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ORIGINAL CONTRIBUTIONS

Gastric Emptying and Food Tolerance Following Banded and Non-banded Roux-en-Y Gastric Bypass

Galzuinda Maria Figueiredo Reis[1,2] · Carlos Alberto Malheiros[1] · Paulo Roberto Savassi-Rocha[3] · Omar Lopes Cançado Júnior[2] · Fábio Rodrigues Thuler[1] · Mauro Lima Faria[2] · Vicente Guerra Filho[3]

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Abstract

Introduction Gastric emptying (GE) and food tolerance (FT) can be altered after Roux-en-Y gastric bypass (RYGB) has been performed, especially when it involved the use of a restrictive mechanism (such as a silastic ring).

Aim To assess GE and FT in patients who underwent banded (BRYGB) or non-banded Roux-en-Y gastric bypass (RYGB).

Methods Forty-seven BRYGB patients and 47 RYGB patients underwent gastric emptying scintigraphy (GES) and FT assessment (by means of a questionnaire) between 6 months and 2 years postoperatively.

Results GES was performed on average 11.7 ± 5.0 months (6 to 24) postoperatively. T½ medians (time taken for the gastric radioactivity to decrease to half of the original value in the gastric pouch) in the RYGB and BRYGB groups were 48.7 min (40.6–183.0 min) and 56.3 min (41.1–390.9 min), respectively ($p = 0.031$). The median of total questionnaire scores was 24 points (18–27) in the RYGB group and 20 points (13–27) in the BRYBG group ($p < 0.001$).

Conclusions The band (silastic ring) delays GE time and does not affect patient satisfaction or food tolerance to vegetables, bread, or rice, but does affect tolerance to the intake of meat, salad, and pasta. The best tolerated foods are vegetables, salad, and fish. Banded patients are more likely to regurgitate and vomit. Gastric emptying does not affect FT.

Keywords Bariatric surgery, · Gastroplasty · Gastric bypass · Roux-en-Y anastomosis · Gastric emptying · Scintigraphy · Food intake · Vomiting

Introduction

Roux-en-Y gastric bypass (RYGB) is one of the most frequently performed bariatric procedures. According to data from the Brazilian Unified Health System (the public system), 93.22% of the 10, 089 bariatric procedures performed in Brazil in the public health system by 2017 were Roux-en-Y gastric bypass (RYGB) [1].

The influence of the anatomical alterations present following Roux-en-Y gastric bypass (banded or non-banded) on GE and FT is poorly understood. In respect of the functional and anatomical changes resulting from the Roux-en-Y gastric bypass (RYGB), GE plays an important role in the mechanism of action of this procedure, either through delayed emptying (resulting from the restrictive factor) or by promoting, in the case of accelerated GE, a neuro-hormonal response (including peptide tyrosine tyrosine [PYY] and glucagon-like peptide-1 [GLP1]), regulating appetite [2–4].

Some authors have defended that these mechanisms would be contrary to the restrictive effects previously recognized as responsible for the result of restrictive surgical procedures, such as delayed emptying [5, 6].

The optional use of a prosthesis in the terminal portion of the gastric pouch in Roux-en-Y gastric bypass (BRYGB) has been related to the potentiation and maintenance of weight loss in patients submitted to this surgery [7, 8]. However,

✉ Galzuinda Maria Figueiredo Reis
galzuinda@gmail.com

[1] Department of Surgery, Santa Casa of São Paulo Medical School, Rua Cesário Mota Jr, 61, São Paulo, SP CEP 02112-020, Brazil

[2] Department of Surgery, Santa Casa of Belo Horizonte, Av. Francisco Sales, 1111 - Santa Efigênia, Belo Horizonte, MG CEP 30150-221, Brazil

[3] Department of Surgery School of Medicine, Federal University of Minas Gerais (UFMG), Av. Prof. Alfredo Balena, 190 - Santa Efigênia, Belo Horizonte, MG CEP 30130-100, Brazil

many authors have abandoned the use of a ring in the procedure due to additional complications, e.g., ring erosion, migration, and stenosis [9–11].

GES is considered the gold standard for evaluating GE because it provides a physiological, noninvasive, quantitative means to assess GE (solids or liquids) [12].

GE post-BRYGB may be influenced by some factors, such as medication, smoking, hyperglycemia, gender, and phase of the female reproductive cycle (pre- and postmenopausal) [13].

The altered anatomy probably changes GE in comparison with individuals without alterations of the gastrointestinal tract. In general, there may be retention of solids in the gastric remnant after Roux-en-Y reconstruction gastrectomy [4].

After bariatric surgery, food intolerances are relatively common as a result of anatomical and functional changes, and are more common with techniques using restrictive components, such as BRYGB [14–16]. Specific questionnaires are used following bariatric intervention to assess FT [15, 17, 18].

Method

A non-randomized clinical trial comparing two groups of patients who underwent RYGB (with and without a containment ring).GE was studied by means of scintigraphy, and FT was investigated by administering a questionnaire to 47 patients who underwent BRYGB and 47 patients who underwent RYGB, in the period between 6 months and 2 years postoperatively (from December 13, 2013, to November 15, 2016) after approval by the Ethics Committee (CAAE: 5676413.4.0000.5138). The inclusion criteria were the following: patients who of either gender who underwent RYGB or BRYGB; and the provision of informed consent. Exclusion criteria were patients with *diabetes mellitus*, pregnant or breastfeeding, claustrophobic, allergic or impaired food intolerance to the GES test meal (egg), and previous surgical procedures on the esophagus, esophagogastric transition, or stomach and small intestine. Patients who reported having made use of anti-emetic or prokinetic medicines, opioid analgesics, and anticholinergic drugs within 48 h prior to the scans (EGS) were excluded from the study, as were those who had smoked cigarettes in the period prior to the GES or during the time of the GES and those who did not complete all phases of the study.

Surgical Technique

Patients underwent the Roux-en-Y gastric bypass technique described by Capella et al. [6], by laparotomy, which was the surgical route authorized by Brazil's Unified Health System (SUS, the Portuguese acronym for *Sistema Único de Saúde*) at the time the study was conducted. Laparoscopy has only been allowed in the Brazilian Public Health System since 2017.

The procedure consisted of a supraumbilical median laparotomy with a small curvature gastric reservoir with approximate dimensions of 6 × 3 cm, made by a 75-mm mechanical suture. Roux-en-Y transit reconstruction with the biliary limb at 70 cm from the Treitz angle and 100 cm Roux limb in the pre-colic position. End-to-side gastrojejunal anastomosis was performed manually. In the BRYGB, a silastic ring 6.2 cm in circumference, closed with a polypropylene-0 yarn, was placed 2 cm above the anastomosis. In the two-year follow-up period, there was no death or leak and there was one thromboembolic event. The most frequent complications were in relation to the abdominal wall with 8 cases of incisional hernias and seroma.

Gastric Emptying Scintigraphy

A gamma camera was employed in conjunction with standardized techniques that had been previously used in other studies [9]. The equipment comprised a Siemens® Symbia® gamma camera, with two angled detectors, coupled to a Syngo® acquisition station. Data processing was performed with a GE® Xeleris processing station, and data were analyzed by a single physician specializing in nuclear medicine.

Patients, who had fasted for 4 h, were given a standardized, predominantly solid, test meal consisting of a medium-sized, 50 g, scrambled egg, mixed with 1 mCi of ^{99m}Technetium (Tc) bound to phytate molecules. The meal was "marked" with approximately 37 MBq (1 mCi) of ^{99m}Tc + phytate.

Following the oral administration of radiocolloid in solid contents, gastric ejection fractions (GEF) (the percentage of food eliminated from the gastric pouch) and gastric content were assessed by static sequential images of the stomach obtained at the following times: T1, T2, T3, T4, T5, T6, and T7—which correspond, respectively, to the following times: 0, 15, 30, 45, 60, 90, and 120 min. In addition, the time after which the stomach had emptied half of its contents of the initial radioactivity was recorded (T ½) Fig. 1.

Questionnaire for Assessing Food Tolerance

The questionnaire used was designed and validated by Suter et al. [19], and translated and validated by Godoy et al. [15] for use in Brazil. The questionnaire was administered to all patients by the principal investigator of this study in order to ensure homogeneity Fig. 2.

Anthropometric measurements were taken using the same piece of equipment (Welmy® body-weight scales, up to 200 kg). Ideal body weights were those yielding BMIs equal to 25 kg/m^2.

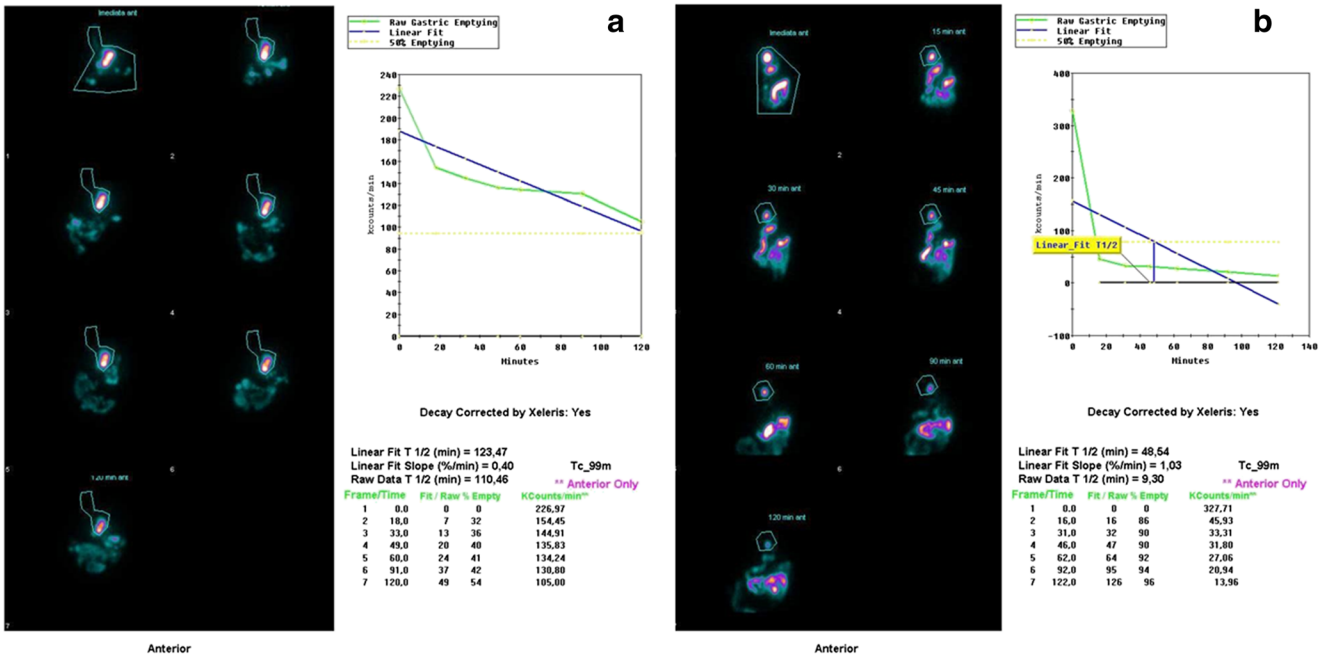

Fig. 1 **a** Gastric emptying scintigraphy in a patient who had undergone RYGB (Case no. 51); **b** Gastric emptying scintigraphy in a patient who had undergone BRYGB (Case no. 03)

Statistical Analysis

To investigate whether there is an association between the numerical variables and the group being studied (with or without the band), the non-parametric Mann-Whitney *U* test was used. The Shapiro-Wilk test was used to verify the normality of the data; a significance level of 5% was considered throughout statistical tests; the STATA software, version 10.0, was used for statistical analysis (Stata Statistical Software: Release 10.0. College Station, Texas: Stata Corporation, 2007).

Results

Of the 100 patients meeting the inclusion criteria, five were excluded because they did not complete all phases of the study, and one because of vomiting during the examination. Eighty-one patients (86.2%) were female and 13 (13.8%) were male. The groups were not homogeneous relative to age and preoperative BMI Table 1.

With respect to GE, the T½ medians in the postoperative period in the RYGB and RYGBD group were 48.7 min (40.6–183.0 min) and 56.3 min (41.1–390.9 min), respectively ($p = 0.031$) Fig 3.

Table 2 shows that the total food score, total vomiting score, and the total questionnaire score were higher in the RYGB group than those in the BRYGB group, which indicates better food tolerance in the non-banded group ($p < 0.001$). In the "total satisfaction" category (on food quality), there was no statistically significant difference between the two groups ($p = 0.235$).

Figure 4 shows FT among BRYGB patients considering the eight food types evaluated. As can be seen in the figure, the ingestion of red meat and white meat was considered more difficult. The best tolerance observed refers to the ingestion of vegetables.

Figure 5 shows food tolerance among RYGB patients considering the eight food types evaluated. As can be seen in the figure, red and white meat were well tolerated by most patients in the group. In both groups, the best tolerated foods are vegetables, salad, and fish (Fig. 6).

Table 3 shows that for the eight types of food, the category "easily" was more frequent in the non-banded group. For these variables, the category "with difficulty" was more frequent in the banded group. This difference was statistically significant for red meat ($p = 0.001$), white meat ($p < 0.001$), and salad (p = 0.001), pasta ($p = 0.017$), and fish ($p = 0.049$).

Table 4 shows that gastric emptying (T½ < 60 min e ≥ 60) does not affect food tolerance considering total satisfaction score, total food score, total vomiting score, and total questionnaire score. There was no statistically significant difference between patients with longer GE and poorer FT.

Discussion

The GE reference values for the different bariatric procedures and food tolerance following RYGB, with or without band (silastic ring), are not well known.

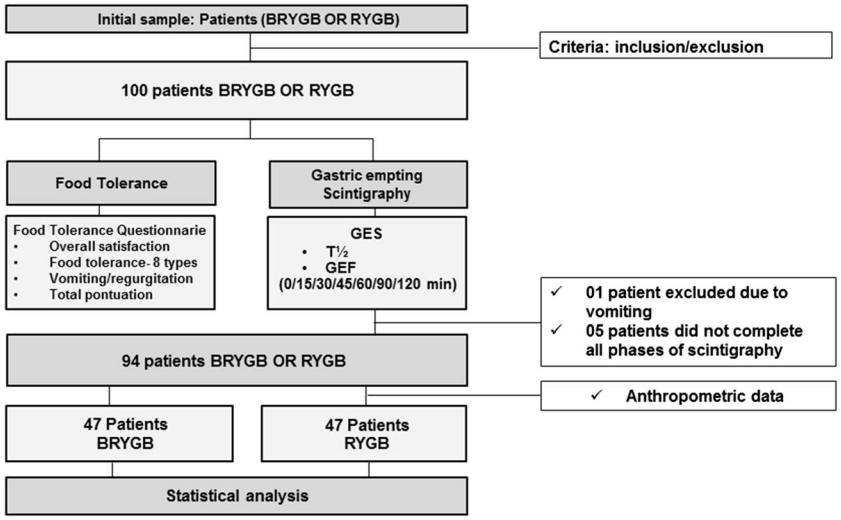

Fig. 2 Study design

Restrictive mechanisms have been commonly used along with various surgical techniques for treating obesity since the beginning of bariatric procedures [20, 21]. Although banding was widely used for many years, there was no suitable evaluation of its impact during the period of time it was used most frequently, neither was its mechanism of action clarified, especially with respect to weight loss, the main justification for its use.

At present, BRYGB is being used less and less frequently due to complications secondary to band use such as migration, erosion, stenosis, and infection [9, 22].

In spite of its use becoming increasingly rare, there are still authors today defending its routine use. Lemmens [23] recently published a study reporting that BRYGB is his procedure of choice, describing it as the gold standard for the surgical treatment of moderate or severe obesity, or still as revision surgery [24, 25].

Regarding weight loss, in the sample studied, considering the mean postoperative time of 11.7 months, the result was 71.4% excess weight loss (PEWL), very similar to that found by Chang et al. [26], (72.32%) in the first postoperative year.

Table 1 Distribution of the demographic variables of patients who underwent RYGB (47 patients) and BRYGB (47 patients)

Variable	Frequency (%)/measurements		*p* value
	RYGB	BRYGB	
Postoperative time (month)	9 (6–24)	10 (6–24)	0.225
Age (years)	46 (20–61)	36 (25–63)	*0.038*
Female	40 (49.4)	41 (50.6)	0.765*
Male	7 (53.8)	6 (46.2)	
Height (m)	1.62 (1.47–1.83)	1.61 (1.49–1.87)	0.431
Preoperative weight (kg)	112.6 (90.9–151.9)	119.9 (85.6–170.0)	0.366
Preoperative BMI (kg/m^2)	42.4 (36.0–54.9)	44.3 (37.5–60.8)	*0.045*
Excess weight	47 (27.7–76.5)	46.8 (28.6–96.5)	0.133
Postoperative weight (kg)	83.1 (63.6–117.1)	82 (54.1–137.8)	0.513
Postoperative BMI (kg/m^2)	30.9 (23.7–43.8)	29.8 (21.8–52.5)	0.449
PEWL1 (%)	68.9 (22.1–109.8)	75 (18.7–124.5)	0.148
PEWL2 (%)	82,2 (47,43–139,1)	87,9 (47,6–136,1)	0.165

Source: study data

p value obtained from the Mann-Whitney *U* test

BMI (body mass index); PEWL1 (percentage of excess weight lost- GE Test day);

PEWL2 (percentage of excess weight lost- maximum 2 years)

RYGB – non-banded Roux-en-Y gastric bypass

BRYGB – banded Roux-en-Y gastric bypass

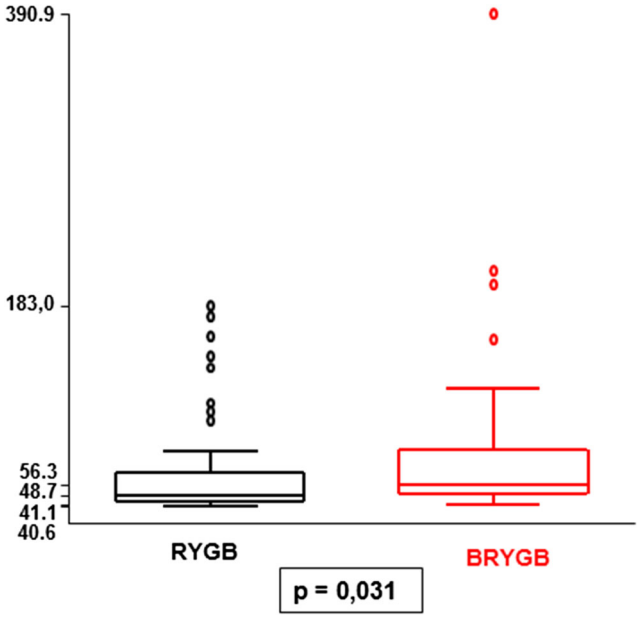

Fig. 3 Comparison of (T½) in the postoperative period in the groups submitted to RYGB and BRYGB

Rasera Jr et al. [8] concluded that after 2 years, ring placement in the BRYGB resulted in a small, though significant, weight loss advantage, with a PEWL medians of 71% (RYGB) × 75.4% in BRYGB group ($p = 0.002$), and weight stability. We found that the median of maximum PEWL at 2 years (median 17.5 months) was 85%, a result which is considered very satisfactory. But Long-term evaluations would be needed to analyze the regain of PEWL. One patient in the BRYGB group had a PEWL of 47.6% at 2 years postoperatively.

The group of patients who underwent BRYGB presented an average age of 37.4 years and a median of 36 years, lower than the group who underwent RYGB, 42 and 46 years old, respectively ($p = 0.038$). Vasavid et al. [27] studied 189 volunteers using GES and found that age did not affect study GE values.

With regard to T½ in the RYGB and BRYGB groups, the medians/mean were 48.7/65.9 min and 56.3/79.4 min, respectively, with a statistically significant difference ($p = 0.031$) between each other. This is supported by findings of Mali et al. [28] who found GE studied by scintigraphy ranged from 58 to 83 min (mean = 71 min) and 58 to 81 min (mean = 70 min) during the first and second postoperative years in obese subjects who underwent BRYGB [28, 29].

One female patient in the BRYGB group, though, had a much higher maximum T½ value (390.94 min) than the other patients. This patient also had frequent vomiting (more than two vomiting episodes per week) and had the second worst score on the questionnaire. The factors that may influence GE in respect of the restrictive aspect of bariatric procedures are gastric pouch capacity, the restriction mechanisms (such as anastomosis diameter), and the presence of an external constriction mechanism (i.e., placement of a band).

GE plays an important role in relation to both the restriction stemming from emptying delay and that due to rapid emptying, which leads to greater enteric hormonal

Table 2 Distribution of the variables of the food tolerance questionnaire and GES of banded ($n = 47$) and non-banded ($n = 47$) patients

Variable	Frequency (%)/measurements		*p* value
	RYGB	BRYGB	
Total satisfaction score	5 (3–5)	4 (2–5)	0.235
Total food score	14 (10–16)	12 (5–16)	< 0.001
Total vomiting score	4 (2–6)	4 (2–6)	< 0.001
Total questionnaire score	24 (18–27)	20 (13–27)	< 0.001
T½ * (median /mean)	48.7/65.9 (40.6–183.0)	56.3/79.4 (41.1–390.9)	0.031
GEF Time 1 (%)– 0	0	0	NSA
GEF Time 2 (%)– 15 min	46 (0–96)	32 (1–98)	0.04
GEF Time 3 (%)– 30 min	67 (8–99)	51 (3–99)	0.019
GEF Time 4 (%)– 45 min	77 (8–100)	65 (5–100)	0.073
GEF Time 5 (%)– 60 min	90 (14–100)	69 (6–100)	0.042
GEF Time 6 (%)– 90 min	96 (31–100)	85 (9–100)	0.066
GEF Time 7 (%)– 120 min	98 (35–100)	92 (16–100)	0.061

Source: study data

p value obtained from the Mann-Whitney *U* test

**p* value obtained from the chi-square frequency test

NA = not statistically assessable; RYGB – non-banded Roux-en-Y gastric bypass; BRYGB – banded Roux-en-Y gastric bypass; GEF – gastric ejection fraction

T½ – mean gastric emptying time; GES – gastric emptying scintigraphy

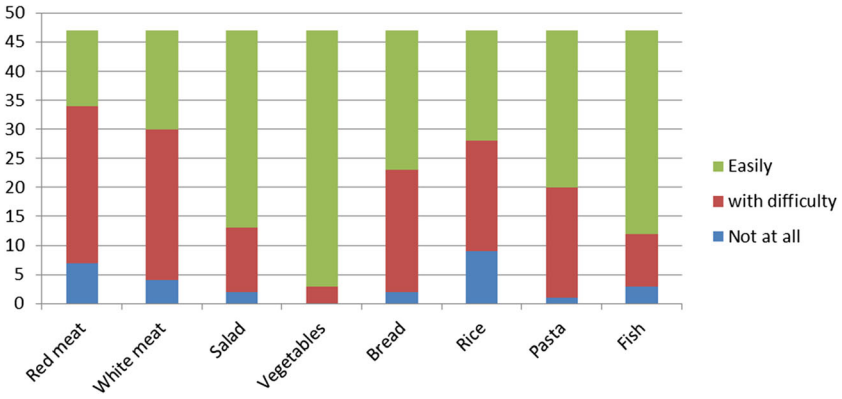

Fig. 4 Food tolerance by food category (eight foods) in the BRYGB group

stimulation. Wang et al. [3] reported that fast GE may play an important role in incretin response following RYGB [4].

The use of questionnaires to evaluate food quality in the postoperative period following bariatric surgery allowed us to assess patients' FT, as well as to compare possible effects of different bariatric interventions.

FT is impaired mostly during the first 6 months after RYGB. Of all the scores for the questionnaire domains, namely satisfaction, feeding, vomiting/regurgitation, and total score, only the satisfaction score did not show a statistically significant difference between the two groups studied, i.e., the banded and non-banded groups ($p = 0.391$). Satisfaction is known to be assessed with great subjectivity, since patients classify their overall satisfaction in relation to their postoperative experience. This means that although they may be satisfied with the outcome of the bariatric surgery specifically in relation to weight loss, this may lost when they answer about their general satisfaction.

It should be noted that, in this study, there was a statistically significant difference in the total score of the food tolerance questionnaire between the two interviewed groups: the median total questionnaire score found in the BRYGB group was 20 points, while that in the RYGB group was 24 points (SD). However, the patients with a longer gastric emptying do not have a poorer food tolerance. The gastric emptying does not affect food tolerance (Table 4).

Freeman et al. [30] reported scores of 22 after RYGB; Godoy et al. [15] 23.02; Cano-Valderrama et al. [31] 24 points; and Suter et al. [19] found that 80.1% of patients had a total score of 24 points postoperatively. Total scores may vary from 1 to 27, with 27 points being the best result and corresponding to excellent food tolerance.

In our study, we found that of the patients that reported easily eating red meat, 28 (68.3%) belonged to the RYGB group, whereas only 13 (31.7%) belonged to the BRYGB group.

Contrary to expectations, rice, which is frequently mentioned in clinical practice and several other studies, such as the one by McMahon et al. [32], as a cause of food intolerance, was not statistically different relative to its acceptance either in the banded or non-banded groups. Thus, 50% ($n = 47$) of the total sample reported easily eating rice, and only 13.8% ($n = 13$) reported not being able to eat this food.

With regard to vomiting, a statistically significant difference was observed between the banded and non-banded groups: 13 patients in the BRYGB group reported frequent vomiting (more than twice a week) as compared to only two in the RYGB group. Eighteen patients in the non-banded group reported never vomiting ($p < 0.001$).

As a result of intentionally modified gastrointestinal anatomy, with a gastric pouch whose size was reduced, bariatric patients do not tolerate large amounts of food or liquids.

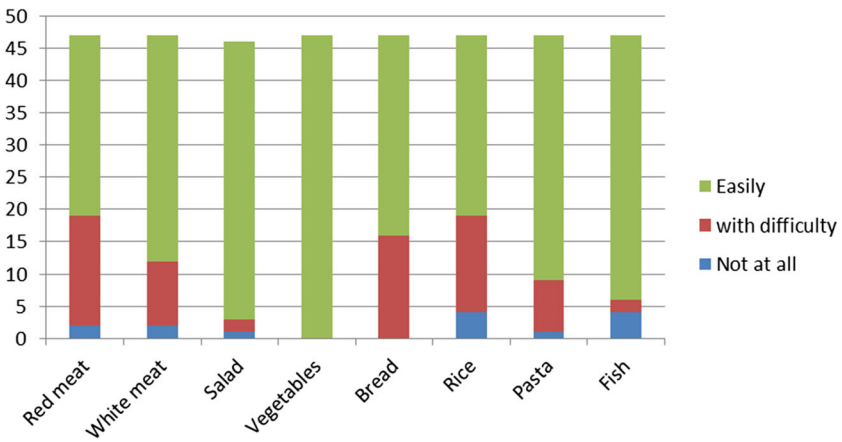

Fig. 5 Food tolerance by food category (eight foods) in the RYGB group

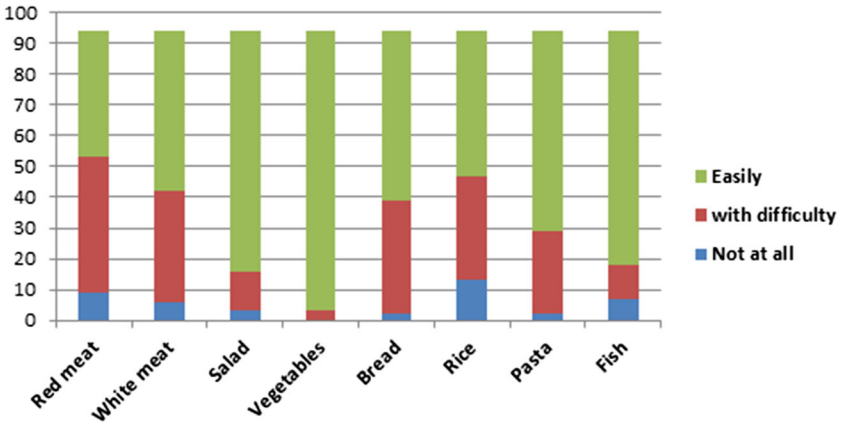

Fig. 6 Food tolerance by food category (eight foods) in the BRYGB and RYGB group (94 patients)

Accordingly, the occurrence of vomiting is one of the most common postbariatric complaints reported at some time in the postoperative period [8, 33].

The frequency of daily or weekly vomiting in the non-banded group was 7.7%, whereas it was 24.4% in the banded group [8].

The frequency of vomiting differed significantly between groups ($p < 0.001$), with the percentage of patients who never reported it being statistically higher in the non-banded group when compared to the banded group (78.3% versus 21.7%).

One limitation of this study is that it was a non-randomized clinical trial with a convenience sample. However, the physician specializing in nuclear medicine did not know whether the patient being assessed had the band or not, or the FT questionnaire results. The period of time chosen for conducting the evaluation was the most appropriate as by this time (the sixth postoperative month), patients have become adapted to the new food phase, particularly regarding volume and chewing speed [20].

Table 3 Distribution of the food tolerance questionnaire variables in the food category (tolerance to eight different food types) of banded ($n = 47$) and non-banded ($n = 47$) patients

Variable	Category	Frequency (%)		*p* value*
		RYGB (non-banded)	BRYGB (banded)	
Red meat	With difficulty	17 (38.6)	*27 (61.4)*	*0.001*
	Easily	*28 (68.3)*	13 (31.7)	
	Not at all	2 (22.2)	*7 (77.8)*	
White meat	With difficulty	10 (27.8)	*26 (72.2)*	*< 0.001*
	Easily	*35 (67.3)*	17 (32.7)	
	Not at all	2 (33.3)	4 (66.7)	
Salad	With difficulty	2 (15.4)	*11 (84.6)*	*0.001*
	Easily	*44 (56.4)*	34 (43.6)	
	Not at all	1 (33.3)	2 (66.7)	
Vegetables	With difficulty	0 (0.0)	3 (100.0)	0.242**
	Easily	47 (51.6)	44 (48.4)	
Bread	With difficulty	16 (43.2)	21 (56.8)	0.217
	Easily	31 (56.4)	24 (43.6)	
	Not at all	0 (0.0)	2 (100.0)	
Rice	With difficulty	15 (44.1)	19 (55.9)	0.169
	Easily	28 (59.6)	19 (40.4)	
	Not at all	4 (30.8)	9 (69.2)	
Fish	With difficulty	2 (18.2)	*9 (81.8)*	*0.049*
	Easily	41 (54.0)	35 (46.0)	
	Not at all	4 (57.14)	3 (42.86)	

Source: study data. *p* value obtained from the chi-square frequency test

*p value obtained from the chi-square frequency test excluding the category "I do not eat it at all"; ** p value obtained from Fisher's exact test

Conclusion

The use of a band (silastic ring) delays GE time and does not affect patient satisfaction or FT to vegetables, bread, or rice but it does affect tolerance to the intake of meat, salad, and pasta. The best tolerated foods for both groups are vegetables, salad, and fish. Banded patients are more likely to regurgitate and vomit. Gastric emptying does not affect food tolerance.

In view of these findings, it is necessary to further investigate not only the role of GE, but also food tolerance in the

Table 4 Distribution of the variables of the food tolerance questionnaire and (T½) < 60 min versus ≥ 60 min)

Variable	Frequency (%)/measurements		*p* value
	(T½) < 60 min	(T½) > 60 min	
Total satisfaction score	5 (2–5)	4,5 (3–5)	0.864
Total food score	14 (5–15)	12 (8–15)	0.783
Total vomiting score	4 (2–6)	4 (2–4)	0.690
Total questionnaire score	22 (13–27)	21.5 (15–27)	0.707

Source: study data

T½ – mean gastric emptying time

p value obtained from the Mann-Whitney *U* test

weight loss process observed in gastric bypasses, with or without use of a band.

All Contributing Authors Galzuinda Maria Figueiredo Reis - Conception and design of study, acquisition of data, performed analysis on all samples, interpreted data, wrote manuscript, and acted as corresponding author; approval of the version of the manuscript to be published

Carlos Alberto Malheiros - Conception and design of study, supervised development of work, helped in data interpretation and manuscript evaluation

Paulo Roberto Savassi Rocha - Conception and design of study, supervised development of work, helped in data interpretation and manuscript evaluation.

Omar Lopes Cançado Júnior - Acquisition of data (surgery procedures), helped to evaluate and edit the manuscript

Fábio Rodrigues Thuler - Analysis and/or interpretation of data, drafting the manuscript; approval of the version of the manuscript to be published. Critical revision

Mauro Lima Faria - Acquisition of data (scintigraphy); analysis and/or interpretation of data

Vicente Guerra Filho - Analysis and/or interpretation of data, checked the references, compiled the literature sources

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

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