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ORIGINAL CONTRIBUTIONS

Food Intake and Changes in Eating Behavior After Laparoscopic Sleeve Gastrectomy

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Abstract
Background Laparoscopic sleeve gastrectomy (LSG) results in reduced calorie intake and weight loss. Whether patients consume the same types of food before and after surgery or whether they reduce the volume and calorie density of the foods they consume remains unknown.
Objectives The aim of this prospective study was to evaluate the changes in daily caloric and macronutrient intake after LSG and the relation between changes of taste and food tolerance over 2 years.
Methods Thirty morbidly obese patients with median body mass index (BMI) of 43.9 kg/m^2 (39.5–57.3) were prospectively enrolled prior to LSG. Weight, BMI, %EWL, weight loss percentage (%WL), and daily intake were evaluated preoperatively at 1, 3, 6, 12, and 24 months after surgery along with a questionnaire evaluating food choices, quality of eating, tolerance of certain types of food, frequency of vomiting, and changes in taste.
Results The median %EWL and %WL at 12 and 24 months was 65 % (33.9–93.6 %), 27.3 % (14.2–45.5 %) and 71.5 % (39.6–101.1 %), 31 % (19.1–50.3 %) respectively. Six months after surgery, the daily caloric intake reduced by 68 % and the reduction was maintained until 24 months. The median score of the eating questionnaire was 18 (10–27) at 6 months, 22 (16–26) at 12 months, and 23 (10–27) at 24 months, suggesting that the quality of nutrition improved over time. At 6, 12, and 24 months, 75 % of the patients reported changes in taste with reduced interest in sweets, high fat food, and alcoholic drinks. However, at 24 months, 20 % of patients reported a heightened interest in sweets compared to 12 months previously.
Conclusions LSG reduced calorie intake both through volume of food and the calorie density of the food consumed. The mechanisms for the changes in food preferences may involve both unconditioned and conditioned effects. The influence of dietary counseling on learning which foods are consumed still requires further exploration.

Keywords Food intake · Eating behavior · Sleeve gastrectomy

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Introduction

Bariatric surgery is the most effective long-term treatment for morbid obesity [1]. Several studies have demonstrated that laparoscopic sleeve gastrectomy (LSG) induces a steady weight loss and improvements in

obesity-related comorbidity [2–6]. The exact mechanisms by which LSG induces weight loss and improvement of comorbidities are not yet clear, but it is likely to be a combination of biological and neurobehavioral effects [7, 8].

While there is general agreement that reduction of volume of food plays a central role in postsurgical weight loss [9], some studies suggest that changes in what patients eat may also contribute. It has been suggested that some patients after bariatric surgery change their preference to lower caloric density food [10]. The decrease in high fat food [11] and sweets [12, 13] suggest that certain bariatric surgical procedures may influence cognitive choices of food [14].

The aim of this prospective study was to evaluate the quantitative reduction and qualitative changes in food intake at 6, 12, and 24 months after LSG by using a modified Suter Questionnaire. The association between weight loss and changes in eating behavior was also analyzed.

Material and Methods

This study was conducted according to the Declaration of Helsinki and approved by the local institution review board. From October to December 2012, 30 consecutive patients (22 female and 8 male) scheduled for LSG were prospectively enrolled. Patients with gastroesophageal reflux disease (GERD), hiatal hernia, type 2 diabetes, and previous gastrointestinal surgery were excluded from the study group.

Nutritional assessment and dietary counseling occurred 4–6 weeks before surgery (baseline) and at 1 week, 1, 3, 6, 12, and 24 months after surgery. At each visit, patients had anthropometric measurements: after overnight fasting, patients were weighed barefoot and in light clothing to the nearest 0.1 kg. Height was measured using a fixed wall stadiometer; height and weight were recorded and BMI (kg/m^2) was calculated. Daily caloric intake was recorded in every visit by the 24-h recall; it includes drinks, snacks, sauces, and salad dressing eaten by the patients during the last 24 h. Food models pictures, and other visual aids, may be used to help patients report portion size. This data were recorded in the database INRAN (National Research Institute for Food and Nutrition) for food composition (nut.entecra.it). The registered dietitian (RD) evaluated nutritional status, food tolerance, adequacy of intake, and diet progression following international guidelines [15].

After surgery, patients were advised to follow four steps as regards the consistency of their diet: liquid (up to 1 week), pureed (2 or 3 weeks), soft solid (progress as tolerated), and firmer, regular food thereafter. Diet progression after sleeve gastrectomy follows the international nutritional guidelines [5] and was described in details in Table 4. After the first months, patients are counseled to meet minimal needs for carbohydrate (130 g/day) and fat (20 g/day). Thus, the dietitian aimed to (a) give advice on a balanced diet that included adequate servings from all food groups, and in particular protein needs of 1.1 g/kg ideal body weight [5]; and to (b) limit or exclude added sugar, concentrated sweets, fruit juice, fried foods, carbonated drinks, caffeine, and alcohol [5, 15, 16].

At 6, 12, and 24 months, patients' quality of eating was assessed by a modified Suter Questionnaire [17], which included additional questions evaluating changes of taste and food choices. Therefore, the questionnaire consisted of five parts: (1) satisfaction about the quality of eating; (2) tolerance of eight different types of food (red meat, white meat, salad, vegetables, bread, rice, pasta, and fish); (3) frequency of vomiting/regurgitation per week; (4) changes in taste; and (5) altered food choices. The total score ranges from 1 to 27 points, where 27 depicts excellent quality of eating. The extended questionnaire is shown in Appendix 1.

Statistical analysis was performed using SPSS for Windows (version 17; SPSS Inc., Chicago, IL. USA). Univariate analysis was performed with Chi-square test for categorical data and with Wilcoxon matched-pairs non-parametric test for continuous data. The data were tested for normality and parametric analysis was used for normally distributed data, and non-parametric analysis was used were data was normally distributed. As most of our data were not normally distributed, we used non-parametric statistical analysis. A p value <0.05 was considered statistically significant.

Results

Weight Changes

Table 1 demonstrated the weight loss of patients as would be expected after LSG over 24 months.

Calorie Intake

Table 2 shows calorie intake decreased by up to 68 % after LSG, and these changes were maintained for 24 months.

Table 1 Characteristics of the study population (values are median and range)

	Baseline	1 month of follow up	3 months of follow up	6 months of follow up	12 months of follow up	24 months of follow up
N	30	30	30	30	30	30
Age (median)	35 (25–66)					
Female/Male	22/8					
Weight (kg)	131 (102–160)	116.6 (90–158)	104.1 (78–149.1)	89 (71–139)	79.7 (70–127)	74.8 (65–115)
BMI[a] (kg/M^2)	43.9 (39.5–57.3)	38.7 (32.7–56.6)	35.4 (29.4–53.4)	31.5 (25.9–49.8)	29.3 (23.9–45.5)	28.1 (22.2–41.2)
%EWL[b]		21.8 (2.05–39.6)	37.6 (11.2–64.6)	60.2 (21.5–82.9)	65 (33.9–93.6)	71.5 (39.6–101.1)
%WL[c]		10.6 (1.2–17)	18.1 (6.8–30.5)	25.4 (13.1–40.4)	27.3 (14.2–45.5)	31 (19.1–50.3)

[a] *BMI* body mass index

[b] %*EWL* percentage of excess weight loss

[c] %*WL* percentage of weight loss

Macronutrient Intake

Table 2 shows that pre surgery, the protein intake was 1.72 g/kg of desirable weight (calculated using a BMI of 22.5 kg/m^2), which is significantly higher than the 0.9 g/kg suggested by the Italian Society of Human Nutrition (www.sinu.it, recommended level of energy intake for Italian population). The American Society for Metabolic and Bariatric Surgery (ASMBS) guidelines suggest that after surgery, protein intake should be 1–1.5 g/kg of desirable body weight [18], and the Academy of Nutrition and Dietetics (AND) suggests 1. 1 g/kg of desirable body weight per day. One month after surgery, daily protein intake was only 0.63 g/kg of desirable body weight. However, it then increased to 0.95 g/kg of desirable body weight at the end of the study. Table 2 also shows that the absolute amount of fat intake decreased within 1 month and the reductions were sustained over 24 months. The percentage intake of fat did not change. Table 2 demonstrates that the absolute amount of carbohydrates decreased by almost 85 % within 1 month, but was then followed by a steady increase resulting in a two-thirds reduction in carbohydrate intake 24 months after surgery compared with pre surgical consumption. The quality of the carbohydrates also changed from high glycemic index to lower glycemic index carbohydrates over the 24 months. Moreover, Table 2 shows that after 1 year from surgery,

Table 2 Change in eating behavior (values are median and range)

	Baseline	1 month	3 months	6 months	12 months	24 months	*P*[a]
Food intake (kcal/day)	3002 (1824–5533)	672 (333–892) [b]$P<0.01$	891 (682–1100) [b]$P<0.01$	961 (786–1193) [b]$P>0.01$	1006 (938–1133) [b]$P>0.01$	900.5 (693–1244)	<0.001
Protein intake (g/day and %)	101.5 (83–220) 17 %	39 (23–55) 25 % [b]$P<0.01$	42 (33–58) 19 % [b]$P<0.01$	54 (41–57) 23 % [b]$P<0.01$	60.5 (57–68) 22 % [b]$P>0.01$	61 (49–90) 27%	<0.001
Fat intake (g/day and %)	120 (89–130) 36 %	38.8 (29–44) 52 % [b]$P<0.01$	56.4 (47–62) 57 % [b]$P<0.01$	35.2 (32–40) 33 % [b]$P>0.01$	40.2 (38–52) 36 % [b]$P>0.01$	31.5 (26–50) 31.5 %	<0.001
Carbohydrate intake (g/day and %)	352.7 (287–403) 47 %	38.6 (28–40) 23 % [b]$P<0.01$	55.7 (45–67) 25 % [b]$P<0.01$	105.7 (98–112) 44 % [b]$P>0.01$	105.5 (83–115) 42 % [b]$P>0.01$	93.4 (80–109) 41.5 %	<0.001
Fiber intake (g/day)	18	7 [b]$P<0.01$	11 [b]$P<0.01$	10 [b]$P<0.01$	12 [b]$P>0.01$	12	<0.001

[a] Friedman Test

[b] Wilcoxon Test with Bonferroni correction

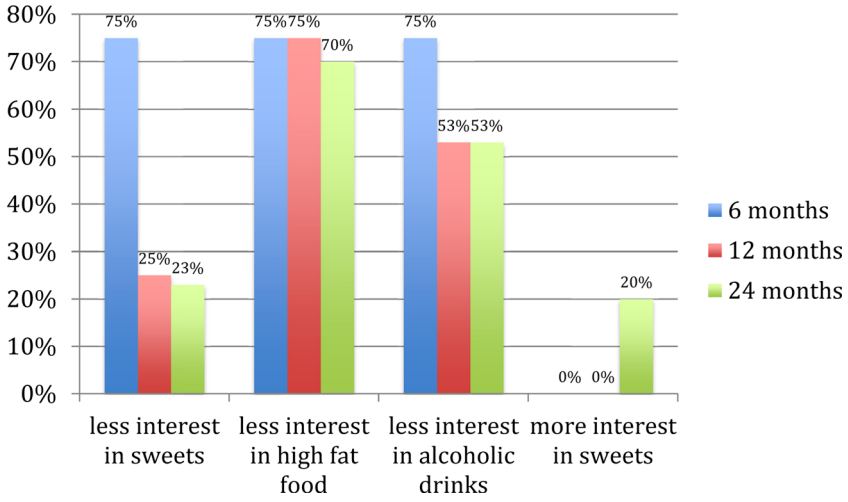

Fig. 1 Taste alterations toward sweets, high fat food, and alcoholic drinks 6, 12, and 24 months after laparoscopic sleeve gastrectomy (LSG)

the eating behavior became stable with no difference between 12 and 24 months.

Taste Preferences

Subjective changes in taste were often associated with changes in smell of foods. Our data were collected using a verbal report, although direct measures of behavior around food preferences are ideal. Figure 1 shows the interest subjects reported for sweets, fats, and alcohol. At 6 months, 75 % of patients reported a reduced interest for sweets, but at 12 months only 25 % and at 24 months only 23 % sustained the reduced interest in sweets ($p = 0.001$). On the other hand, 2 years after surgery, 20 % of patients had an increased interest in sweets compared to the 12 months previously.

Interest in alcoholic drinks and fatty food remained low throughout the 2 years. For alcohol, 75 % at 6 months, 53 % at 12 months, and 53 % at 24 months reported a reduced interest compared with pre surgery. For fatty foods, 75 % at 6 months, 75 % at 12 months, and 70 % at 24 months reported a reduced interest compared with pre surgery.

The non-specific question: "After surgery, can you make healthier food choices?" resulted at 6, 12, and 24 months in 80 % of patients answering "enough" or "a lot," to the question, with no statistical differences between the three time point ($p > 0.05$). Similarly, 75 % of patients answered "enough" or "a lot," to both the questions "Do you have a better understanding of food?" and "Are you more aware of food choices?" The responses to the latter two questions also did not change between 6 and 24 months ($p > 0.05$).

Quality of Eating

Table 3 shows the Suter questionnaire scores, at 6, 12, and 24 months after surgery. After 6 months, the quality of eating was considered "excellent" by 25 % of patients, "good" by 55 %, and "acceptable" by 20 %; none of the patient considered it "poor" or "very poor." After 1 year, the quality of eating was unchanged compared to 6 months with scores indicating "excellent" by 20 % patients, "good" by 55 %, and "acceptable" by 25 %. Twenty-four months after surgery, findings were similar with 40 % of patients considering their quality of eating "excellent," 53 % "good," and 7 % "acceptable" (Table 4).

Tolerance of food improved considerably between 6 and 12 months ($p = 0.002$), especially for rice, vegetables, and salad. During the postoperative period, there was a progressive improvement in the tolerance of different foods. Fish, vegetables, and white meat were moderately tolerated at 6 months by

Table 3 Suter questionnaire results (median and range) after LSG

Suter questionnaire	6 months	12 months	24 months	P^a
Satisfaction of eating ability (1–5 points)	4 (3–5)	4 (3–5)	4 (3–5)	0.6
Food tolerance (0–16 points)	8 (5–16)	12 (8–16)	13 (7–16)	0.0002
Frequency of vomiting/regurgitation (0–6 points)	6 (2–6)	6 (4–6)	6 (2–6)	0.4
Total score (1–27 points)	18 (10–27)	22 (16–26)	23 (10–27)	0.004

LSG laparoscopic sleeve gastrectomy

[a] $P < 0.05$ value vs. baseline. Comparison with Wilcoxon/Mann–Whitney non-parametric test

Table 4 Diet progression after laparoscopic sleeve gastrectomy

Length of time Texture	Up to 1 week Liquid	2–3 weeks Pureed	From 2 to 4 weeks Soft solid	Maintenance Regular food
Sample food	- Water - Vegetables clear broth - Reduced fat milk - Soy milk - Lactose-free milk - Decaf or herbal tea	- Pureed lean beef, lean pork, chicken or turkey, fish (or baby food meats) fruits and vegetables - Scrambled egg - Low fat Cheese - Low calorie yogurt (no chunks of fruit) - Mashed potatoes	- Soft cooked meats - Chopped lean meats - Lean ground beef or turkey - Deli-sliced turkey, breast, chicken, ham - Scrambled egg - Tuna fish, salmon or white fish - Low fat cheese - Mashed or well	-Toasted breads - Low fat crackers - Well-cooked pasta - Tender chicken, turkey and fish - Egg - Legumes - Raw and cooked vegetables and fruits - Lean red meat
Food to avoid	- Viscous fluids - Lumpy liquids - Alcohol - Frizzy drinks	- Tough meats - Fibrous vegetables and vegetables with thick skins	- Tough meats - Fibrous vegetables and vegetables with thick skins	- Untoasted breads - Tough meats - Fruit with skins - Fibrous vegetables

70, 65, and 55 % of the patients, respectively, but after 1 year, this improved to 95, 85, and 65 %, respectively. At 1 month after surgery, salad, red meat, and rice were poorly tolerated by 30, 30, and 25 % of patients, respectively, whereas at 12 months after surgery, pasta, rice, and bread were poorly tolerated. Two years after surgery, the majority of food indicated in the questionnaire was tolerated, with 98 and 90 % of patients reporting that they could eat vegetables, fish, and white meat, while red meat remained the only food that was poorly tolerated by 63 % of patients (not tolerated at all by 10 % of patients and 53 % of patients having some difficulties).

At 6 months, regurgitation and vomiting were "often" present in 10 % of patients and "never" present in 55 %. These percentages changed at 1 year, when regurgitation and vomiting were "rarely" present in 35 % of patients and "never" present in 65 %. The Suter test did not show difference between the two periods ($p = 0.4$) (Table 3). Two years after surgery, regurgitation and vomiting was "never" present in 63 % of patients, "rarely" present in 30 % of patients, and "often" present in 7 % of patients.

Discussion

In our study, the median %EWL and %WL was 60.2 and 30 % after the sixth month, 65.0 and 27.3 % after the twelfth month, and 71.5 and 31 % after the twenty-fourth month, respectively, consistent with previous reports [5]. At 6 months, there was a 68 % reduction in calorie intake, which was sustained for 24 months. Long-term follow up of patients after surgery are crucial to ensure that long-term calorie restriction does not result in malnutrition. Each patient needs to be individually assessed by a healthcare professional that can detect subtle symptoms and signs of malnutrition.

This study suggests that the combination of biological factors after the LSG and dietetic counseling may be important in the food selection of bariatric patients. The biological changes may enable the patient to accept the recommendation from the RD thus helping the patient to choose the foods that they feel hungry for, but also the foods that decrease gastrointestinal symptoms. Thus, the patient is able to plan meals that can be tolerated and may be preferred secondary to changes in taste, so the visceral signals after sleeve gastrectomy generates the opportunity for the dietetic advice to be heeded. This together can achieve optimal weight loss and weight loss maintenance [18, 19]. Moreover, our data suggest the importance of protein supplementation products in order to meet daily needs and to attenuate lean body mass loss, although there is no evidence that protein supplementation is required.

Few studies have evaluated taste perception after bariatric surgery [11, 12, 20], but very little data exists regarding LSG. The changes in food choice we demonstrated may be secondary to learning and influenced by biological and psychological factors. Six and 12 months after LSG, all patients report reduced interest in sweet and high fat food. Two years after LSG, 20 % of patients had a heightened interest in sweets compared to 12 months before. Moreover, most patients reported to be more aware of the importance of healthier food choices and to select their meals more consciously, suggesting a conditional response secondary to learning. Although our data was taken by verbal report which is prone to difficulty interpretation, they describe a real underlying phenomena that requires further exploration.

This study is limited by the relatively small number of patients recruited, but the effect size of the modification in dietary behavior of these patients was large enough to support the hypothesis. Our prospectively recruited patient group had

above average weight loss, and it is possible that by chance the patients recruited were "responders" and thus the factors influencing food preferences were exaggerated or that the patients had better adherence to the advice from the RD (Fig. 1). The shifts in food preferences and the change in eating behavior may be a function of both the surgical procedure as well as the interventions of the dietitian. Studying the range of responses in a larger group may be instructive to determine how many patients after LSG are responders or non-responders as regards changes in food preference and specifically whether this bears relation to their long-term weight loss maintenance. It would also be useful to identify additional factors influencing postoperative outcomes in order to promote specific behavioral changes that could maintain long-term weight loss after LSG. Our study was not designed to differentiate between the influence of dietetic counseling and the biological effects of LSG, but given the effect size observed, a study to determine the relative contribution of these two factors now seems feasible. Food preferences are to a large extent speculative, as the study design did not allow us to distinguish the role of the operation from dietitian-suggested shifts in food choices.

Conclusion

LSG results in weight loss, reduction of daily caloric intake, and altered food choices, with patients reporting reduced interest in sweet and high fat food. The majority of patients reported a change of taste and food choices 6, 12, and 24 months after surgery. The change in food choices could be an important factor that determines the success of postoperative caloric restriction and weight loss. However, at 2 years, 20 % of patients reported an increase preference for sweets, thus long-term results are needed to confirm whether the beneficial changes in food preferences are maintained long term. Our patients were part of a research protocol where they knew their food choices were being observed. The Hawthorn effect suggests that by observing a phenomena, you may alter it; however, we think the effect size of the changes in reported behavior were large and consistent within the group and as such we think the data suggests a potential shift in food preferences. Understanding the mechanisms for the changes in food preferences and whether either unconditioned and or conditioned effects are involved may improve long-term weight loss maintenance.

Compliance with Ethical Standard

Conflict of Interest The authors declare that they have no conflict of interest. ClR is supported by the Science Foundation Ireland (ref 12/YI/B2480).

Ethical Approval All procedures performed in the study were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants for whom identifying information is included in this article.

Appendix 1 Suter questionnaire modified

QUALITY OF EATING

Name _____ Surname_____ Months after surgery _____

How would you rate your overall satisfaction regarding how you can eat presently?

- ❒ Excellent
- ❒ Good
- ❒ Acceptable
- ❒ Poor
- ❒ Very poor

Why?_____
_____
_____
_____

How many meals do you eat a day?_____

Among the following meals, which one do you have**?**

- ❒ Breakfast
- ❒ Lunch
- ❒ Dinner

Which of them constitutes your daily main meal?_____

Do you eat between meals?

- ❒ Yes
- ❒ No

If yes, when?

- ❒ Morning
- ❒ Afternoon
- ❒ Evening

Can you eat everything?

- ❒ Yes
- ❒ No

More specifically, how can you eat?

Red meat

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

White meat

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Fish

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Salad

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Vegetables

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Bread

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Rice

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Pasta

- ❒ Easily
- ❒ With some difficulties
- ❒ Not at all

Are there other types of food that you cannot eat at all?

Do you vomit or rigurgitate?

- ❒ Daily
- ❒ Often (>2x/week)
- ❒ Rarely
- ❒ Never

Do you think your taste toward some food has changed due to the surgery ?

- ❒ Not at all
- ❒ A little
- ❒ Enough
- ❒ A lot

If you say a little, enough or a lot:

- ❒ I dont'like sweets anymore
- ❒ I like sweets a lot
- ❒ I have less interest towards alcoholic drinks
- ❒ I have more interest towards alcoholic drinks
- ❒ I don't like high fat food anymore
- ❒ I like high fat food a lot

What thing had a significant impact on the change in taste after surgery?

- ❒ Food smells
- ❒ Food presentation
- ❒ Cooking method

After surgery can you make healthier food choices?

- ❒ Not at all
- ❒ A little
- ❒ Enough
- ❒ A lot

Do you have a better understanding of food?

- ❒ Not at all
- ❒ A little
- ❒ Enough
- ❒ A lot

Are you more aware of food choices?

- ❒ Not at all
- ❒ A little
- ❒ Enough
- ❒ A lot

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