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LIPID AND METABOLIC EFFECTS OF GASTROINTESTINAL SURGERY (R COHEN, SECTION EDITOR)

Do Food Preferences Change After Bariatric Surgery?

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Abstract

Purpose of Review Insights into physiological mechanisms responsible for weight loss after bariatric surgery (BS) have challenged the traditional view that mechanical restriction and caloric malabsorption are major drivers of weight loss and health benefits after BS. Altered diet selection with an increased postoperative preference for low-sugar and low-fat food has also been implicated as a potential mechanism beyond mere reduction of calorie intake. However, the empirical support for this phenomenon is not uniform and evidence is largely based on indirect measurements, such as self-reported food intake data, which are prone to inaccuracy due to their subjective character.

Recent Findings Most studies indicate that patients not only reduce their caloric intake after BS, but also show a reduced preference of food with high sugar and high fat content. So far, standard behavioral tests to directly measure changes in food intake behavior after BS have been mainly used in animal models. It remains unclear whether there are fundamental shifts in the palatability of high-fat and sugary foods after BS or simply a decrease in the appetitive drive to ingest them.

Summary Studies of appetitive behavior in humans after BS have produced equivocal results. Learning processes may play a role as changes in diet selection seem to progress with time after surgery. So far, direct measures of altered food selection in humans after BS are rare and the durability of altered food selection as well as the role of learning remains elusive.

Keywords Morbid obesity · Laparoscopic sleeve gastrectomy · Laparoscopic Roux-en-Y gastric bypass · Taste preferences · Food choices · Rodent model

Introduction

Bariatric surgery (BS) is very effective in achieving and maintaining body weight loss in patients with obesity [1•, 2] as well as treating obesity-related comorbidities, especially type 2 diabetes mellitus (T2DM) [1•, 2]. Currently, the most frequently performed BS procedures are laparoscopic Roux-en-Y gastric bypass (RYGB) and laparoscopic sleeve gastrectomy (SG) [3]. Growing evidence from clinical and experimental research challenges whether mechanical restriction and caloric malabsorption are important mechanisms for weight loss and health benefits after BS [4]. Instead, other mechanisms that promote metabolic changes after BS have been described: reduced hunger, increased satiation, increased energy expenditure, altered secretion of gut hormones, alteration in the gut microbiota and bile acid levels and composition, as well as changes in vagal nerve signaling [5, 6••, 7, 8]. Furthermore, a trend of decreased postbariatric preference for different nutrients, especially for sugar and fatty food has been described [4, 9••, 10•, 11, 12, 13•, 14]. Due to postbariatric changes in eating behavior, the term "behavior surgery" has even been coined [9••].

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The available evidence on the impact of BS on patients' food preference is however equivocal and largely based on indirect measures (verbal reports, food diaries and questionnaires) which have been shown to be prone to inaccuracy due to their subjective character including underestimation of food intake, especially of unhealthy foods [15•, 16]. Thus, direct measures of eating behavior could represent an essential component in the attempt to understand how BS alters eating and diet selection. Such studies in humans have rarely been performed; most likely due to the significant methodological and conceptual challenges they pose to researchers and study design [17••]. Until significant human research is done in this field, we rely on observations gained from translational research using animal models of BS. Although the postbariatric food preferences of rodents may not entirely reflect the respective behavioral eating patterns of humans, the advantage of the animal model is the elimination of several biases of human studies, like the influence of cultural and social environment [18••] and of nutritional counseling typically given to patients with obesity in general and to BS candidates in particular.

Ingestive behavior can be subdivided into two functional components: First, to an appetitive/avoidance component representing actions leading to, or avoiding contact with the food stimulus (e.g., searching, foraging, approaching, or avoiding food). Second, to a consummatory/rejection component representing behavior that is elicited during the contact with the taste stimulus (e.g., oral motor responses, swallowing) and that represents the final act of an appetitive sequence [19].

Both humans and rats eat less and display altered food choices after several types of BS such as RYGB or SG, but it remains to be elucidated how this is achieved from a behavioral point of view. For example, food intake after BS could be reduced by changes in the appetitive component alone (e.g., decreased drive to start eating), even if the consummatory component of the eating process remains unaffected (e.g., size of a bite, number of swallows, chewing). Vice versa, food intake after RYGB could also be reduced by changes in how the food is consumed (microstructure of eating and drinking), while the motivational properties of the food remain unchanged.

It therefore appears plausible that BS can induce a lowered food intake and an altered diet selection by modification of different functional components of eating behavior [20•]. Against this background, it seems unlikely that one single behavioral test alone is sufficient to capture the full impact of BS on food intake behavior.

In this article, we will discuss food preference changes after BS and potential underlying behavioral mechanisms, with a particular focus on RYGB in laboratory animals and humans. We will start by providing a brief overview on standard behavioral tests with different methodological and interpretive properties that are typically used in animal models to directly assess food intake behavior.

Common Principles in the Assessment of Feeding in Animal Models

In laboratory rodent research, there are several standard behavioral tests to assess food intake behavior.

In the two-bottle preference test, animals are presented with two bottles of which one contains a taste solution and the other contains another taste solution, typically water. The relative intake of the two solutions is calculated and preference is determined on the 48-h values. Although the affective potency of the tested solution certainly affects outcome, the test does not distinguish between the appetitive and consummatory components of ingestive behavior. Further, as intake is measured over a prolonged period of time, postingestive events (e.g., nausea, hypoglycemia, pain) can influence intake and complicate the interpretation of the results [21].

The influence of postingestive events can be reduced by employment of a brief access taste test, where animals are presented with very brief access (few seconds) to taste solutions, during which licking responses are measured [22–24]. The briefness of the test as suggested by its name allows the minimization of postingestive effects during testing as only small amounts of a stimulus are ingested and immediate responses are measured. Here, the motivational characteristics (i.e., affective potency) of a stimulus can be assessed while the procedure involves both an appetitive component and consummatory component.

Other test procedures, like the Progressive Ratio Taste Reinforcer Efficacy Test, allow assessing the appetitive component independent of the consummatory component. Here, animals are trained to execute a specific operant response, e.g., lever pressing, to receive only a small volume of a given taste stimulus (reinforcer). The response requirement is progressively raised as the session continues until the animal reaches a breakpoint and stops to respond further [25, 26]. As the behavior leading to presentation of the reinforcer is produced without stimulus delivery, this test method represents a pure measure of appetitive behavior.

Similarly, the consummatory component can be assessed independently from the appetitive component by the Oromotor Taste Reactivity Test. In this procedure, cannulas are surgically implanted into the oral cavity of animals through which test solutions are infused at a variable rate. Oral motor and somatic responses can then be monitored [27]. As stimulus delivery is entirely under the control of the experimenter and no appetitive action is necessary to get in contact with the stimulus, the method represents a pure measurement of the consummatory behavior. This test has not yet been applied in human bariatric research.

Eating Behavior After Bariatric Surgery

Animal Data

Rodent models are extremely valuable for the direct investigation of eating behavior. They represent the ideal platform allowing researchers a greater scope of action in behavioral, endocrine, and molecular measurements while providing a conceptual bridge with reports of changes in human taste acceptability following surgery—a strategy that has proven very successful in the past [28•].

By applying the two-bottle preference test, Bueter et al. found that RYGB rats significantly decreased their preference for Intralipid® (fat emulsion, containing 20% soybean oil, 1.2% egg yolk phospholipids, and 2.25% glycerin) and sucrose relative to water, but not for non-caloric compounds representative of other taste qualities, e.g., bitter, sour, or salty [28•, 29]. Postprandial levels of GLP-1 and PYY increased and changes were observed in the small bowel in both mRNA and tissue protein levels of the sweet taste receptor proteins T1R2 and T1R3, which form a heterodimer that binds with natural and artificial sweeteners.

However, as interpretation of results from a two-bottle preference test is complicated due to postingestive events, the brief access taste test helps to further investigate intake when postingestive effects are minimized. Tichansky et al. [30] found a decrease in licks in rats after RYGB relative to sham-operated rats in response to the highest three concentrations of sucrose (0.25–1.0 mol/l). There was no effect of RYGB on water licks, indicating that the effect was specific for the sweet stimulus and not a general overall decrease in licking behavior. This change may reflect changes in sensory or hedonic processing, as the brief access test minimizes the effects of postingestive factors. However, le Roux et al. found no difference in appetitive or consummatory behavior in the brief access test for Intralipid® between rats after RYGB versus sham surgery [29]. Moreover, Mathes et al. observed that RYGB rats licked sucrose even more than sham controls if concentration-dependent responsiveness to sucrose instead of Intralipid® was tested [15•]. These data suggest that RYGB may not reduce the motivation to approach and consume sweet and/or fatty nutritive stimuli and that negative postingestive feedback may be necessary to promote the observed difference in food selection after RYGB.

In a progressive ratio behavioral task, Mathes et al. found that the amount of work in which rats, that received a high-fat diet preoperatively and were weight stable after RYGB, engage to receive caloric sugar- and/or fat-containing fluids does not show the expected decrease after RYGB surgery [31•]. Instead, the authors found that rats after RYGB worked even harder for Ensure Plus (milk-chocolate flavored) and Intralipid® solutions compared with sham-operated rats [31•]. The same group demonstrated that RYGB rats drank less sucrose and Intralipid® than sham-operated rats. This intake difference took at least a 60-min test period to emerge [32]. Therefore, the authors stipulate the role of a learned process based on postingestive consequences as opposed to an immediate reaction to changes in the perceived orosensory properties of the stimuli.

This further supports the hypothesis that a change in palatability is not the main mechanism for a reduced preference for food high in fat and/or sugar after RYGB. To further explore a more complex food choice after RYGB, the same group conducted an experiment presenting rats simultaneously with normal laboratory chow, refried beans, low-fat yogurt, peanut butter, and a prepared sugar fat whip for 8 days before and 8 days after surgery [33•]. These items were specifically chosen by the investigators as their macronutrient content imitates the different combinations of low fat, high fat, low glycemic, and high glycemic index. Postsurgical differences in the intake of the different food between RYGB and sham rats were apparent and led to predictable changes in the proportion of total calories ingested from macronutrient categories. Moreover, the changes were progressive in the RYGB group over time, suggesting again that learning processes might be at the root of the observed changes in diet selection after RYGB.

Wilson-Perez et al. also performed the progressive ratio lever-pressing paradigm but in SG rats, and found decreased preferences for high-fat or calorically dense foods, and neither restriction nor caloric malabsorption could account for these effects [34•]. Rats earned significantly fewer sucrose and peanut-oil reinforcers than naïve or sham rats, showing a decreased reward value of these taste stimuli.

Observational diet selection studies further support postbariatric food preference changes in rats. Shin et al. administered a two-choice diet and observed a food choice change 3 month after RYGB: rats shifted preferences from high-fat diet to regular chow [35]. Further, Geary et al. observed that RYGB rats, in contrast to sham-operated rats, progressively increased their food preference for low-energy artificially sweetened diet from energy-dense Ensure. This trend correlated with postoperative weight loss [36]. Seyfried et al. showed that rats who have never been exposed to high-fat diets prior to RYGB refused to eat any high fat after surgery, while rats that were exposed prior to surgery consumed high-fat diet after surgery, but progressively declined their intake and stabilized at a low level albeit never going down to zero intake [37•].

Overall, the observed changes in food intake behavior in rats after BS are reminiscent of what patients' state after RYGB. Patients often report still liking to consume chocolate, but that significantly smaller amounts of chocolate are sufficient to reach a level of satisfaction after RYGB when compared to preoperatively [38]. Moreover, eating too much chocolate after RYGB may even lead to unpleasant gastrointestinal consequences.

Thus, instead of conditioned taste aversion, the type of learning after RYGB might rather be a process referred to as conditioned taste avoidance. Although both conditioned taste aversion and conditioned taste avoidance lead to decreased intake of a taste stimulus via a learned association with the onset of postprandial discomfort, they represent two distinct processes as palatability and/or the hedonic characteristics of taste stimuli remain unchanged only after conditioned taste avoidance.

Human Data

Indirect Measurements

Structured interviews in 1981 reported decrease in consumption of calorically dense high carbohydrate foods 6 months after RYGB [39, 40]. Subsequent studies confirmed a reduction in total calories consumed and food preference changes after RYGB, but found less consistent changes within the macronutrient composition. The first randomized controlled study comparing eating behavior following RYGB and horizontal gastroplasty used structured interviews and was published in 1987 [41]. Here, Sugerman et al. observed that during the first 3 postoperative years, sweet eaters lost less weight compared to non-sweet eaters following gastroplasty, but not after RYGB. The authors suggested dumping syndrome to be responsible for the carbohydrate avoidance in patients after RYGB. Therefore, the authors suggested tailoring BS according to the patients' preoperative eating behavior by recommending RYGB over gastroplasty to sweet eaters.

A questionnaire study published in 1990 showed that protein intake increased after both RYGB and gastroplasty at 1 year, however, patients after RYGB reported to ingest less sweets, high calories beverages, milk, and ice cream [42]. Further, some patients reported a decreased preference for milk and ice cream even in the absence of unpleasant gastrointestinal symptoms.

A Swedish prospective randomized trial assigned patients to undergo RYGB or vertical banded gastroplasty (VBG) [43]. The Swedish Obese Subjects study questionnaire was used for dietary assessment where participants had to recall their dietary intake over the last 3 months. Amounts of consumed food reported by the subjects were converted into grams, from which daily intake of energy and 29 different nutrients were computed. While both groups reduced their total energy intake at 1 year, VBG patients reported a higher proportion of their intake from foods high in sugar and fat. In contrast, patients after RYGB reported a higher relative intake from fruits and vegetables and avoidance of fatty food due to intestinal malaise.

Tichansky et al. used a 23-item questionnaire and reported that subjective taste changes were more common post-RYGB than following gastric banding (GB) [44]. The questionnaire was amended by 10 items by Graham et al. and used to evaluate preferences 19 months after RYGB [12]. They found that 93% of patients reported a change in appetite; 73%, a change in taste; 42%, a change in smell; and 73%, developed food aversions. By using the same questionnaire, Zerrweck et al. found that appetite, taste, smell, and food aversions (especially for fatty and sweet foods) were reported by the majority of patients after BS, in equal proportions after RYGB and SG at 10 months postsurgery, with some changes already detectable during the first 2 months [13•].

At 6 months after RYGB, Molin Netto et al. reported a decrease in consumption frequency of unhealthy foods (from 15.4 to 5.1% for pizza and 18 to 0% for hamburger) and increased consumption of some healthy foods (from 0 to 5.1% for fish and from 0 to 25.6% for plain yogurt) [45•]. Nevertheless, there was a decrease in the frequency of fruit and vegetable consumption.

Schultes et al. used the Power of Food scale to measure the motivation to consume highly palatable foods [46]. In comparison with non-obese controls, patients with severe obesity displayed a marked increase in hedonic hunger that was not present in patients after RYGB, suggesting that the operation normalizes excessive food cravings. The few studies on patients after SG found comparable results to those after RYGB: hedonic ratings and enjoyment decreased for foods high in both fat and sugar content and patients reported lower calorie intake both through volume and through calorie density of food [11, 14, 47, 48•].

Although all the abovementioned studies show similar patterns regarding how BS affects food intake behavior, the informative value is limited for several reasons. First, there is significant variability across the studies in terms of when the postoperative measurements were conducted. Before and more so after surgery, patients receive intense nutritional counseling and a prescribed restricted diet which is low in fat and sugar usually for a period of 2 to 3 months. However, patients experience the largest weight loss exactly in this period, which is also associated with a subset of patients experiencing early postprandial intestinal discomfort (e.g., dumping syndrome, satiety, postprandial hypoglycemia) after consuming refined carbohydrates [17••]. One could hypothesize that when patients report the experience of occasional unpleasant physiological responses to food after surgery, it indicates a non-compliance with the restrictive postoperative nutritional recommendations [17••]. Animal studies suggest that food preferences and eating behavior could be quite dynamic following RYGB, thus patients may progressively adapt their eating behavior over time. Thus, human studies may have simply failed to detect the dynamic pattern of adaptation by performing their measurements in a brief and early postoperative time period.

Second, methodologies employed in these studies assessing food intake and preference consist mainly of food diaries, questionnaires, interviews, and dietary recall sometimes over a period of several months. Although such instruments are practical and inexpensive to use, these tools have a limited informative value as they measure eating behavior only indirectly and are reliant on verbal report and/or memory. Data from such methods can certainly provide initial insight regarding the consequences of the surgery and generate hypotheses, but without direct and objective validation, the results may be vulnerable to misguided interpretation and may thus lead to spurious conclusions [16].

Finally, other factors related to the surgery such as differences in surgical techniques or demographics such as gender, body mass index (BMI), and stage of menstrual cycle may contribute to conflicting results. In summary, changes in the relative macronutrient intake after RYGB in humans need further investigations to be conclusive.

Direct Measurements

So far, direct measurements of food intake focusing on altered food preference in humans after RYGB are rare.

Bueter et al. examined oral-sensory sucrose taste-detection thresholds of patients and controls before and after RYGB by asking subjects to taste, but not to swallow sucrose solutions with increasing concentrations [28•]. Taste-detection thresholds are valuable to assess the functional status of oral-sensory receptors and the sensitivity of neural circuits activated by gustatory stimuli [49]. In contrast to previous experiments, the authors used the method of constant stimuli in which taste stimuli are presented randomly and performance is assessed across a set of concentrations allowing for derivation of a psychometric function [28•]. Moreover, a game-like competitive setting with immediate feedback kept subjects vigilant and motivated: correct responses were compensated by tokens and incorrect responses were penalized by losing them. Using this novel approach, Bueter et al. confirmed that patients after RYGB detect lower sucrose concentrations compared both with their preoperative performance and with that of lean controls. A visual analogue scale that is designed to estimate the sucrose concentration that is “just about right” was also used [50]. Despite an increased sensitivity to detect sucrose at lower concentrations, there was no difference in hedonic ratings of sucrose solutions by patients after RYGB compared to the same patients prior to surgery. This suggests that changes in food preference observed after RYGB might not represent a fundamental shift in hedonic evaluation of food, but may instead be more related to other factors such as postingestive events and learning.

Other groups also investigated the effects of BS on taste detection. Holinski et al. found that impaired gustatory function is frequently associated to extreme obesity [51]. By using the taste grip tests, the authors found that 6 months after BS, the rate of gustatory function improved. Further, Pepino et al. used a comprehensive approach to analyze the impact of RYGB and gastric banding on taste sensitivity by using sensory-discriminative tests (threshold and above-threshold discrimination), preference tests, sweet palatability tests, and tongue biopsy [52]. Interestingly, taste-detection thresholds after surgery-induced weight loss were not different than those measured before surgery, however, the above-threshold perception of taste intensity increased progressively. Both procedures were associated with decreased cravings for fast food and sweets, decreased effect of eating sweets on mood, and decreased preference for high sucrose concentration.

El Labban et al. observed a decreased sweet acceptability after RYGB compared to SG by objective measurements (3 Alternative food choice test to measure recognition thresholds for salty, sour, sweet, and bitter and sweetness acceptability test to measure acceptability for different sucrose solutions) [53].

Other authors however obtained contradictory results by a procedure called stimulus drop testing: Scruggs et al. found increased sensitivity for the taste qualities bitter and sour and decreased sensitivity for the qualities salty and sweet at 60 days after RYGB [54]. In contrast, Burge et al. observed that 6 weeks postoperatively, all patients reported that foods tasted sweeter, which induced respective modifications in food selection, but the perception of other tastes remained unchanged [55]. Altun et al. assessed patients after SG by the taste strip test and found a statistically significant improvement in gustatory sensitivity 3 months postoperatively [56]. Sweet and salty perception improved the most, whereas sour and bitter perception improved but with a lower magnitude.

Miras et al. applied the progressive ratio task 2 weeks before and 8 weeks after RYGB (when patients were in a steep negative energy balance) to assess changes in the rewarding properties of food [38]. Patients and matched normal-weight controls were placed in front of a computer screen and a plate of 20 chocolate candies containing 4 kcal composed of 43% sugars and 44% fat. Participants could earn a candy by clicking with the mouse in a progressive ratio by geometric increments of 2. The postoperative reinforcing efficacy of the sweet and fat candy stimulus decreased by factor of 2, but remained unchanged in normal-weight control subjects. When the same test was done with vegetables, its reinforcing efficacy did not alter postoperatively.

Goldstone et al. demonstrated in a similar progressive ratio task that patients after RYGB were willing to “work” more for chocolate reinforcers when the postprandial release of gut hormones, such as GLP-1 and PYY, was suppressed by octreotide administration [57••]. Furthermore, functional magnetic resonance imaging of the brain showed that the patients’ hedonic responses to anticipatory food reward increased. These findings support the hypothesis that BS may decrease the hedonic reward value of food by altered gut hormone secretion.

A very recent study represents one of the first applications of a “cafeteria” diet design to assess food selection patterns before and after BS in humans [17••]. Here, the authors used an ad libitum buffet meal test coupled with a “pre-meal hunger” and an “experience of unpleasant postingestive response” questionnaire 3 months before and 6 months after BS in 31 patients after RYGB and 10 patients after SG. Patients received standard nutritional counseling and had to achieve 8% body weight loss prior to surgery. Before consuming the buffet meal, the patients’ energy intake was standardized by two artificial liquid meals comprising 2600 kJ. The buffet meal had 20 food items and the only liquid served was water. On average, patients after BS lost 11.7 BMI units in 6 months, but their pre-meal hunger remained unchanged. Their total energy intake at the buffet meal decreased with 54%, their eating speed decreased with 28%, and their eating time decreased by 31%; however, the energy density of the meal and food preferences did not change. Previous experiences of unpleasant postingestive responses were not associated with intake of high-fat or sweet foods. In a picture display test done on the same day, patients preferred food from the low-fat savory group postsurgery compared to pre-surgery more often, but did not change their selection from the high-fat high-sweet groups. The authors concluded that reduction in energy intake and the subsequent weight loss was caused simply by eating smaller portions of the same food items.

Clinical Relevance of Food Preference Changes To the best of our knowledge, the link between altered food preference and clinical outcome after BS has not been systematically assessed so far. Moreover, the duration of the observed changes in diet selection after BS remains unclear. Only few studies investigated the correlation between altered diet selection and weight loss and none of them assessed the correlation with metabolic outcomes.

Zerrweck et al. observed an 8% higher EWL for patients reporting food aversion by indirect measurement at 10 months after RYGB and LSG [13•]. Graham et al. also reported that patients after RYGB who developed food aversions achieved higher absolute postoperative weight loss and greater reduction in BMI [12]. Van Vuuren et al. found a weak association between changes in savory enjoyment and extent of %EWL at 6 months after LSG [11]. Gero et al. found a significant correlation between a low or decreased desire to consume salty snacks (food picture) and the extent of percent total weight loss achieved at 6 months after SG [14]. Even though the highest decreases in taste preferences after SG were observed for fatty and sweet, surprisingly, they did not correlate with weight loss. Patients maintained a constantly high preference for water and constantly low preference for red wine and cigarette over 6 months; however, they modified their preferences for fat and sweet in >75% of cases. Twenty-two percent of patients reported an increased postoperative preference for sweet, but only 5% reported it for fat.

Conclusions

Indirect and direct measurements of eating behavior in both humans and rodents suggest that food selection does indeed change after BS with a reduction in the preference for food high in sugar and fat. There is however a paucity of direct measurements in humans, especially when patients become weight stable over time. Based on the majority of available data, changes in diet selection after BS are likely to occur during the first postoperative months and persist for at least 2 years with variable intensity for different taste qualities.

The underlying behavioral and physiological mechanisms of the described phenomenon seem to be complex, which is reflected by the rather unstructured way of how it has been scientifically approached [58]. However, results from animal models of BS indicate that learning processes may play a role as changes in diet selection progress with time in rats after RYGB.

Further studies are certainly needed to assess whether changes in food preferences are sustained over time and whether an altered diet selection could be used as a surrogate marker for the extent and durability of weight loss and for treatment of comorbidities such as T2DM.

Compliance with Ethical Standards

Conflict of Interest Daniel Gero, Robert E Steinert, Carel W. le Roux, and Marco Bueter each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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