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Metabolic Surgery: Concepts and New Classification

Paulo Reis Rizzo Esselin de Melo[1,2], Victor Ramos Mussa Dib[3], Carlos Augusto Scussel Madalosso[4], Chetan Parmar[5], Omar Ghanem[6], Miguel Ángel Carbajo[7], Ricardo Zorron[8], Amador García Ruiz de Gordejuela[9], Caio Gustavo Gaspar de Aquino[10], Luiz Alfredo Vieira d'Almeida[11], Luciano Antozzi[12], Rui Ribeiro[13], Halit Eren Taskin[14], Jorge Bravo López[15], Christine Stier[16], Patrick Noel[17], José Sergio Verboonen Sotelo[18], Laurent Abram Layani[19], Ramon Vilallonga Puy[20], Elinton Adami Chaim[21], Helmuth Billy[22], Carlos Eduardo Domene[23], Paula Volpe[23], Nilton Tokio Kawahara[24], Augusto Cláudio de Almeida Tinoco[25], Antelmo Sasso Fin[26], Hiroji Okano Júnior[27], Nicholas Tavares Kruel[28], Giorgio Alfredo Pedroso Baretta[29], Diogo Swain Kfouri[30], Anna Carolina Hoff[31], Fernando Reis Esselin Melo[1,32], Thonya Cruz Braga[1,33], Clayton Alencar Moreira[34], Luis Poggi[35], Almino Cardoso Ramos[36], Antonio Torres[37]

[1]Paulo Reis Institute, Goiânia, Brazil
[2]Alfredo Nasser University Center (UNIFAN), Goiânia, Brazil
[3]Victor Dib Institute, Manaus, Brazil
[4]Gastrobese Clinic, Passo Fundo, Brazil
[5]Department of Surgery, Whittington Hospital, London, UK
[6]Department of Surgery, Mayo Clinic, Rochester, USA
[7]Center of Excellence for the Study and Treatment of Obesity and Diabetes, Valladolid, Spain
[8]Department of Bariatric and Metabolic Surgery, CUF Descobertas Hospital, Lisbon, Portugal
[9]Esophagogastric and Bariatric Surgery Unit, Donostia University Hospital, Basque Country University, Donostia-San Sebastian, Spain
[10]Einstein Surgery Program, Hospital Israelita Albert Einstein, São Paulo, Brazil
[11]Department of Bariatric and Metabolic Surgery, Pro-Cardiac Hospital, Rio de Janeiro, Brazil
[12]Department of Surgery Service, Southern Region Italian Hospital, Buenos Aires, Argentina
[13]Lusíadas Amadora Hospital, Lisboa, Portugal
[14]Cerrahpasa Medical Faculty, Department of General Surgery, Istanbul University Cerrahpasa, Istanbul, Türkiye
[15]Asis Surgery U de Chile, Universidad de Chile, Santiago, Chile
[16]Obesity Center NRW, Sana Hospitals Germany, Huerth, Germany
[17]Private Hospital Bouchard, Elsan, Marseille, France
[18]Obesity Goodbye Center, Tijuana, Baja California, Mexico
[19]HOD Surgical Bariatric Department, Al Sharq Hospital, Fujairah, UAE
[20]Endocrine-Metabolic and Bariatric Surgery Unit, Vall Hebron Barcelona Hospital Campus, Barcelona, Spain
[21]Department of Surgery, Faculty of Medical Sciences, State University of Campinas, Campinas, Brazil
[22]Ventura Advanced Surgical Associates, Ventura, USA
[23]Integrated Center for Advanced Medicine (CIMAMED), São Paulo, Brazil
[24]Hospital das Clínicas, University of São Paulo Medical School, São Paulo, Brazil
[25]Department of General Surgery, Hospital São José do Avaí, Itaperuna, Brazil
[26]Meridional Cariacica Hospital, Cariacica, Brazil
[27]Gastrocare Clinic, Brasília, Brazil
[28]Dr. Nicholas Kruel Institute (Nkbariatrics), Florianópolis, Brazil
[29]Giorgio Baretta Institute, Curitiba, Brazil

[30]Paraná Obesity Treatment Center (OBEPAR), Curitiba, Brazil
[31]Angioskope International Interventional Endoscopy Training Center, São Paulo, Brazil
[32]IOM-Intraoperative Medical Services, Brasília, Brazil
[33]Clianest Group, Renaissance Hospital, Goiânia, Brazil
[34]Experimental Surgery Laboratory, Universidade do Estado do Pará, Belém, Brazil
[35]Department of Surgery, Gastrointestinal and Bariatric Surgery, Clinica Anglo Americana, Lima, Perú
[36]Gastro Obeso Center, São Paulo, Brazil
[37]Department of Surgery, Hospital Clinico San Carlos, Universidad Complutense de Madrid, Madrid, Spain

Email: prcirurgia@icloud.com, victormussadib@gmail.com, gbbariatrica@gmail.com, cparmar@nhs.net, ghanem.omar@mayo.edu, doctorcarbajo@obesos.info, rzorron@gmail.com, gordeju@gmail.com, caioaquino@hotmail.com, ladalmeidaster@gmail.com, lantozzi@gmail.com, ruijsribeiro@gmail.com, eren_taskin@hotmail.com, drjorgebravolo@gmail.com, christine.stier@sana.de, casanoel@gmail.com, sverboonen@gmail.com, sur1.shf@fng.ae, ramon.vilallonga@vallhebron.cat, chaim@hc.unicamp.br, htbilly@gmail.com, cedomene@terra.com.br, pvolpe@uol.com.br, niltonkawahara@gmail.com, augtinoco@gmail.com, antelmosasso@yahoo.com, hirojimed@gmail.com, nicholaskruel@hotmail.com, giorgio.baretta@gmail.com, diogokfouri@yahoo.com, nathoff@yahoo.com, iom.neurodf@gmail.com, thonyabraga@icloud.com, cammedbel@uol.com.br, poggiluis@gmail.com, ramos.almino@gmail.com, ajtorresgarcia@gmail.com

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Abstract

Bariatric and metabolic surgeries have gained extensive popularity and trust due to their documented efficacy and safety in managing not only obesity but also associated comorbidities such as diabetes mellitus, hypertension, dyslipidemia, sleep apnea, and joint pain. Traditionally, bariatric surgeries have been categorized into hypoabsorptive, restrictive, or hybrid approaches. However, these classifications inadequately reflect the complex anatomical and physiological alterations associated with modern surgical methodologies. This paper explores the evolution of metabolic surgeries, emphasizing the integration of physiological concepts into classic procedures to provide more tailored and effective treatment options for obesity and its comorbidities. Finally, the proposal for a new classification based on current metabolic concepts will facilitate communication among patients, doctors, and healthcare professionals. Additionally, it will enable a more didactic and standardized approach to data collection for conducting studies and publications.

Keywords

Metabolic Surgery, Bariatric Surgery, Obesity, Physiological Concepts, Gastrointestinal Procedures, Transit Bipartition, Long Common Channel, Metabolically Functional Stomach, Wide Anastomosis, Duodenal Transit Bipartition, Duodenal Bipartition, Hybrid Duodenal Transit Bipartition, Isolated Duodenal Bipartition, SADIS, OAGB, BAGUA, Classification of Bariatric Surgeries, Classification of Metabolic Surgeries, New Classification of Bariatric and Metabolic Surgery

1. Introduction

Bariatric and metabolic surgeries have gained widespread popularity and trust due to their documented efficacy and safety in managing not only obesity but also associated comorbidities such as diabetes mellitus, hypertension, dyslipidemia, metabolic associated steatosis, sleep apnea and others.

Traditionally, bariatric surgeries (BS) have been categorized into three distinct types: hypoabsorptive, restrictive, or hybrid approaches [1] [2]. However, these conventional classifications do not adequately reflect the complex anatomical and physiological changes associated with modern surgical methodologies [1]. Recent advances in physiological knowledge enable the development of bariatric procedures targeting neuroendocrine changes rather than focusing solely on restriction, malabsorption, and/or exclusions [3] [4]. The classic bariatric procedures currently in use were conceived before updated knowledge was available. Consequently, these procedures rely on mechanical restrictions, intestinal malabsorption, or a combination of both, which are clearly nonphysiological. The ideal metabolic procedure should avoid these elements, as well as the use of foreign bodies and gastrointestinal exclusions. The preservation of gastrointestinal functions should be sought, as much as possible, in metabolic surgery, in addition to maintaining gastrointestinal endoscopic access for proper evaluation and nutritional support, if necessary [3]-[5].

Proposing an ideal metabolic procedure that meets all the previously mentioned characteristics may not be entirely feasible and also depends on the patient's features. However, it is possible to technically apply some of the new physiological concepts to offer the patient the best possible operation. Over the years, surgeons from various parts of the world have dedicated themselves to this goal by proposing physiological adaptations in classic bariatric procedures. The physiological understanding and metabolic concepts applied in both classic bariatric surgeries and new procedures have given rise to the conceptualization of metabolic surgeries [3]-[6].

The objective here is to propose a new classification of metabolic/bariatric operations, emphasizing the relationship between surgical anatomy and its influence on metabolic changes and improvements. Furthermore, this proposal aims to facilitate the understanding of surgical rationale, integrate and standardize procedures in a logical manner, and create surgical algorithms based on patient profiles to facilitate the choice of operation.

In the following sections, we will discuss the concepts and classification of metabolic surgeries.

2. Metabolic Concepts

Key physiological concepts integrated into classic bariatric procedures include gastrointestinal bipartitions, the creation of long common channels, the preservation of metabolically functional stomachs, the creation of wide anastomoses, and long bilopancreatic limbs. Although duodenal partial or total exclusions are anatomically undesirable, they can enhance metabolic outcomes.

2.1. Transit Bipartition (TB)

The concept of transit bipartition has been established for over 20 years. In its initial publication, transit bipartition was defined as: "TB creates a gastroileal anastomosis in the antrum, after a sleeve gastrectomy (SG); food partially passes through the duodenum, avoiding blind loops, minimizing malabsorption. The stomach keeps two outputs" [6].

Thus, TB is a physiological and metabolic strategy adapted to classic bariatric procedures to enhance incretin stimulation without requiring gastrointestinal exclusions.

TB preserves nutrient absorption across all intestinal segments-including the duodenum, jejunum, and ileum-and maintains gastroduodenal endoscopic access. The concept of TB can be applied in both, the gastric antrum and the duodenum [2] [4]-[6].

TB can be subdivided in terms of its anatomical position, intestinal component, and transit reconstruction. According to its anatomical position, the concept of bipartition can shift to a unidirectional, preferential food flow, as described below:

- Anatomical position
  - Pre-pyloric: Located in the proximal antrum
  - Juxta-pre pyloric: very near to the pylorus, favoring pyloric functional exclusion
  - Post-pyloric: Located in the duodenum.
- Intestinal component
  - Ileal component: Also known as "ileal surgeries."
  - Jejunal component: Primarily in the distal jejunum.
- Transit reconstruction
  - Roux-en-Y (RYGB)
  - One anastomosis (Single anastomosis)

2.2. Long Common Channel (CC)

Bile is present in the common channel. Both bile and digested nutrients serve as crucial stimuli for key intestinal hormones, such as glucagon-like peptide 1 (GLP-1) and fibroblast growth factor 19 (FGF-19). It is possible that, as an endocrine organ, the "Holoileum" (defined as the "ileum with all its elements"—bile and digested nutrients) functions optimally. We refer to this as the "Holoileum Hypothesis". If this hypothesis holds true, extending the common channel (CC) may reduce malabsorption and, additionally, enhance the hormone-producing efficiency of the ileum [4]-[7]. However, irrespective of the Holoileum Hypothesis, a larger common channel, accommodating all digestive secretions and nutrients, is more physiological and facilitates improved nutritional absorption.

2.3. Metabolically Functional Stomachs

Metabolically functional stomachs are created through the formation of long gastric pouches through vertical gastrectomies [3]-[5] [8]-[11]. These surgically designed stomachs aim to optimize the metabolic and hormonal functions of the gastrointestinal tract. Consequently, alterations in stomach structure, along with hormonal regulation, effectively control appetite and food intake, thereby facilitating weight loss and metabolic regulation.

2.4. Wide Anastomoses

The purpose of wide anastomoses is to ensure functional restriction, mediated by the intestinal incretin response. This response is initially stimulated by gastric emptying, without the mechanical restriction caused by rings or narrow anastomoses [3]-[6] [8]-[10] [12].

Based on the modern metabolic concepts discussed above, we propose a new classification for metabolic procedures aimed at adequately stratifying surgeries according to their anatomical and functional structures, as described below.

2.5. Intestinal Exclusion

Scientific evidence demonstrates the metabolic control achieved through various interventions on the gastrointestinal system. This control is attributed to the enhanced stimulation of intestinal hormones following metabolic surgery. The intestinal hormones (incretins) most significantly connected to the metabolic benefits of these surgeries are: GLP-1, GIP, PYY, oxyntomodulin, and FGF-19, although numerous other hormones are involved. In addition to their effects on appetite control in the hypothalamus and improvement of the metabolic profile, these hormones act on β-cells, promoting insulin secretion and reducing its peripheral resistance. Two hypotheses have been formulated to explain the changes in these hormones due to the operations: the proximal intestine hypothesis, which suggests that duodenal and proximal jejunal exclusion would prevent the secretion stimulus of an (as yet unidentified) anti-incretin factor that would increase peripheral insulin resistance and worsen the metabolic profile; and the distal intestine hypothesis, where intestinal bypass would facilitate the rapid passage of chyme to the distal intestine, inducing the early secretion of incretin hormones, and resulting in metabolic benefits for patients with obesity and related conditions, such as those with obesity and type 2 diabetes [13] [14].

2.6. Long Biliopancreatic Limb

Evidence indicates that the release of entero-hormones in response to a nutrient load in the distal small intestine plays a crucial role in the remission of metabolic diseases. Consequently, the increased length of the biliopancreatic limb may be significant in this process [15]. Another important metabolic benefit of longer biliopancreatic limbs concerns the absorption of bile acids that occurs along the intestinal segments excluded from food transit, which stimulates the release of incretins and FGF-19. These concepts have prompted a global trend towards elongating BPLs in RYGB to achieve better metabolic and weight loss outcomes [16].

3. Classification of Metabolic Surgery

3.1. Metabolic Surgeries with Gastrointestinal Exclusion (GIE)

These procedures incorporate physiological and metabolic concepts and are represented by the Classic Gastric Bypass (RYGB) (**Figure 1**) and its adaptations, such as the Long Pouch Gastric Bypass (LPGB) and the One Anastomosis Gastric Bypass (BAGUA/OAGB) (**Figure 2** and **Figure 3**) [8]-[11] [17]-[24]

The metabolic concepts applied in LPGB and BAGUA/OAGB are:

- Long gastric pouch
- Wide anastomosis
- Absence of mechanical restrictive component
- Longer biliopancreatic limb (BPL), optimizing incretin stimuli. Here it's worth it saying: OAGB utilizes fixed BPL lengths (180 - 200 cm) while BAGUA, proportions related to the total limb length (BPL varying from 40% to 60% of the total).

Specific Details

The RYGB is a globally renowned metabolic procedure, celebrated for its safety and effectiveness in controlling obesity and its related comorbidities. In recent years, it has integrated modern metabolic concepts, further optimizing its outcomes. For instance, it has moved away from using mechanical restriction methods such as rings or calibrated anastomoses, instead enhancing incretin stimulation through longer biliopancreatic limbs [23] [24].

In the LPGB procedure, gastrointestinal transit reconstruction is performed using a Roux-en-Y configuration, implementing a much longer tubular gastric pouch, aiming to preserving gastric digestion functions. In BAGUA/OAGB, reconstruction is achieved through a single gastrointestinal anastomosis, where alimentary limb doesn't exist, increasing common channel length, which carries metabolic benefits.

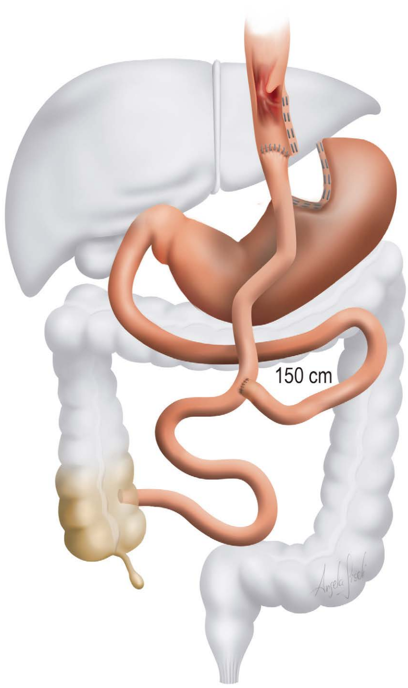

Figure 1. Classic Gastric Bypass (RYGB).

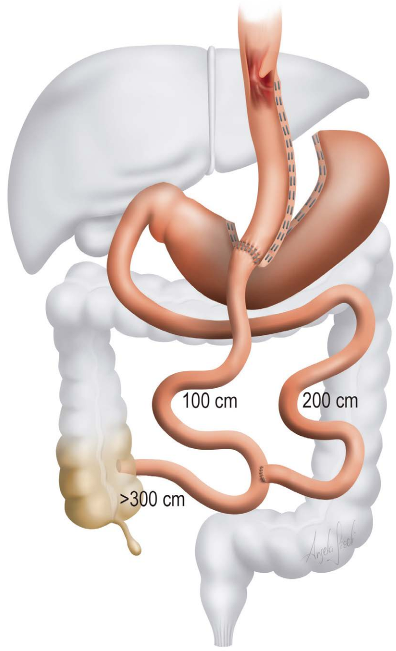

Figure 2. Long Pouch Gastric Bypass (LPGB).

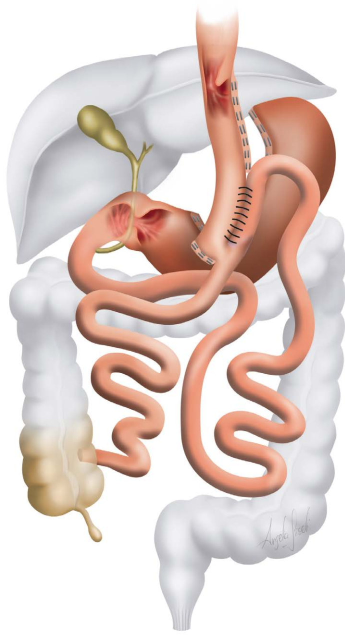

Figure 3. One Anastomosis Gastric Bypass (BAGUA/OAGB).

These procedures should be considered as options for populations at high risk of gastric cancer; however, the resection of the excluded stomach during the procedure must be taken into consideration.

3.2. Metabolic Surgery with Intestinal Exclusion (IE)

Metabolic surgery with intestinal exclusion is represented by the Classical Duodenal Switch (DS) (**Figure 4**) and its adaptations. These variations incorporate physiological and metabolic concepts into the traditional DS, and these are further exemplified by the SADIS (Single Anastomosis Duodeno-Ileal Bypass with Sleeve Gastrectomy) and Ileal Interposition in the Duodenum (IID) (**Figure 5** and **Figure 6**).

The metabolic concepts applied in SADI-S and IID are:

- Metabolically functional stomach-SG
- Long common channel
- Post-pyloric anastomosis (Metabolic switch)
- Absence of mechanical restrictive component

Specific Details

Despite incorporating a hypoabsorptive intestinal component (with a short common channel), the Classical Duodenal Switch was the first procedure to include a metabolically functional stomach, represented by the sleeve gastrectomy. Moreover, it is a well-established procedure for the surgical treatment of obesity and its comorbidities [25] [26].

In SADI-S, unlike the classic DS, the reconstruction of intestinal transit is performed by a single duodenoilelostomy, typically 250 to 300 cm from the ileocecal valve, increasing the common channel, which considerably improves the absorptive component and metabolic ileal stimuli of this procedure. It is notable for its effective results in weight loss and metabolic control. This procedure can also be performed with more proximal intestinal segment (in the jejunal portion), as described by some authors [27]-[34].

In the IID procedure, a 170 cm of distal ileum is interposed between the first portion of the duodenum and the jejunum, approximately 30 to 40 cm distal to the Treitz angle. This strategy significantly increases incretin stimuli and reduces exclusions, optimizing nutrient absorption and metabolic improvement [34]-[38].

These procedures should be considered as options for populations at high risk of gastric cancer with severe metabolic disease and/or advanced obesity.

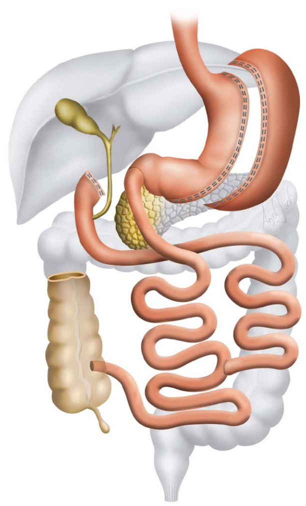

Figure 4. Classical Duodenal Switch (DS).

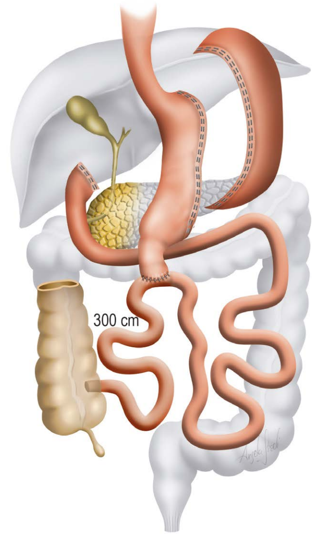

Figure 5. Single Anastomosis Duodeno-Ileal Bypass with Sleeve Gastrectomy (SADI-S).

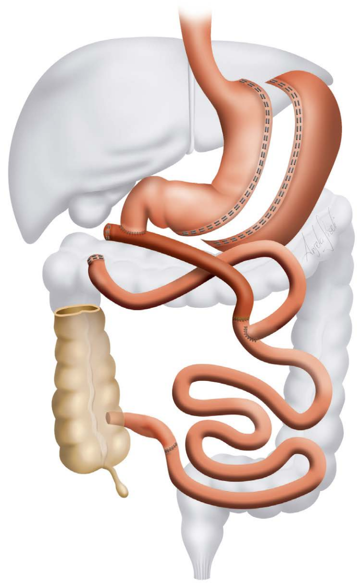

Figure 6. Ileal Interposition in the Duodenum (IID).

3.3. Metabolic Surgery without Gastrointestinal Exclusion (WGIE)

Metabolic surgeries without gastrointestinal exclusion are adaptations of the classic DS (**Table 1**). These techniques include Intestinal Transit Bipartition (ITB), Duodenal Transit Bipartition (DTB), Ileal Interposition in the Jejunum (JII), One Anastomosis Transit Bipartition/Single Anastomosis Stomach Ileal bypass (OATB/SASI), and Pylorus-Preserving Roux-en-Y Gastric Bypass (PP-RYGB). These procedures are designed to optimize metabolic control without the need for intestinal exclusion, thereby preserving the continuity of the gastrointestinal tract (**Figures 7-11**).

The metabolic concepts applied in ITB, DTB, and JII are:

- Metabolically functional stomach—SG
- Long common channel—"Holoileum"
- No gastrointestinal exclusion
- Wide anastomosis
- Absence of mechanical restrictive component

Specific Details

ITB represents the original model of bipartition surgeries. Its metabolic structure is characterized by several components: performance of a SG, a pre-pyloric anastomosis in the antrum greater curvature and reconstruction of intestinal transit in a Roux-en-Y fashion. This is accomplished with an antrum-ileal anastomosis, approximately 300 cm from the ileocecal valve, with a common channel measuring 240 to 260 cm. Over the years, variants of ITB have emerged, such as the OATB/SASI, which differs from ITB by it's one anastomosis fashion, adopting the same ileal measurements and anastomosis position, although, some authors adopted proximal intestine (jejunum) for nutritional safety [2] [3] [6] [7] [39]-[46].

DTB is a simplified duodenal switch, like SADI-S, but without intestinal exclusion. DTB implements the metabolic concept of transit bipartition within the duodenum. Its metabolic structure consists of an intact SG and a post-pyloric anastomosis, which can be either duodeno-ileal, approximately 250 to 300 cm from the ileocecal valve, or duodeno-jejunal, about 200 cm from the Treitz angle. Preferably, the reconstruction of intestinal transit is performed through a single anastomosis, although the Roux-en-Y configuration may be utilized in specific situations. Recently, a hybrid form of DTB was introduced, a concept that will be explored further. The duodenal anastomosis can be performed manually or with staplers; currently, the magnetic technique has gained significant prominence [4] [5] [47]-[51].

JII is not considered a transit bipartition but is classified as a metabolic surgery with no exclusions. Its metabolic structure is defined by an intact SG. The ileal segment is resected approximately 40 to 50 cm from the ileocecal valve and interposed into the jejunum, about 20 to 30 cm from the Treitz angle, without incorporating hypoabsorptive components. This configuration is designed to optimize metabolism without compromising nutrient absorption [34] [36] [37] [52].

Table 1. Metabolic surgery without exclusions.

Metabolic Surgery Without Exclusions
• Metabolically functional stomach
• No gastrointestinal exclusion
• Wide anastomosis
• Ileal or distal jejunal approximation for early incretin stimulation

The Pylorus-Preserving RYGB incorporates the anatomical concept of Transit Bipartition, but in a different gastric position (anterior wall of the juxta-pre-pyloric antrum), promoting a very preferential flow to the gastrointestinal anastomosis while anatomically preserving pylorus accessibility, but functionally excluding it. Therefore, this technique can only be accomplished using the jejunum and is not intended to bifurcate the food flow but to replicate RYGB results without anatomical exclusions. This technique involves a SG beginning 3 cm proximal to the pylorus. A large antrum-jejunal anastomosis is created on the anterior gastric wall, in close proximity to the pylorus, utilizing a Roux-en-Y configuration. The biliopancreatic limb, measured from the Treitz angle, constitutes 35% of the total intestinal limb length, while the alimentary limb measures 60 cm. All mesenteric spaces are carefully closed [53] [54].

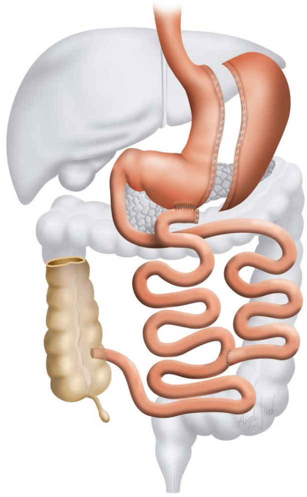

Figure 7. Intestinal Transit Bipartition (ITB).

These procedures should be considered as options for populations at high risk of gastric cancer.

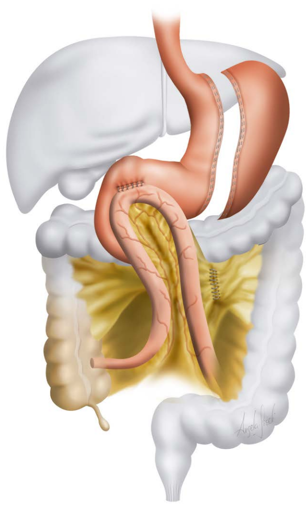

Figure 8. Duodenal Transit Bipartition (DTB).

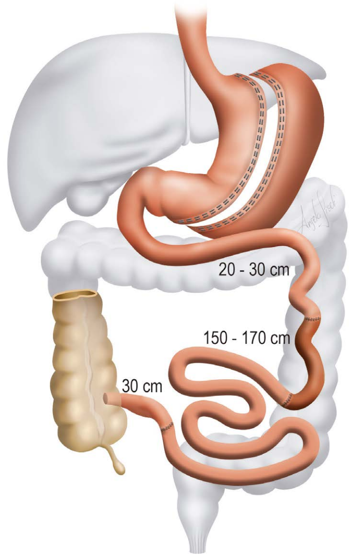

Figure 9. Ileal Interposition in the Jejunum (JII).

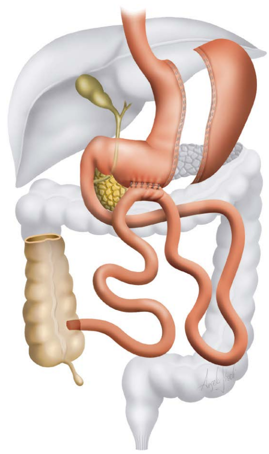

Figure 10. One Anastomosis Transit Bipartition (OATB/SASI).

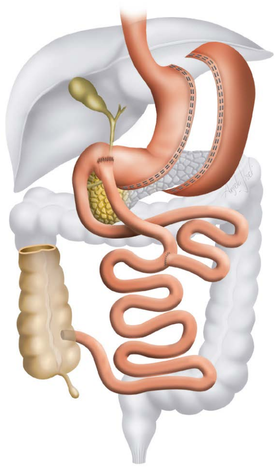

Figure 11. Pylorus-Preserving Roux-en-Y Gastric Bypass (PP-RYGB).

3.4. Metabolic Surgery with Isolated Gastric or Intestinal Component (IGIC)

The metabolic procedure with an isolated gastric component is represented by the SG, while the metabolic procedure with an isolated intestinal component is represented by isolated Transit Bipartitions (isolated ITB and DTB), without SG (**Figures 12-14**).

The SG is the most frequently performed metabolic procedure worldwide, recognized for its safety and efficacy in treating obesity and its comorbidities. It is preferably indicated as a primary surgery intervention [55]. However, it can also be indicated in specific special/adverse clinical and/or anatomical situations as the initial step in a procedure for super-obese patients, with the second step completed by an ITB, SADIS, DTB, IID, DS, etc., after the patient has metabolically benefited from the initial weight loss achieved with the SG [3] [4] [12].

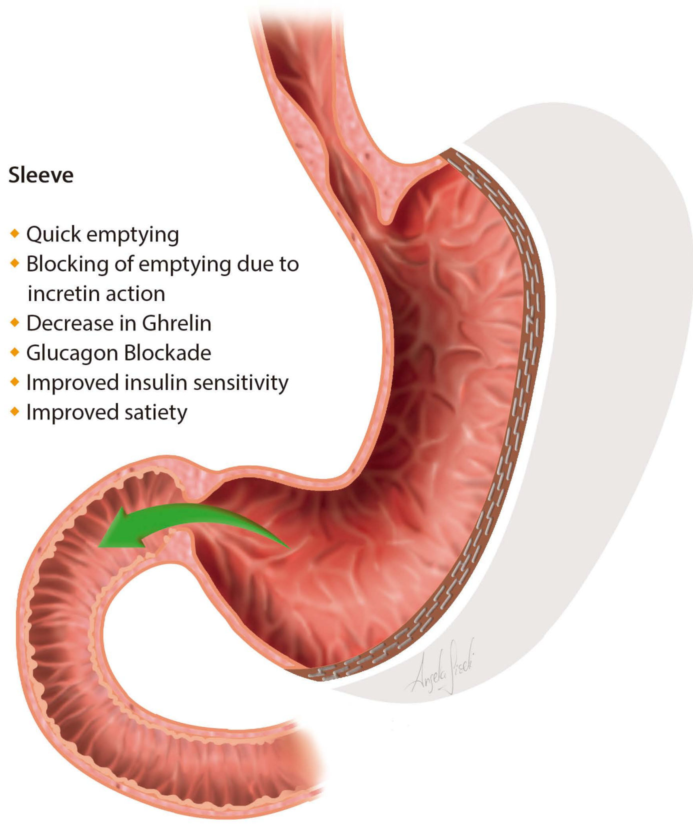

Figure 12. Sleeve Gastrectomy (SG).

Isolated transit bipartitions (ITB and DTB) are described in the literature and should preferably be utilized in special/adverse situations, especially in patients where the access to the upper abdomen is not feasible. In such cases, the option exists to perform the intestinal phase of the intended surgery, as an initial step, typically followed by the surgeon's primary recommended technique, after 6 months [56] [57].

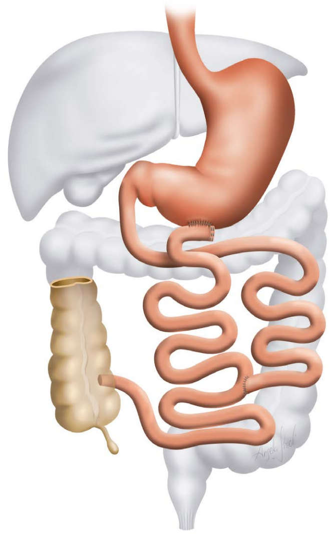

Figure 13. Isolated Intestinal Transit Bipartition (ITB).

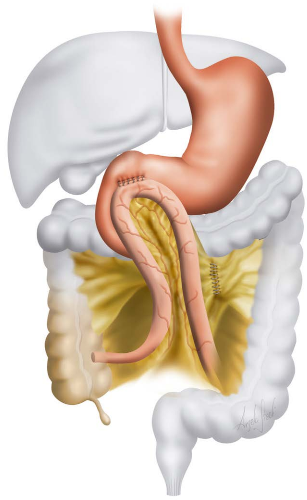

Figure 14. Isolated Duodenal Transit Bipartition (DTB).

3.5. Hybrid Metabolic Procedures (HP)

Hybrid metabolic procedures, often referred to as endobariatric or endometabolic procedures, are a recent innovation in the treatment of obesity and its comorbidities. These promising procedures represent the future of metabolic surgery, characterized by a combination of surgical and endoscopic techniques designed to optimize treatment in a metabolic and minimally invasive way.

Within this classification, the Hybrid Duodenal Transit Bipartition is particularly notable, combining Endoscopic Sleeve Gastrectomy (ESG) with laparoscopic duodenal transit bipartition. Additionally, it encompasses the performance of isolated duodeno-ileal magnetic anastomosis, along with magnetic anastomosis for sleeve revisions and in simultaneous association with laparoscopic sleeve procedures (**Figure 15** and **Figure 16**) [5] [47]-[51] [58] [59].

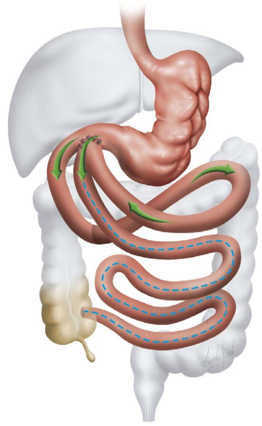

Figure 15. Endoscopic Sleeve Gastrectomy (ESG) with laparoscopic duodenal transit bipartition.

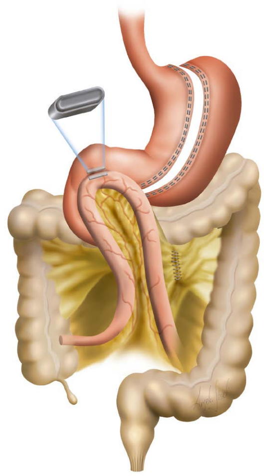

Figure 16. Duodeno-ileal magnetic anastomosis.

3.6. Revisional Metabolic Surgery

Revisional surgeries are procedures indicated for patients who have previously undergone bariatric surgery, aiming to reach weight loss and/or metabolic control. It is also indicated to manage complications that may arise after initial surgery [60]-[66].

Types of Revisional Metabolic Surgery

- **Rescue:** The primary objective of this type of surgery is to reignite weight loss and manage comorbidities in patients who have previously undergone metabolic surgery. Depending on the surgeon's technique and expertise, options may include converting the current procedure to an alternative metabolic surgical model, incorporating an additional metabolic component (be it intestinal or gastric), or optimizing the original metabolic surgery.
- **Control:** This approach is centered on addressing complications such as diarrhea, vomiting, dumping syndrome, malnutrition, reflux, and similar issues. These complications often arise due to intestinal maladaptation, post-surgical

anatomical distortions, or patient behavior. Based on the technique employed and the surgeon's experience, modifications can be made to the initial surgery to effectively manage these complications.

- **Reconstructive:** This type of revisional surgery seeks to reconstruct the patient's anatomy with the intent of reversing the metabolic surgery. The reversal can be either total or partial, depending on the technique initially implemented. This measure is deemed exceptional and is reserved for extreme cases.

3.7. Organizational Chart of the Classification of Metabolic Surgeries

Outlined below is the proposed organizational chart for the Classification of Metabolic Surgeries (Figure 17).

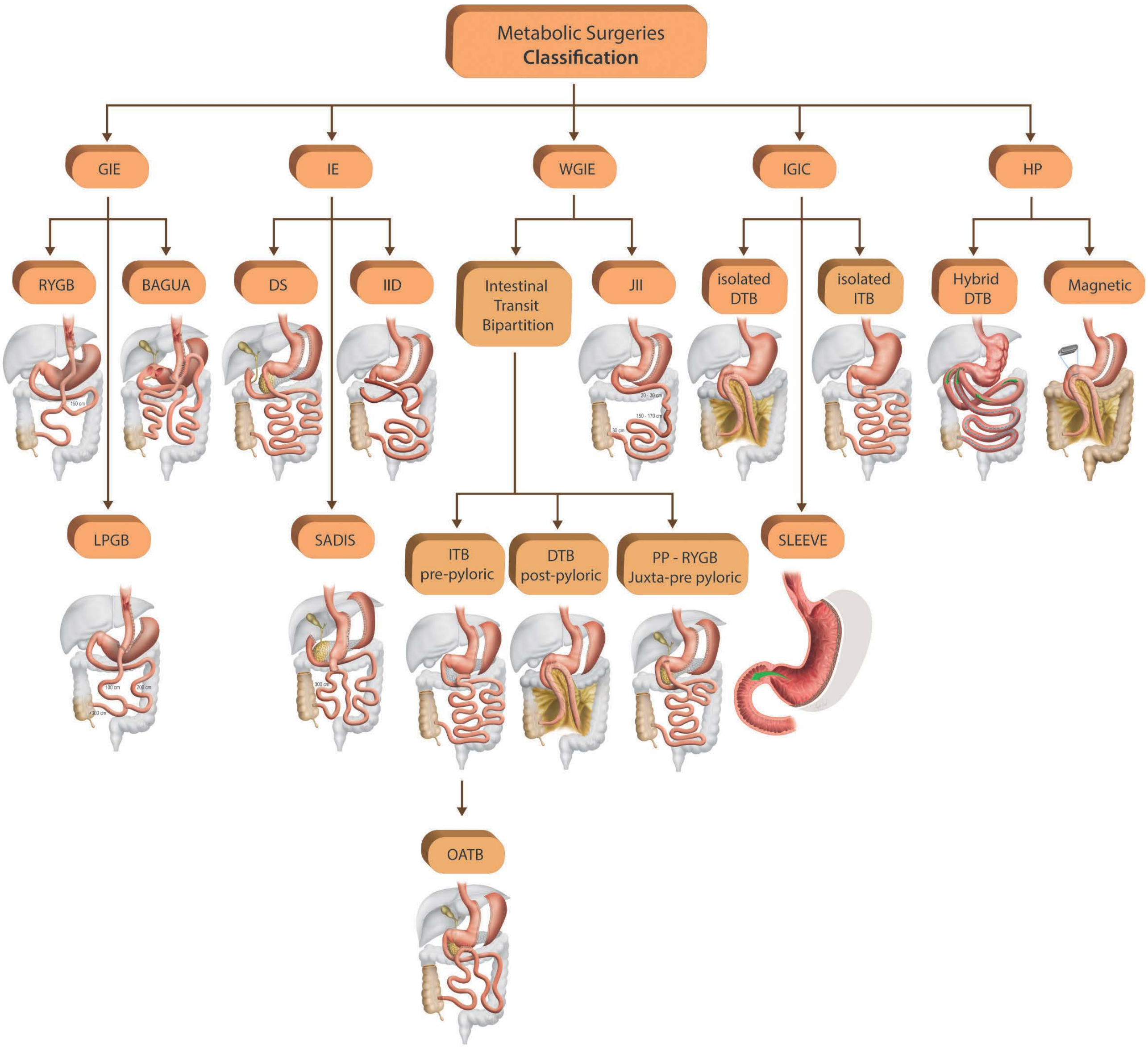

Figure 17. Organizational chart of the classification of metabolic surgeries.

4. Discussion

Classic bariatric surgeries have traditionally been classified into three categories: hypoabsorptive, restrictive, and mixed, based on the concepts of mechanical restriction and malabsorption. With the advancement of metabolic concepts, new perspectives have emerged for the surgical treatment of obesity, offering more physiological oriented procedures. Obesity is a chronic and complex disease, and each patient presents unique individual characteristics. Therefore, it is essential to possess a variety of surgical "tools" to effectively address the diverse needs of patients.

The metabolic procedures discussed in this article represent adaptations of classic bariatric surgeries and have been practiced for several years both in Brazil and globally. Recently, in Brazil, a Multi-Society declaration recognized the low morbidity rates, satisfactory weight loss, and comorbidities control, associated with these procedures, which are derived from the classic surgeries mentioned in this article [67]. These adaptations primarily aimed to integrate physiological metabolic and neuroendocrine aspects into traditional procedures by resizing the gastric "pouch" and enhancing intestinal absorption, while minimizing or eliminating gastrointestinal exclusion and avoiding restrictions. The integration of physiological principles should be prioritized in any treatment to maximize patient benefits.

The classification of metabolic surgeries plays a vital role in standardizing the techniques, establishing physiological surgical rationals and optimizing the treatment of patients with obesity. This may contribute in several ways:

- **Choice of Technique:** Facilitates the selection of the most suitable surgical technique for each patient.
- **Optimization of Results:** The ability to select the most appropriate technique enables the prediction and enhancement of surgical outcomes.
- **Didactic Standardization:** Offers a standardized language that aids in patient comprehension during consultations.
- **Effective Communication:** Enhances the exchange of information among healthcare professionals.
- **Records and Studies:** Supports the creation of records and facilitates research development, by using a consistent language.
- **Risk Control:** The combination of these factors directly assists the surgeon's evaluation, offering data and options to mitigate patient risks.

In its original definition, bariatric surgery is a collective term for procedures designed to reduce excessive weight. Metabolic surgery encompasses a group of gastrointestinal procedures that enhance physiological responses, by addressing and ameliorating metabolic conditions and diminishing excess adiposity, as a consequence. Consequently, it is not appropriate to consider these groups of procedures as equivalent. Bariatric surgery has served the population for many decades; however, we believe that Metabolic Surgery is a more appropriate term for this new era, and thus, we propose adopting this terminology in this classification [68].

5. Conclusions

This article does not aim to provide technical details or make comparisons between the previously mentioned metabolic surgical procedures. Most of these procedures, along with their underlying concepts, have been practiced for decades and are well-documented in extensive scientific literature. The intention here is to clearly delineate their concepts and propose a more suitable and didactic classification, facilitating the comprehension of each surgery.

We assert that the metabolic adaptations integrated into classic bariatric surgeries further underscore the significance of surgical treatment for metabolic disease and its comorbidities. This is primarily due to the incorporation of physiological concepts into their structures, thereby offering more options for bariatric-metabolic surgeons and better results for the patients.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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