedures for severe obesity: comparison of pancreaticobiliary bypass and very very long limb Roux-en-Y gastric bypass. J Gastrointest Surg Off J Soc Surg Alimentary Tract 3:607–612
14. Pinheiro JS, Schiavon CA, Pereira PB, Correa JL, Noujaim P, Cohen R (2008) Long-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 Off J Am Soc Bariatr Surg 4:521–525 **Discussion 526–527**
15. Suter M, Donadini A, Romy S, Demartines N, Giusti V (2011) Laparoscopic Roux-en-Y gastric bypass: significant long-term weight loss, improvement of obesity-related comorbidities and quality of life. Ann Surg 254:267–273
16. Suter M, Paroz A, Calmes JM, Giusti V (2006) European experience with laparoscopic Roux-en-Y gastric bypass in 466 obese patients. Br J Surg 93:726–732
17. Freeman JB, Kotlarewsky M, Phoenix C (1997) Weight loss after extended gastric bypass. Obes Surg 7:337–344
18. Sarhan M, Choi JJ, Al Sawwaf M, Murtaza G, Getty JL, Ahmed L (2011) Is weight loss better sustained with long-limb gastric bypass in the super-obese? Obes Surg 21:1337–1343
19. Valezi AC, Marson AC, Merguizo RA, Costa FL (2014) Roux-en-Y gastric bypass: limb length and weight loss. Arquivos brasileiros de cirurgia digestiva: ABCD = Brazilian archives of digestive surgery 27(Suppl 1):56–58
20. NIH conference (1991) Gastrointestinal surgery for severe obesity consensus development conference panel. Ann Intern Med 115:956–961
21. Christou NV, Look D, Maclean LD (2006) Weight gain after short- and long-limb gastric bypass in patients followed for longer than 10 years. Ann Surg 244:734–740
22. Higa K, Ho T, Tercero F, Yunus T, Boone KB (2011) Laparoscopic Roux-en-Y gastric bypass: 10-year follow-up. Surgery Obes Relat Dis Off J Am Soc Bariatr Surg 7:516–525
23. Orci L, Chilcott M, Huber O (2011) 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 21:797–804
24. van de Laar A, de Caluwe L, Dillemans B (2011) Relative outcome measures for bariatric surgery. Evidence against excess weight loss and excess body mass index loss from a series of laparoscopic Roux-en-Y gastric bypass patients. Obes Surg 21:763–767
25. Mahawar KK, Kumar P, Parmar C, Graham Y, Carr WR, Jennings N, Schroeder N, Balupuri S, Small PK (2016) Small bowel limb lengths and Roux-en-Y gastric bypass: a systematic review. Obes Surg 26:660–671
26. Homan J, Betzel B, Aarts EO, Dogan K, van Laarhoven KJ, Janssen IM, Berends FJ (2015) Vitamin and mineral deficiencies after biliopancreatic diversion and biliopancreatic diversion with duodenal switch—the rule rather than the exception. Obes Surg 25:1626–1632
27. Sovik TT, Karlsson J, Aasheim ET, Fagerland MW, Bjorkman S, Engstrom M, Kristinsson J, Olbers T, Mala T (2013) Gastrointestinal function and eating behavior after gastric bypass and duodenal switch. Surg Obes Relat Dis Off J Am Soc Bariatr Surg 9:641–647
28. Homan J, Betzel B, Aarts EO, van Laarhoven KJ, Janssen IM, Berends FJ (2015) Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch. Surg Obes Relat Dis Off J Am Soc Bariatr Surg 11:771–777
29. Tran DD, Nwokeabia ID, Purnell S, Zafar SN, Ortega G, Hughes K, Fullum TM (2016) Revision of Roux-En-Y gastric bypass for

weight regain: a systematic review of techniques and outcomes. Obes Surg 26:1627–1634
30. Kalarchian MA, Marcus MD, Courcoulas AP, Lutz C, Cheng Y, Sweeny G (2016) Structured dietary intervention to facilitate weight loss after bariatric surgery: a randomized, controlled pilot study. Obesity. doi:10.1002/oby.21591
31. McGrice M, Don Paul K (2015) Interventions to improve long-term weight loss in patients following bariatric surgery: challenges and solutions. Diabetes, Metab Syndr Obes Targets Ther 8:263–274
32. Montesi L, El Ghoch M, Brodosi L, Calugi S, Marchesini G, Dalle Grave R (2016) Long-term weight loss maintenance for obesity: a multidisciplinary approach. Diabetes, Metab Syndr Obes Targets Ther 9:37–46
33. Beckman LM, Beckman TR, Earthman CP (2010) Changes in gastrointestinal hormones and leptin after Roux-en-Y gastric bypass procedure: a review. J Am Diet Assoc 110:571–584
34. Lee WJ, Ser KH, Lee YC, Tsou JJ, Chen SC, Chen JC (2012) Laparoscopic Roux-en-Y versus mini-gastric bypass for the treatment of morbid obesity: a 10-year experience. Obes Surg 22:1827–1834
35. Rubino F, Forgione A, Cummings DE, Vix M, Gnuli D, Mingrone G, Castagneto M, Marescaux J (2006) The mechanism of diabetes control after gastrointestinal bypass surgery reveals a role of the proximal small intestine in the pathophysiology of type 2 diabetes. Ann Surg 244:741–749
36. Rubino F, Gagner M, Gentileschi P, Kini S, Fukuyama S, Feng J, Diamond E (2004) The early effect of the Roux-en-Y gastric bypass on hormones involved in body weight regulation and glucose metabolism. Ann Surg 240:236–242
37. Nergaard BJ, Leifsson BG, Hedenbro J, Gislason H (2014) 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 24:1595–1602
38. Peterli R, Steinert RE, Woelnerhanssen B, Peters T, Christoffel-Courtin C, Gass M, Kern B, von Fluee M, Beglinger C (2012) Metabolic and hormonal changes after laparoscopic Roux-en-Y gastric bypass and sleeve gastrectomy: a randomized, prospective trial. Obes Surg 22:740–748
39. Leifsson BG, Gislason HG (2005) Laparoscopic Roux-en-Y gastric bypass with 2-m long biliopancreatic limb for morbid obesity: technique and experience with the first 150 patients. Obes Surg 15:35–42
40. Sanchez-Santos R, Estevez S, Tome C, Gonzalez S, Brox A, Nicolas R, Crego R, Pinon M, Masdevall C, Torres A (2012) Training programs influence in the learning curve of laparoscopic gastric bypass for morbid obesity: a systematic review. Obes Surg 22:34–41
41. Dallal RM, Trang A (2012) Analysis of perioperative outcomes, length of hospital stay, and readmission rate after gastric bypass. Surg Endosc 26:754–758
42. Lancaster RT, Hutter MM (2008) Bands and bypasses: 30-day morbidity and mortality of bariatric surgical procedures as assessed by prospective, multi-center, risk-adjusted ACS-NSQIP data. Surg Endosc 22:2554–2563
43. Aghajani E, Jacobsen HJ, Nergaard BJ, Hedenbro JL, Leifson BG, Gislason H (2012) Internal hernia after gastric bypass: a new and simplified technique for laparoscopic primary closure of the mesenteric defects. J Gastrointest Surg Off J Soc Surg Alimentary Tract 16:641–645