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Mini Review

Unpacking the Influences of Bariatric Surgery on Gut Microbiota: A Mini Review

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Abstract

Bariatric surgery is a highly effective treatment for obesity and related comorbidities. Recent evidence suggests that changes in gut microbiota composition and function may play a significant role in the metabolic and weight loss benefits of bariatric surgery. However, the mechanisms underlying the effects of gut microbiota changes following bariatric surgery remain unclear. This review summarizes recent research on the effects of gut microbiota changes following bariatric surgery, including both the beneficial and negative health outcomes. Beneficial effects include improved metabolic health, reduced inflammation, and increased satiety, while negative effects include nutrient deficiencies, infections, weight regain, and adverse metabolic effects. The review also discusses potential mechanisms underlying these effects, including changes in bile acid metabolism, gut hormone secretion, and immune function. A better understanding of the role of gut microbiota in the metabolic and weight loss benefits of bariatric surgery may lead to improved patient outcomes and the development of personalized treatments for obesity and related comorbidities.

Conclusion: While changes in gut microbiota following bariatric surgery can have both beneficial and negative effects on health outcomes, there is still much to learn about the underlying mechanisms that drive these changes. Further research is needed to better understand the role of gut microbiota in bariatric surgery outcomes and identify ways to optimize health outcomes in patients undergoing the procedure.

Keywords: Gut microbiota; bariatric surgery; obesity; metabolic health; inflammation; nutrient deficiencies; weight regain; microbial diversity

Introduction

The scientific term “micro-biome” refers to the set of genes of all microorganisms that inhabit almost all human body parts. The microbiome is thus considered as a second genome that has a symbiotic relationship with the host. This relationship may be positive or beneficial, negative or pathogenic, or neutral; hence, micro-biome interactions play a key role in human health [1].

Functions of the human microbiome

Metabolism and digestion:

The microbiome plays an essential role in the breakdown and absorption of nutrients, as well as the production of vitamins and other metabolites [2,3]. Immune system regulation: The microbiome helps regulate the immune system, both locally and systemically, by promoting the development of immune cells and helping to prevent the overgrowth of harmful bacteria, a dominant action of the healthy microbiota on the immune system is aimed at reinforcing barrier immunity and therefore their own containment. A central strategy utilized by the host to maintain its homeostatic relationship with the microbiota is to minimize contact between microorganisms and the epithelial cell surface thereby limiting tissue inflammation and microbial translocation [1]. Barrier function: The microbiome acts as a barrier against pathogens by occupying niches in the body and competing for resources with potentially harmful microorganisms.

Neurological function:

The microbiome has been linked to a range of neurological functions, including behavior, mood, and brain development [4,5]. Hormonal regulation: The microbiome can affect hormone levels and activity, particularly in the gut-brain axis [5].

Protection against infection

The microbiome can help protect against infections by producing antimicrobial compounds, competing for resources with harmful microorganisms, and supporting the development of the immune system [6].

Nutrient synthesis: The microbiome can synthesize essential nutrients, including vitamin K, folate, and biotin, that are not readily available in the diet [7].

Detoxification: The microbiome can detoxify harmful compounds, including drugs, carcinogens, and environmental toxins [7,8].

Oral health: The oral microbiome helps maintain oral health by preventing the growth of harmful bacteria, protecting against tooth decay and gum disease, and promoting tissue healing. Metabolic disorders: The microbiome has been implicated in the development of metabolic disorders, including obesity, diabetes, and metabolic syndrome.

Cardiovascular health: The microbiome can affect cardiovascular health by regulating blood pressure, cholesterol levels, and inflammation [9].

Sleep: Emerging evidence suggests that gut microbiota may also play a role in regulating sleep [10]. A recent study found that modulation of the gut microbiota through fecal microbiota transplantation improved sleep quality and reduced symptoms of insomnia in patients with chronic insomnia [10]. Recent research has suggested that gut microbes and their metabolites may play an important role in mediating the ameliorative effects of melatonin on cognitive impairment induced by sleep deprivation (SD).

Factors affecting microbiota

The gut microbiota is influenced by various factors, including diet, age, genetics, and environmental exposures. Recent research has highlighted the complex interplay between these factors and the gut microbiota. Diet is one of the primary factors influencing gut microbiota composition. Studies have shown that high-fat and high-sugar diets can lead to alterations in gut microbiota composition and function, which can contribute to metabolic disorders such as obesity and type 2 diabetes. On the other hand, diets rich in fiber and plant-based foods have been associated with a more diverse and beneficial gut microbiota [11]. Age is another important factor affecting gut microbiota composition. Studies have shown that the gut microbiota undergoes significant changes throughout the lifespan, with the greatest shifts occurring in early childhood and again in older adulthood [12,13]. These changes may contribute to age-related changes in immune function and metabolic health.

Genetics also play a role in determining gut microbiota composition. Studies have identified several host genes that are associated with specific microbial taxa and metabolic pathways. These findings suggest that host genetics may influence the gut microbiota and contribute to individual differences in health outcomes [14]. Environmental exposures, such as antibiotics, pollutants, and stress, can also affect gut microbiota composition and function [15]. Antibiotic use, in particular, has been shown to cause significant disruptions in gut microbiota composition, which can have long-lasting effects on host health. Exposure to pollutants such as air pollution and pesticides has also been associated with alterations in gut microbiota composition and increased risk of metabolic disorders [16]. Overall, these studies demonstrate the complex interplay between various factors and the gut microbiota. Further research is needed to fully understand the mechanisms underlying these interactions and their implications for human health.

Obesity

Obesity is a persistent medical condition impacting individuals of all age groups around the world. The World Health Organization (WHO) reports that roughly 35% of adults and 17% of children in the United States are currently dealing with obesity. On a global scale, there are approximately 650 million adults and 42 million children under the age of 5 who are struggling with obesity. Obesity is characterized by a body mass index (BMI) equal to or exceeding 30 kg/m^2, and it is further categorized into different classes based on severity [17]. Obesity exerts a psychosocial influence and leads to heightened medical and economic challenges. The accumulation of excess adipose tissue corresponds to elevated occurrence of accompanying health issues and medical complexities, include Type 2 diabetes mellitus, cardiovascular disease, cerebrovascular accidents, malignancies like colon, breast, and uterine cancers, osteoarthritis, obstructive sleep apnea, major depressive disorder, and liver diseases.

Relations of gut microbiota to obesity and other comorbidity

The gut microbiota, in particular, has been shown to play a crucial role in human health, such as a decrease in diversity or an increase in harmful bacteria with studies linking changes in its composition, can contribute to a variety of diseases and disorders, including obesity, inflammatory bowel disease, type 2 diabetes, and even mental health conditions such as depression and anxiety. Recent research has highlighted the role of the gut microbiota in obesity and related comorbidities [18]. Research has shown that there is a relationship between the gut microbiota and obesity. Studies have found that individuals who are obese have a different composition of gut microbiota compared to those who are lean. Gut microbiota alterations affect the energy balance of the host organism; namely, as a factor affecting energy production from the diet and as a factor affecting host genes regulating energy expenditure and storage. Specifically, obese individuals tend to have a lower diversity of gut microbiota and a higher proportion of Firmicutes bacteria compared to Bacteroidetes bacteria. This ratio of Firmicutes to Bacteroidetes has been shown to be associated with increased calorie harvest from the diet, increased fat storage, and a higher risk of obesity. In addition, the gut microbiota has

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been shown to influence appetite and food cravings [19,20]. Some studies have suggested that certain species of gut bacteria may be able to extract more energy from food mainly from short-chain fatty acids (SCFAs), together with an increase in low-grade inflammation and altered bile acid metabolism [21] and thus make individuals feel less full after eating, leading to overeating and weight gain [22-24]. However, it is important to note that the relationship between the gut microbiota and obesity is complex and not fully understood. More research is needed to fully elucidate the mechanisms by which the gut microbiota influences obesity and to identify potential therapeutic targets for treating obesity through modulating the gut microbiota.

Bariatric surgery and relation to gut microbiome

Bariatric surgery, a treatment for obesity, has been shown to alter the gut microbiota composition, leading to changes in the diversity and abundance of different bacterial species. Bariatric surgery also induces important changes in the composition of the gut microbiota of patients undergoing these procedures. The main changes reported after surgical intervention include increases in Proteobacteria (E. coli, Enterobacter spp.), decreases in Clostridium and changes in Bacteroides and Prevotella. These changes have been linked to the metabolic improvements seen after bariatric surgery, such as improved glucose metabolism and insulin sensitivity, suggesting that the gut microbiota may play a crucial role in the success of bariatric surgery. Studies have demonstrated that bariatric surgery results in an increase in the abundance of beneficial bacteria, such as Akkermansia muciniphila, and a decrease in the abundance of harmful bacteria, such as Firmicutes [25]. These changes in the gut microbiota have been linked to the metabolic improvements seen after bariatric surgery, such as improved glucose metabolism and insulin sensitivity [26]. It has been reported that these taxonomical and functional changes in the microbiota are stable nine years after Roux-En-Y Gastric Bypass (RYGB) intervention [27]. This suggested that the gut microbiota is an active player in weight loss in obesity surgery, and that weight loss is a transmissible trait of the microbiota post-surgery [28].

There are several types of bariatric surgery procedures, but the most commonly performed ones include:

a) Sleeve Gastrectomy: In this procedure, a large portion of the stomach is removed, leaving a small, banana-shaped sleeve. The reduced stomach size restricts the amount of food that can be consumed, leading to early satiety and reduced caloric intake.

b) Roux-En-Y Gastric Bypass: This procedure involves creating a small pouch at the top of the stomach and connecting it directly to the small intestine, bypassing a large portion of the stomach and the upper part of the small intestine. This restricts food intake and reduces nutrient absorption. One-anastomosis gastric bypass is an attractive option in the armament of a Bariatric surgeon. A relatively simple procedure, it has been effective in inducing weight loss and resolution of obesity-associated comorbidities. Easy technique, shorter operative times, and low complication rates make it an attractive alternative option, particularly in super-obese individuals.

c) Biliopancreatic Diversion with Duodenal Switch (BPD/DS): This procedure involves a partial gastrectomy to create a smaller stomach pouch and a more extensive bypass of the small intestine, resulting in reduced food intake and limited nutrient absorption.

Mechanisms of action

In the context of microbiota and bariatric surgery aim to uncover and understand the underlying biological processes by which bariatric surgery affects the gut microbiota and, subsequently, how these changes impact various health outcomes. The specific mechanisms underlying microbiota modifications provided by Bariatric surgery (BS) have not yet been elucidated. Here are some key areas of interest in mechanisms of action studies related to microbiota and bariatric surgery:

a. pH and high levels of dissolved oxygen: Proteobacteria proliferates following BS due to increased luminal pH and high levels of dissolved oxygen that enables the growth of facultative aerobic microorganisms and inhibits anaerobic populations [29].

b. Dietary Changes: Diet is a critical factor that interacts with the gut microbiota [30]. Mechanisms of action studies often assess how post-operative dietary modifications interact with the altered microbiota and contribute to health outcomes. Caloric restriction (with an average decrease of 1800 kilocalories/day compared to prior surgery intake), alters bacterial community structure in a matter of days to weeks. Due to transient intolerance of protein-rich foods, in the first year following BS the actual protein intake is 0.5 g/kg/day and does not meet the recommended daily allowances for bariatric patients of 1.5 g/kg/day. Fat and carbohydrate intake are also diminished during the first year postoperatively. Lower glycemic index carbohydrates are often preferred to high glycemic index carbohydrates [31].

c. Gut Hormone Regulation: there are major metabolic and hormonal changes occurring concomitantly in the early postoperative state, researchers explore how bariatric surgery influences the secretion and function of gut hormones such as ghrelin, leptin, and GLP-1. These hormones play crucial roles in appetite control, energy metabolism, and weight regulation [32].

d. Bile Acid Metabolism: It appears that bile acid alteration is an important component of bariatric surgery, and represents a promising target for the management of metabolic disorders. Bile acids play a role in metabolic regulation as signaling molecules other than digestive juice, most of the metabolism-beneficial effects are mediated through nuclear receptor and membrane receptor, as well as reciprocal influence on gut microbiota. In the last years, gut microbiota has emerged as one of the drivers through its metabolites, especially secondary bile acids. Secondary bile acids could have a role in the amelioration of the glucose and HDL-cholesterol levels. Possible relationship between the interaction of the bile acids pool metabolized by the gut microbiota in the metabolic improvements obtained by bariatric surgery in the frame of morbid obesity. Blautia and Veillonella were the two genera that showed more relationships with secondary bile acids, indicating a possible role in their formation and inhibition.

e. Intestinal Barrier Function: The integrity of the intestinal barrier is essential for maintaining gut health. One of the important phenomena associated with bariatric surgery is the concept of "leaky gut." Leaky gut refers to increased permeability of the intestinal barrier, which can lead to the translocation of bacterial products such as endotoxins from the gut lumen into the bloodstream. This translocation of endotoxins is known to trigger low-grade inflammation and has been associated with the development of insulin resistance and metabolic syndrome. Bariatric surgery, by physically altering the gastrointestinal tract, appears to have beneficial effects on the integrity of the gut barrier. Studies have demonstrated that these surgeries can lead to changes in the molecular building blocks of the gut barrier, which subsequently reduce the permeability of the gut and decrease the translocation of endotoxins. This, in turn, contributes to a reduction in the low-grade inflammation and insulin resistance associated with metabolic syndrome [33].

f. Inflammation: Chronic low-grade inflammation is a hallmark of obesity. Researchers investigate how bariatric surgery-induced changes in the gut microbiota may modulate inflammatory responses in the body. Dysbiosis with an impaired intestinal barrier leads to accelerated contact of microbiota with the host's immune cells [34].

g. Short-Chain Fatty Acids (SCFAs): SCFAs are microbial metabolites with important roles in gut health and metabolism. Research examines how bariatric surgery affects SCFA production and its consequences for host health, the total amount of SCFA was reduced, the total and relative amounts of the main straight SCFA (acetic-, propionic-, and butyric- acids) were reduced, and the total and relative amounts of branched SCFA (isobutyric-, isovaleric-, and isocaproic- acids) were increased. The changes indicate a shift toward a proteolytic fermentation pattern with unfavorable health effects [35,36].

h. Host Genetics: The interplay between host genetics and the gut microbiota is an area of interest. Researchers examine how genetic factors may interact with surgery-induced microbiota changes to influence health outcomes. Studies carried out in the last ten years have shown that the metabolites made up from the gut microbiota are essential for multiple functions, such as the correct development of the immune system of newborns, interception of pathogens, and nutritional enrichment of the diet [37]. Candidate human genes encoding enzymes, inflammatory cytokines, and proteins show similarity with those included in the gut microbiome.

It's important to note that the effects of bariatric surgery on the gut microbiota can vary depending on the specific procedure performed, as well as individual factors such as diet and lifestyle. Nonetheless, the growing body of research suggests that the gut microbiota may play an important role in the metabolic improvements seen after bariatric surgery, and may be a target for future therapies to treat obesity and metabolic diseases.

Bad outcome of Bariatric Surgery on microbiota

While bariatric surgery has many potential benefits, there are also some potential negative outcomes that have been associated with the procedure. Here are a few examples of how bariatric surgery can negatively affect the gut microbiota:

a) Malabsorption of nutrients: Some types of bariatric surgery can lead to malabsorption of nutrients, which can affect both the gut microbiota and overall health. For example, some studies have suggested that malabsorption of dietary fats after bariatric surgery can lead to an overgrowth of bacteria that feed on these fats, potentially contributing to inflammation and other negative health outcomes [38].

Increased risk of inflammatory bowel disease: Bariatric surgery has been associated with an increased risk of inflammatory bowel disease (IBD), a chronic condition characterized by inflammation of the gut. While the exact mechanisms underlying this association are not well understood, some studies have suggested that changes in the gut microbiota may play a role [39].

b) Increased risk of nutrient deficiencies: Some types of bariatric surgery, such as Roux-en-Y gastric bypass, can increase the risk of nutrient deficiencies due to malabsorption. This can in turn affect the gut microbiota, which depends on a steady supply of nutrients from the host for optimal function. For example, some studies have suggested that nutrient deficiencies after bariatric surgery can lead to alterations in the gut microbiota that contribute to inflammation and other negative health outcomes [38]

It's worth noting that the negative outcomes of bariatric surgery on the gut microbiota are not well understood and may depend on a range of factors, including the specific surgical procedure, the patient's individual microbiome, and other lifestyle factors. Nevertheless, these potential negative outcomes highlight the importance of careful monitoring and management of the gut microbiota in patients undergoing bariatric surgery.

Summery

The gut microbiota has been linked to various aspects of human health, including metabolism, immunity, and mental health. Changes in gut microbiota composition and function following bariatric surgery have been associated with both beneficial and negative health outcomes. Beneficial effects include improved metabolic health, reduced inflammation, and increased satiety, while negative effects include nutrient deficiencies, infections, weight regain, and adverse metabolic effects. It is important to monitor and manage changes in gut microbiota composition in patients undergoing bariatric surgery to maximize the beneficial effects and minimize the negative effects. More research is needed to fully understand the mechanisms underlying these effects.

Author Declaration

All authors declare that they have no conflicts of interest. No funding was used in this study.

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The datasets generated during and/or analyzed during the current study are available in the [PUBMED] repository, [https://pubmed.ncbi.nlm.nih.gov].

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