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INTEGRATED STUDY MASTER'S THESIS

Long-Term Results (10 and More Years) After By-Pass Roux Y Operation for the Treatment of Obesity

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ABBREVIATION LIST

American Society of Metabolic and Bariatric Surgery - ASMBS

Body Mass Index – BMI

Chronic kidney disease - CKD

Continuous positive airway pressure - CPAP

Deep venous thrombosis - DVT

Electrocardiography - ECG

Endoscopic retrograde cholangiopancreatography - ERCP

Graduated compression stockings - GCS

Gastric esophageal reflux disease - GERD

Gastrointestinal bleeding - GIB

Glucagon-like peptide-1 - GLP-1

High-density lipoprotein cholesterol - HDL

Hyperlipidemia - HL

Hypertension - HTN

Indocyanine green - ICG

International Federation for the Surgery of Obesity and Metabolic Disorders - IFSO

Low-density lipoprotein cholesterol - LDL

Low molecular weight heparin - LMWH

Laparoscopic RYGB - LRYGB

Metabolic and bariatric surgery - MBS

Non-alcoholic fatty liver disease - NAFLD

Obesity-related non-communicable diseases - OR-NCDs

Obstructive Sleep Apnoe Syndrome - OSAS

Polycystic ovarian syndrome - PCOS

Percentile excess BMI loss - %EBMIL

Percentile excess weight loss - %EWL

Percentile total weight loss - %TWL

Prospective Cohort Study - PCS

Pulmonary embolism - PE

Proton-pump inhibitor - PPI

Quality of life - QoL

Retrospective Cohort Study - RCS

Roux-en-Y Gastric Bypass - RYGB

Small bowel obstruction - SBO

Sleeve gastrectomy - SG

Type 2 Diabetes Mellitus - T2DM

Venous thromboembolism - VTE

Weight regain - WR

World Health Organisation - WHO

1. ABSTRACT

Purpose: Roux-en-Y Gastric Bypass (RYGB) is the second most commonly performed bariatric surgery and has demonstrated significant postoperative weight loss and improvement in obesity-related comorbidities. However, long-term results of 10 years or more are insufficiently documented. This systematic review aims to analyze the outcomes of studies and provide an up-to-date perspective on the successes and challenges of RYGB.

Methods: The comprehensive literature review followed the 2020 PRISMA guidelines using PubMed, Cochrane Controlled Trials Register, and ScienceDirect databases. It includes publications from the years 2014- 2024. The research was conducted from January 2024 to May 2024 and included only articles with full texts available in English.

Results: Of the initial 313 articles, 257 were excluded for not fulfilling the predetermined inclusion criteria. 40 full-text articles were assessed for eligibility, with 29 articles meeting the inclusion criteria. In the included studies, 11,435 patients underwent RYGB as the primary surgery procedure; therefrom, 4,995 patients (44%) completed the 10-year follow-up. After ten years, the BMI decreased to 35.9 (±4.1) kg/m² from an initial average of 49.1 (±3.4) kg/m². The % TWL, %EWL, and %EBMIL results were 28.9 (±3.8)%, 60.9 (±7.6)%, and 57.8 (±9.8)%, respectively, ten years post-RYGB. Comparing the 2-year and 10-year results, a decrease in % TWL, %EWL, and %EBMIL values by -6.75%, -14.23%, and -18.19% was revealed, along with an increase in the BMI of 19.04%, indicating a gradual reduction in weight loss in the long term. These differences in weight loss values between the 2-year and 10-year time mark were statistically significant. A remission of type 2 diabetes was noted in 61.9% of patients 10 years post-RYGB. Arterial hypertension, dyslipidemia, obstructive sleep apnea, and gastroesophageal reflux disease displayed remission rates of 49.5%, 61.3%, 66.1%, and 54.4%, respectively.

Conclusion: This systematic review confirms the highly effective outcomes of RYGB surgery, including the success in reducing specific weight loss values and improving the remission rates of obesity-related comorbidities. However, low follow-up rates and the lack of unity in the definition of RYGB success make it challenging for the reviewer to evaluate the overall effectiveness.

Keywords: Bariatric surgery; Roux-en-Y Gastric bypass; Treatment outcomes; Long-term; 10-years and more

2. INTRODUCTION

2.0 PROBLEM STATEMENT

During the course of the last 40 years, obesity rates have increased profoundly (1). In the USA, obesity prevalence reached 36,5%, which is the highest level globally; Europe accounts for the second highest prevalence, with an average of 15,9% throughout all the EU states (1). These increasing numbers have become a national endemic and bear significant issues for the public healthcare system (2). The development of Obesity-related non-communicable diseases (OR-NCDs), which account for chronic diseases including insulin resistance, cardiovascular disease, hypertension, stroke, and psychological problems, affects both the patient's overall well-being and enhances mortality rates (2). The goal of preventive measures is to counterbalance these contributing factors and to provide an overall healthy and comfortable life without any limitations. Conservative measures, consisting of a diet-based therapy and physical exercise, along with controlling OR-NCD via pharmacotherapy, are the first actions in managing the critical risks of metabolic syndrome (3).

Bariatric surgery interventions have been associated with sustained weight loss and a reduction in morbidness in severely obese patients, making it the first-line treatment in the instance of conservative failure (3,4). During the course of the past few years, the estimated quantity of endoluminal bariatric surgeries has risen worldwide, reaching a total of 598,834 surgeries in 2021, which indicates the importance of evaluating the outcomes and associated complications, especially in the long run (5).

The latest data on metabolic and bariatric surgery (MBS) have shown that RYGB is among the most commonly carried out surgical procedures after sleeve gastrectomy (SG) (5). This surgical method of gastric bypass was firstly introduced in the year 1960 to treat gastric ulcers after partial gastric removal, subsequently leading to weight reduction (6). Because of increased bile reflux, the initial method has been modified over the years to the now widely used term RYGB, with a Roux-en-Y intestine limb connection amidst the remaining proximal gastric pouch and the bypassed stomach and duodenal part (6). The postoperative results showed a substantial weight reduction from the third year onward, and the sustained outcomes of five years have been summarized (7). However, studies that have evaluated extending results exceeding ten years are still lacking.

2.1 AIM

This systematic literature review intends to investigate the long-term results of 10 years or more of the bariatric surgery technique of RYGB in obese patients.

2.2 OBJECTIVES

(1) To clarify the implications for bariatric surgery, the procedure, and the complications considering RYGB.

(2) To evaluate the long-term success rates of 10 years and more in terms of weight loss and to compare different weight loss measurements.

(3) To review the long-term improvements of OR-NCDs.

3. MATERIALS AND METHODS

A structured evaluation of the effects on long-term outcomes of RYGB concerning weight loss and improvements in OR-NCDs, including T2DM, hypertension, dyslipidemia, GERD, and OSAS in the course of 10 years and more. While prior reviews have addressed the results of RYGB, comprehensive analyses remain scarce for outcomes beyond a decade. Additionally, many recent studies, which reflect advancements in surgical techniques, updated clinical guidelines, and progressive, long-term management strategies, have yet to be incorporated into existing reviews.

This review aims to fill that gap by analyzing studies published within the last 10 years and offering an up-to-date perspective on RYGB's success and challenges. By comparing weight outcomes at the two-year mark—identified in the literature as the period of peak weight reduction - with data at 10-year follow-up, this review seeks to deliver new observations in the durability of RYGBs benefits and areas that may benefit from strategic improvements, as well as the improvement and/ or remission of OR-NCDs.

3.0 INFORMATION SOURCES AND SEARCH STRATEGY

The comprehensive literature review followed the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) guidelines, using PubMed, Cochrane Controlled Trials

Register, and ScienceDirect databases. The research was conducted from January 2024 to May 2024. The search terms used were "Roux-en-Y gastric bypass," "Gastric bypass," and "Laparoscopic Roux-en-Y gastric bypass." Additional terms such as "Long-term," "Treatment outcomes," "10-year follow-up," and "15-year follow-up" were also included. An electronic search was performed with a publication date filter, limiting results to articles published between 2014 and 2024. The search criteria solely consist of articles that are available in English.

By utilizing the PICO model (P = Population, I = Intervention, C = Comparison, O = Outcome), the following research question has been formulated to establish this literature review:

How do long-term (10 years or more) outcomes after RYGB surgery succeed in the context of weight reduction and betterment of obesity linked comorbidities in obese patients?

Table 1. PICO model

Components	Description
Population (P)	Obese patients whose conservative measures had been exhausted and who suffer from obesity-related conditions and/or comorbidities.
Intervention (I)	The patients who receive treatment for bariatric surgery, particularly Roux-en-Y Gastric Bypass.
Comparison (C)	Comparison of the weight loss success rate, and failure rates (weight regain), along with the improvement of obesity associated comorbidities within 10 years or more after surgery.
Outcome (O)	Weight loss success rate, failure of the intervention, non-/ improvement of OR-NCDs

3.1 ELIGIBILITY CRITERIA

Only human studies were included in the systematic review, in which the indication criteria for surgery of the American Society of Metabolic and Bariatric Surgery (ASMBS) and the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) were applied. Studies were included in which the surgical intervention was primary, and the individuals were above 18 years old with a Body Mass Index (BMI) >40 kg/m2 or a BMI >35 kg/m2 with diagnosed OR-NCDs. Studies were considered eligible if the overall follow-up time included >10 years and if at least one of the listed outcomes was declared: weight loss, and comorbidities. To further assess and evaluate weight loss, the following factors were evaluated: BMI at ten years, the percentile total weight loss (%TWL), the percentile excess weight loss (%EWL), and the percentile excess BMI loss (%EBMIL). The most common comorbidities that are related to obesity were selected and included Diabetes Mellitus Type II (T2DM), Hypertension (HTN), Hyperlipidemia (HL), Gastric Esophageal Reflux Disease (GERD), as well as Obstructive Sleep Apnoea Syndrome (OSAS).

Studies were omitted if they did not fulfill the previously mentioned requirements, as well as the following surgical procedures: Banded RYBG, one-anastomosis gastric bypass (OAGB), laparoscopic single anastomosis (LMGB), Roux-en-Y gastric bypass after failure of paraoesophageal hernia repair, or single-anastomosis duodenal-ileal bypass with sleeve gastrectomy. Publications limited to case report abstracts, meta-analyses, comments, systematic reviews, and general reviews were not included.

3.2 STUDY SELECTION

Study selection and data extraction were conducted by two independent reviewers, with a third expert resolving any disagreements. Titles and abstracts of all articles were reviewed on the basis of the previously defined inclusion and exclusion criteria. Case reports, abstracts only, meta-analyses, comments, systematic reviews, and reviews were excluded from consideration. Full reports were obtained for studies that appeared to meet the inclusion criteria or lacked sufficient detail in the title as well as the abstract. The residual articles were assessed in terms of eligibility, and the complete texts of eligible studies were evaluated.

3.3 DATA ITEMS

The upcoming information was obtained from all incorporated articles: **1.) First Author**: the Name of the first author who has published the article; **2.) Year:** the year the article has been published; **3.) Type of Study**: retrospective cohort study (RCS); prospective cohort study (PCS); **4.) Surgical Technique**: open RYGB, Laparoscopic RYGB (LRYGB); **5.) Number of Patients at Baseline (A), Number of Patients after 10 Years (B):** Number of patients that have been included at the beginning of the study (A); Number of patients who were assessed after 10 years or more (B); **6.) BMI at the Baseline:** BMI measured before the surgical procedure; **7.) BMI at 10 years or more**: BMI follow-up results of the patients after 10 years or more; **8.) % TWL at 10 years or more**: %TWL follow-up results; **9.) %EWL at 10 years or more**: %EWL follow-up results.

To evaluate the comorbidities, the following information was extracted from all included studies: **1.) Diabetes mellitus at Baseline (%)**: The percentage of patients who have been diagnosed with Type 2 Diabetes Mellitus before undergoing bariatric RYGB surgery; **2.) Diabetes Mellitus Remission Rate (%):** the percentage of patients who have experienced an improvement/ remission of T2DM 10 years after RYGB; **3.) Hypertension at Baseline (%)**: the percentage of patients diagnosed with hypertension before undergoing bariatric RYGB surgery; **4.) Hypertension Remission Rate (%):** the percentage of patients who have endured improvement/ remission of hypertension 10 years after RYGB; **5.) Hyperlipidemia at Baseline (%):** the percentile of patients diagnosed with hyperlipidemia before undergoing bariatric RYGB surgery; **6.) Hyperlipidemia Remission Rate (%):** the percentage of patients who have experienced an improvement/ remission of hyperlipidemia 10 years after RYGB; **7.) GERD at Baseline (%):** the percentile of patients who showed symptoms of GERD before undergoing bariatric RYGB surgery; **8.) GERD Remission Rate (%):** the percentile of patients that experienced improvement/ remission of symptoms 10 years after RYGB; **9.) OSAS at Baseline (%):** the percentile of patients that manifested symptoms and/ or medical interventions for OSAS before undergoing bariatric RYGB surgery; **10.) OSAS Remission Rate (%)**: the percentage of patients who showed improvement/ remission of OSAS symptoms/ medical interventions 10 years after RYGB.

3.4 STATISTICS

The statistical analyses compared weight loss values at 2 and 10 years, including BMI, %TWL, %EWL, and % EBMIL. By applying the paired T-test (dependent T-test), it has been possible to analyze two time periods within related samples. By maintaining a p-value below 0.05, the null hypothesis (H_0) was disproven, indicating statistically significant differences in the observed groups. Values with significant p-values are marked with *. Highly significant p-values, indicated by results of <0.001, are labeled with **.

4. A COMPREHENSIVE OVERVIEW OF INDICATIONS, PROCEDURE, FOLLOW-UP, AND COMPLICATIONS IN RYGB

The RYGB procedure was first introduced by Edward Manson in the year 1966 and is classified as a restrictive-malabsorptive procedure (8,9).
This classification indicates that the procedure aids weight loss through two primary key mechanisms: The restrictive mechanism, which limits the volume of food a person can consume, and the malabsorptive component, which confines the absorption of nutrients and calories (10). As stated by the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO), the RYGB procedure accounts for 30.2% of all metabolic bariatric procedures (5). Therefore, it is the second most widespread surgery technique after sleeve gastrectomy, which represents 60,6% (5). However, RYGB has been shown to be the most often used procedure for revisional metabolic bariatric operations (5).

4.1 INDICATIONS AND CONTRAINDICATIONS FOR RYGB

The indication for considering Metabolic and bariatric surgery (MBS) depends upon the degree of BMI and whether acquired OR-NCDs are present. In the past, literature recommended MBS for patients who presented with Obesity class III (BMI greater than or equal to 40 kg/m^2) or Obesity class II (BMI 35 to 39.9 kg/m^2) and one or more OR-NCDs (11). These OR-NCDs include T2DM, hypertension, dyslipidemia, non-alcoholic fatty liver disease (NAFLD), GERD, OSAS, asthma, venous stasis disease, severe urinary incontinence, debilitating arthritis, polycystic ovarian syndrome (PCOS), chronic kidney disease (CKD), infertility, or significantly impaired quality of life (12,13).

However, updated ASMBS guidelines 2022 recommended considering MBS for patients with an exacerbation of multiple comorbidities that greatly influence their overall well-being for class I obesity (BMI 30–34.9 kg/m2) (14).

Current data showed a benefit in patients with obesity class I who underwent MBS, which has demonstrated a significant weight reduction during the initial 5-year period and an improvement of comorbidities or remission, such as T2DM, hypertension, and dyslipidemia (15). Patients with a BMI <35 kg/m^2 potentially achieve more significant weight loss and regression of comorbid condition rates compared to individuals with a BMI >35 kg/m^2 (14). Therefore, surgical interventions shall be performed for individuals with a BMI <35 kg/m^2 after non-surgical procedures have been utilized (14).

Recent research has led to revised recommendations in terms of the indications of MBS in the Asian population (14). This patient group has shown a higher risk of developing T2DM and cardiovascular diseases, even if their BMI, in comparison, is relatively low (14). Therefore, surgery should be adjusted according to a BMI of 25 - 27.5 kg/m² in Asian patients (14). Unlike other races, Asian individuals are encouraged to seek surgical intervention at lower BMI levels due to their increased vulnerability to obesity-related health conditions (16).

In terms of age limit, several studies have shown that in elderly patients, the positive effects of MBS, such as a reduction in the severity of comorbidities, outweigh the risks associated with this surgery (17). Nevertheless, there have been more post-operative complications in the elderly compared to younger patients. However, various studies concluded that in the elderly, an increase in complications is likely caused by fragility. Due to higher operative and postoperative complications in this specific age group, the fragility index should be determined before considering MBS (18).

Increased intra- and postoperative complications as well as an overall high mortality risk can be seen in " super obese" patients marked with a BMI of more than 50 kg/m^2, or even "super-super obese" patients who show a BMI of more than 60 kg/m^2 (19). In the case of an extremely high BMI, it has been shown that there is no unanimous treatment protocol (14). However, if an MBS can be performed safely and a timely mobilization is achieved, patients who are super obese or super-super obese can overall benefit from the procedure (14).

A prior assessment of the patient should be made to accomplish sufficient and successful surgery outcomes. The following criteria, such as medical condition, surgical criteria, motivation, psychiatric state, and nutritional state, should be evaluated in a multidisciplinary team assessment to further prevent short- and long-term complications (14).
A preliminary evaluation of the risk factors regarding general anesthesia and life-threatening comorbidities should be performed by the surgeon and the anesthesiologist (14). A thorough medical history and physical examination of the patients, with laboratory studies, should be carried out in advance (20). Additional examinations might be indicated, such as cardiopulmonary assessments, including electrocardiography (ECG), echocardiography, or further investigations if pulmonary hypertension is suspected (20). In the case of gallbladder symptoms or suspected gastric ulcers with or without H. pylori, upper endoscopy, and other gastrointestinal evaluations are needed (20).
Educational classes and psychological group sessions before the surgical procedure can prevent poor outcomes and help patients prepare for common complications or challenges they could face (14).

Furthermore, consultations with dietitians are crucial for educating patients about dietary changes, such as nutritional deficiencies they might develop and their lifestyle habits that could negatively affect the outcomes (14).
Psychiatrists or psychologists should evaluate the patient's mental state and diagnose severe psychopathologies such as severe depression, binge eating habits, or substance abuse beforehand to reduce the chance of treatment failure (14).
This interdisciplinary presurgical procedure should be a 6-month process evaluating the patient's suitability to perform MBS (13,20).

There are no absolute contraindications for conducting MBS (13). However, it is essential to evaluate the severity of comorbidities such as heart failure, unstable coronary artery disease, active cancer treatment, portal hypertension, or severe drug/ alcohol abuse (13). Additionally, the patient's intellectual ability and compliance to follow medical instructions should be evaluated to further increase long-term success (8). The decision to undergo surgery should always be made on an individual basis, prioritizing the surgical benefits for the patient (13).
Prior to the surgery it is inevitable to obtain consent from the specialists in anesthesiology to determine whether the patient's physical state is adequate to perform general anesthesia (13).

4.2 SURGICAL TECHNIQUES OF RYGB

Since minimally invasive techniques are gaining more and more importance in medicine due to shorter hospital stays, reduced complications, faster recovery, and mobilization, as well as reduced pain, laparoscopic RYGB has replaced the open and more invasive procedure (21). Out of all bariatric operations, around 99.1% were performed laparoscopically (22).

There are standardized techniques for the surgical procedure of LRYGB; however, the exact surgical steps can vary from surgeon to surgeon (8). The RYGB surgery is essentially based on four key surgical steps: 1.) gastric pouch creation, 2.) creation of biliopancreatic limb, 3.) jejunojejunostomy creation, and 4.) creation of gastrojejunostomy (8). Figure 1 displays two images: the first illustrates the preoperative anatomical structures of the stomach and intestines, while the second shows the postoperative view, highlighting the outcome of the surgery along with the anastomosis of the gastric pouch and the merge of the intestinal limbs.

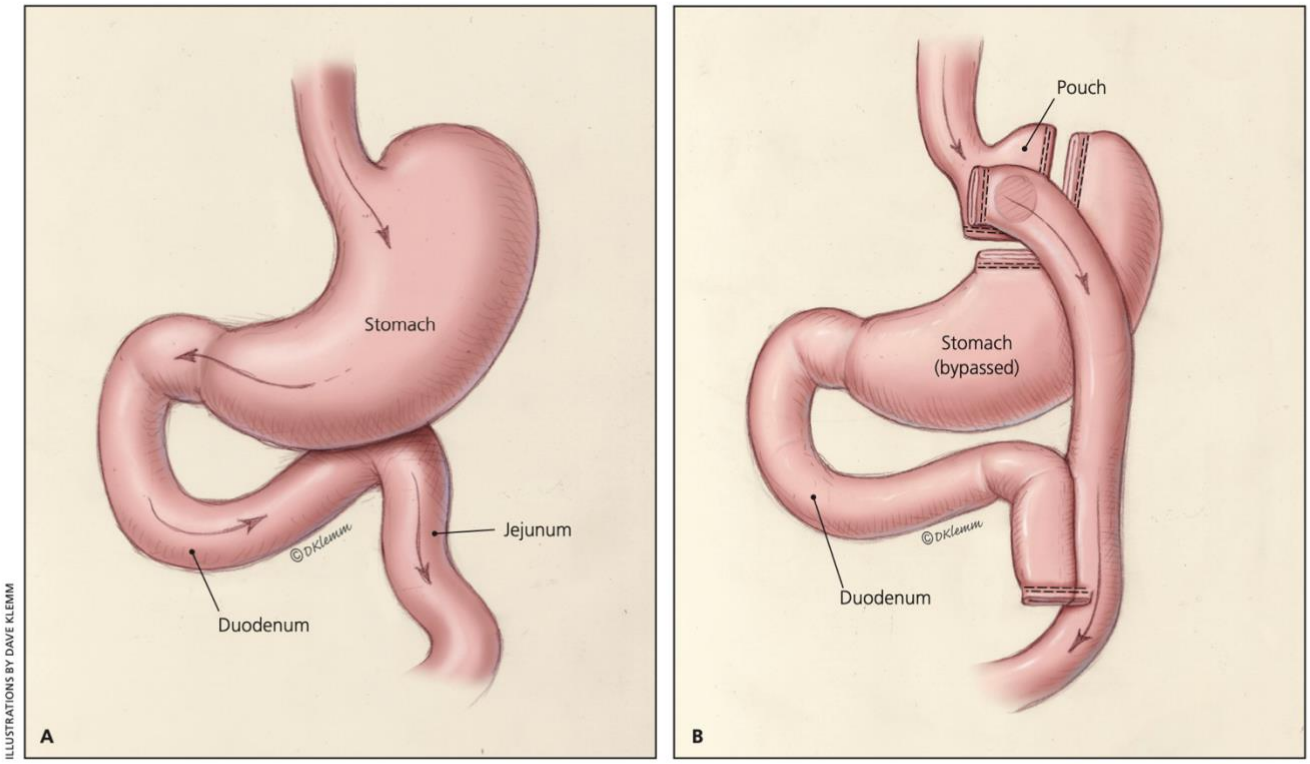

Figure 1- A) Stomach, duodenum, and jejunum before bariatric surgery. (B) Stomach, duodenum, and jejunum after Roux-en-Y gastric bypass (20).

The preferred position for surgery is the reverse Trendelenburg position, where the surgeon stands between the patient's split legs, facing the patient's abdomen (20). To prevent the patient from sliding off the operating table, the legs and hip are tightened with a strap (20). The patient's legs and arms should be upholstered adequately to avoid pressure injuries during surgery (20).
The pneumoperitoneum should be approached either via a Veress needle in the right hypochondrium or by inserting a bladeless optical view trocar to avoid injuries of the intestine or bleeding of adhesions (8) (20). The abdomen should be insufflated with up to 18 mm Hg of CO_2 (20). The 10mm optical trochar is placed 4-5cm above the umbilicus (8). The other trocars are placed in the left (12mm trocar) and right upper quadrant (12mm trocar), and one or two 5 mm trocars are either inserted into the right upper, left lower, or in the subxiphoid level depending on the surgeon's preference (21).

Starting with the creation of the gastric pouch, the liver must be held upwards to enable a view of the operative field (8). A liver retractor is commonly used (8).
The methods of measuring the pouch size may vary (20). However, a generalized pouch size should be maintained around 25 to 30 cm^3 (20). Firstly, the stomach has to be mobilized, and one starting point can be the “His-angle”, which indicates where the left border of the intraabdominal esophagus meets

the fundus of the stomach (8,23). Afterward, the pars flaccida, a portion of the lesser omentum lying near the lesser curvature and the retro gastric attachments, are detached (8,24). The stapling device is directed above the angle of His and is released vertically (20). It is important to note that the staple should be positioned away from the esophageal fat so that transection or narrowing of the esophagus is prevented (23).

The second step after completing the gastric pouch is the construction of the Roux and the Biliopancreatic Limbs (23). The ligament of Treitz is a band of peritoneum that expands from the diaphragm and connects the distal part of the duodenum and the beginning of the jejunum (25). It serves as a reference point for evaluating the start of the jejunum (23). The biliopancreatic limb is measured 30-50cm from the Treitz ligament (25). The Roux limb, also called the "alimentary limb", extends around 75 to 150 cm, on average 120cm, from the gastric remnant, where it will be anastomosed with the biliopancreatic limb (8,23).

The jejunojenostomy, which is the third step, will connect the two limbs, recreating the passage of the pouch content with the gastric, biliary, and pancreatic secretion of the other limb (8). This will be performed by an anastomosis with a linear stapler passing through an enterotomy of the two limbs and creating a side-to-side, called the J-J-anastomosis (8). The closing of the enterotomies is performed by perpendicular stapling of the incisions (23).

The final step includes the formation of the gastrojejunostomy. The position of the Roux limb can either be antecolic-antegastric or retrocolic-retrogastric (8). The antecolic-antegastric orientation is most commonly used (20). However, it depends on the tension of the limb whether to use an antecolic-antegastric or retrocolic-retrogastric orientation (23). In the case of high limb tension, a retrocolic-retrogastric approach is more convenient (23). The most common technique for gastrojejunostomy is the transoral circular stapler (23). Nevertheless, a linear stapler, creating a side-to-side- anastomosis or hand sewing, can also be used (23).

After completing the surgical procedure, an endoscopic leaking test is performed (8). Two techniques can be initiated. By inducing saline with the endoscope and inflating the gastric pouch with air, leakage and, therefore, air bubbles at the anastomosis side can be seen from the laparoscopic view (8). The other option included infusing Methylene blue dye via the gastric tube or the intravenous injection of Indocyanine green fluorescence (ICG) (8,26). The application of ICG can be used in addition to

Methylene blue to further evaluate the perfusion of the anastomosis, preventing fistula or necrosis. A special laparoscopic camera would be needed to switch to ICG mode after injection (26).

4.3 POST-OPERATIVE CARE AND FOLLOW-UP MANAGEMENT

Following the procedure, post-operative care includes monitoring and adequate pain management in the medical recovery room (20). Specialized nurses should be familiar with complications that might occur immediately after surgery (20). Further monitoring or observation in the intensive care unit shall be considered in the case of OSAS, difficult cardiac conditions, or insufficient respiration (20). For pain management, intravenous pain medication or peridural anesthesia should be administered, which eliminates the sensation of pain in the nerves that cross the epidural space (20). The peridural catheter is placed before surgery and can be operated via a mechanical pump with opioid analgesics (20). To prevent venous thromboembolism or pulmonary embolism, fast mobilization, early training with physiotherapists, and graduated compression stockings (GCS) are mechanical prophylaxis standards (20). Adequate chemical prophylaxis should be initiated with low molecular weight heparin (LMWH) due to adiposity and its possible comorbidities, which can increase the risk of developing thrombosis (20). For high-risk patients, prophylaxis beyond hospitalization should be considered (20). Postoperatively, a clear bariatric fluid diet consisting of sugar-free fluids with minimal gastrointestinal residue is initiated to avoid irritation of the pouch (23,27). Recording fluid intake is recommended to ensure adequate hydration (23). Post-operative advice on the introduction and progression of diet, as well as sufficient hydration and intake of vitamins and minerals, should be supported by an educated dietitian (23). The postoperative hospital stay, in general, is around 1-3 days, on average 2,1 days (22,23). This is mostly dependent on the country in which the procedure is performed (22). For instance, the hospital stay after RYGB in Norway, Netherlands, Sweden, or Brazil is, on average, 2 days. However, if it is carried out in other countries like China, France, or Venezuela, the average hospital stay is up to 6 days postoperatively (22).

The recommended follow-up schedule for RYGB patients depends on whether they have nutritional or metabolic comorbidities (27). If they do not have any comorbidities, follow-ups should take place every 2 to 3 months within the first half of the year. In the second half of the year, a single follow-up appointment is sufficient (27). In the case of nutritional or metabolic comorbidities, the follow-up schedule is designed to be flexible, empowering healthcare professionals to adapt as needed. In the first 6 months, the patient will be seen every 1-2 months, and in the second half of the year, every 3-6 months, depending on the severity of the comorbidities or the outcomes of the last follow-ups (27). In the second postoperative year, the follow-up rate will be the same, with appointments every 6 months, continuing with annual follow-ups onwards (27).

4.4 COMPLICATIONS

As with every medical intervention, especially surgical intervention, the risk of developing complications is inevitable and always present.
Complications can be further subdivided into early and late complications, which occur either within the first month after the surgery or, in the case of late complications, months or years later (28).

As for the early complications, deep venous thrombosis (DVT), pulmonary embolism (PE), anastomotic leaks, and gastrointestinal bleeding may occur (29).

Venous thromboembolism (VTE), comprising DVT and PE is a serious adverse event and is the most prevalent reason for mortality after bariatric surgery (29). The possibility of developing VTE ranges from 0.12% to 3.8% (29). Therefore, fast mobilization and thromboprophylaxis are essential and should be adjusted to age, the grade of obesity, oral contraceptive intake, and smoking (29). Venous thromboembolism (VTE), comprising DVT and PE is a serious adverse event and is the most prevalent reason for mortality after bariatric surgery (29).

Anastomotic leaks most commonly occur 5 to 7 postoperatively and are perceived as being caused by ischemic parts of the anastomosis (29). If these complications are shown in the earlier postoperative days (2 days after surgery), they are more prone to be affected by technical errors, such as faulty activation of the stapler device or loosening sutures (29). Checking the perfusion of the anastomosis and the remaining limbs can reduce the risk of ischemia of the tissue and, therefore, prolonged hospital stay, intensive care unit, and further operative interventions (29).

The prevalence of gastrointestinal bleeding (GIB) has been stated to be low after laparoscopic RYGB (1.1% to 4%) (29). Nevertheless, GIB can be a fatal adverse medical event if not detected early, and necessary intervention is not promptly performed (29). The most common onset of GIB after RYGB is early postoperative bleeding, typically arising in the first hours post-surgery (29). Late-onset bleeding, which occurs more than 48 hours post-surgery, is less common and often presents with milder symptoms such as melena (29). GIB most often originates from the staple lines: "the gastric pouch, excluded stomach, Roux limb, gastrojejunostomy, and jejunojejunostomy" (29). Common causes can be oversewn staple lines, the utilization of chemoprophylaxis of DVT, and staple-line bleeding from tissue edges (29). Key clinical signs include hematemesis, rectal blood, tachycardia, hypotension, dizziness, confusion, pallor, and low urine output (29). Early and severe gastrointestinal bleeding often necessitates urgent reexploration, which could be carried out either laparoscopically or by open surgery based on the individual's hemodynamic stability (29). Effective endoscopic interventions, such as thermal coagulation, vasoconstrictor injections, or clipping, are typically to control bleeding arising either from the gastric pouch or gastrojejunostomy (29).

Late complications involve internal Hernia, intestinal or biliary obstruction, anastomotic strictures, and dietary or nutritional problems that can appear (29).
The incidence of intestinal hernias is between 3% and 4.5% (29). The fast weight reduction after RYGB reduces intraperitoneal fat and enlarges mesenteric defects, that can consequently heighten the risk of intestinal hernia (29). Subsequently, this condition can lead to a closed-loop bowel obstruction with or without strangulation or small bowel obstruction (SBO), hat can consequently heighten the risk of which has been considered the most common cause of complications following laparoscopic RYGB (29).

Internal hernias can develop at several different areas: "jejunojejunostomy mesenteric defect, Petersen's space, and the transverse mesocolic defect", as seen in Figure 2 (29). The specific site of herniation often depends on the surgical technique used, with retrocolic approaches showing a higher incidence of mesocolic hernias, while antecolic approaches are more commonly associated with Petersen's and jejunojejunostomy hernias (29).

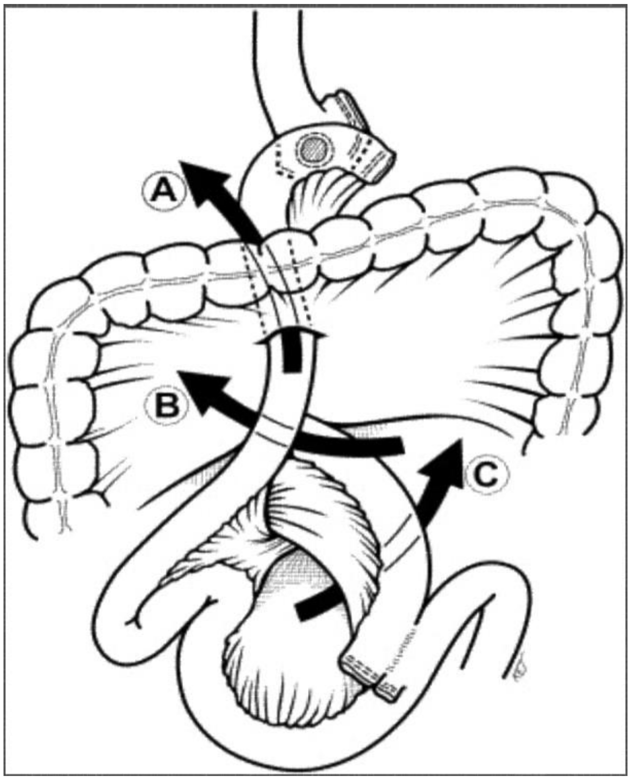

Figure 2 - Mesenteric defects: (A) transverse mesocolic, (B) Petersen's space, and (C) jejunojejunostomy mesentery (29).

Among the more prevalent adverse effects occurring post-RYGB surgery is the anastomotic stricture, which is most commonly located at the site of the gastrojejunal anastomosis (30). The prevalence rate for this complication ranges from 1%-7% and occurs predominantly after LRYGB due to scarring, ischemia, or an insufficient surgery technique (30,31). Patients' symptoms typically involve dysphagia and daily reoccurring vomiting, which subsequently might need surgical revision (30). Another complication that predominantly occurs after LRYGB is marginal ulceration, which is defined as a peptic ulcer-like appearance on the jejunal mucosa of the gastrojejunal anastomosis (30). Prevalence numbers for this specific complication range from 1%-16% and are caused by an acid insult to the jejunal mucosa (30,31). Patients suffering from this particular complication typically present within the first three months after surgery or even up to one year after the surgery with the following symptoms: epigastric pain, bleeding, vomiting, or dysphagia (30,31). Proton pump inhibitors (PPI) are the primary therapy for these complications, and patients are repeatedly undergoing endoscopy to ensure the healing process, which is typically successful with 85%-95%. Non-healing or worsening of the condition might need surgical revision (30).

Gastro-gastric fistula (GGF) is another but less frequently arising complication classified as the space separating the created pouch and the omitted remaining stomach (31). The prevalence rate for GGF ranges from 1%-2% and is usually attributed to insufficient stomach transection, marginal ulcer perforation, or an anastomotic leak (30). The most frequent clinical feature is an increase in the body mass, and patients who are treated with PPI (30,31). Nonetheless, surgical treatment is typically indicated, and it varies from gastrectomy of the remnant tissue to revision of the gastrojejunal anastomosis (31).

Another subsequent complication is cholecystolithiasis, with a probability of occurrence from 24-48% (30,32). The augmented gallstone formation in these patients is the result of excessive saturation of bile with cholesterol due to the caloric restriction and, thereby, decreased bile acid secretion (30,32). The treatment of this complication remains a topic of controversy, and patients can either be treated with ursodeoxycholic acid or need surgical intervention (25)(32).

An additional possible complication is Choledocholithiasis, in which patients experience stones in the common bile duct, that might direct to cholangitis or pancreatitis (30,33). Because the duodenum is omitted and linked with the stomach, the typical treatment, which involves endoscopic retrograde cholangiopancreatography (ERCP), is impossible (30,33). Further treatment modalities include a laparoscopic-aided ERCP in combination with a residual stomach gastrostomy or an open commode bile duct exploration (30,33).

The SBO presents with an incidence rate of 1.5%-5% after LRYGB (30). The origin of this complication is commonly assigned to strictures, adhesions, and internal hernias (30). The possible sites for developing internal hernias vary and are dependent on the surgical technique that was used (30,34). In the case of the colic roux limb technique, the following defects are created: defect in the mesocolon, defect in the mesentery, and Petersen´s defect (30). Patients typically present with abdominal pain, possible vomiting, and cramps, which are then further evaluated with a CT scan (30). The treatment involves open or laparoscopic investigation, and the surgical treatment itself is based on the etiology of the obstruction itself (30).

Other complications include the dumping syndrome, which is more frequently found in women, with an incidence rate of 13% in an average monitoring of 4.5 years (35). This complication is further categorized as early and late and comprises different clinical pictures (35).

The early dumping syndrome occurs in the first 60 minutes of consuming food and is linked to a fast delivery of nutrients into the small bowel (35). By implication, this causes an osmosis-induced fluid motion into the lumen of the small bowel (35). The symptoms involve flushing, dizziness, and diarrhea and are typically treated with a change in diet, such as low carbohydrates and a high protein or fiber diet (35). Medications such as octreotide can be indicated in case of inadequate response to the previous measures (35). Early dumping syndrome is considered a naturally resolving disease and usually recedes within one year to one and a half years post-surgery (35).

On the contrary, the late dumping syndrome manifests within 60-180 minutes post food intake and is caused by a hypoglycemic response to an excess amount of insulin in the bloodstream. The patient's symptoms include tremors, palpitations, and diaphoresis (30). The treatment of this condition consists of the identical actions as in the case of the early dumping syndrome (35). In case of severe side effects due to hypoglycemia, surgery might be required, which can include a bypass reversion back to the normal anatomy, an increase in the gastric reservoir, or a transition to a sleeve gastrectomy (35).

Another key complication after the RYGB surgery includes a variety of nutritional deficiencies (30). These nutritional deficiencies include B12, Folate, Thiamine, Iron, Calcium and Vitamin D, Zinc, Copper, Selenium, and Vitamin C (30).

Low vitamin B12 levels are reported in 30% to 35% of the patients one year post-RYGB surgery (30). In a healthy patient, Vitamin B12 is freed with the help of stomach acid and then bound by a protein called R-Binder (30). In the small intestine, enzymes from the pancreas then break up that bond in order to free the Vitamin B12, allowing the vitamin to complex with the intrinsic factor (30). In the following, the complex is assimilated in the terminal ileum (30). After RYGB surgery, this cascade of steps is altered or even disrupted due to changes in the stomach and intestines, consequently leading to a deficiency of vitamin B12 in patients (30). Vitamin B12 supplementation, either administered orally or via injection, is indicated in these patients (36).

Low folate levels are reported in 6% to 35% of the patients after RYGB surgery (30). Although the resorption of folate occurs in the jejunum, the deficiency is mainly caused by an inadequate intake (30). Acute treatment involves the administration of supplements to resolve symptoms such as irritability or forgetfulness, which can then be prevented by the daily intake of 400 mg as a multivitamin (30,37).

With an occurrence rate of 30% to 55%, iron deficiency is the most prevalent reported nutritional deficiency in patients after RYGB surgery (30). Iron uptake is facilitated by exposure to gastric acid and proteolytic enzymes from the duodenum, which then results in molecular changes (30). Although iron can be taken up everywhere in the intestinal tract, the absorption is primarliy in the duodenum

(30). Insufficient iron saturation is consequently due to the bypass of this mechanism in RYGB patients (30). The acute treatment involves oral or even intravenous supplementation and is then maintained with multivitamins (30).
Oral supplementation is the treatment of choice for thiamine deficiency (vitamin B1), Zinc, Copper, Selenium, and Vitamin C and is usually achieved with multivitamins (38).

Just as complications, mortality is further subdivided into early, within up to one month post-surgery, and late morbidity, which accounts for 90 days post-MBS (39). It has been stated that the combined mortality rate of the open and laparoscopic RYGB procedures is 0.46% (39). The laparoscopic technique has shown a much lower death rate of 0.22% compared to open RYGB, which has a mortality incidence of 0.82% (39). Decreased complications of LRYGB are decisive for these widely divergent values (39). Since, almost exclusively, the laparoscopic technique is applied, the mortality rates of the MBS procedure for RYGB are significantly low (39). However, low complication and mortality rates can only be expected in highly specialized centers (39).

Weight regain (WR) is among the long-term complications many patients face following bariatric surgery and can be attributed to multifactorial causes (40). Recent literature states that subsequent to achieving peak weight loss (around 2 years post-surgery), 50.2% of patients experienced an increase of more than 15% from the lowest weight 5 years post-RYGB. In 86.5% of patients, more than 10% of the lowest measured weight was regained after that time (41). A study by Cooper et al. concluded that after 7 years, a mean WR of 23.4% was recorded (42).

5 RESULTS OF INCLUDED STUDIES

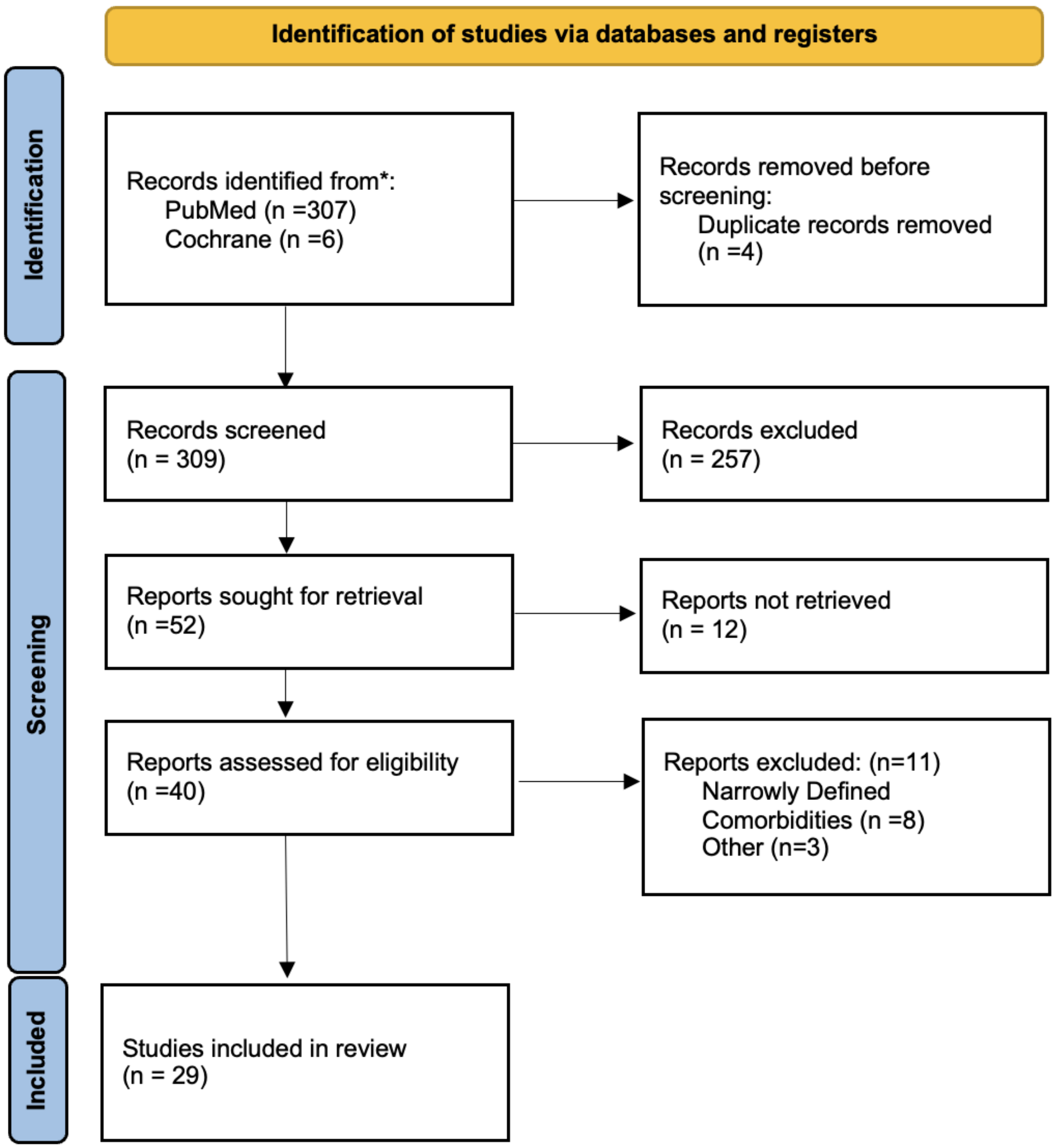

Figure 3 - PRISMA 2020 Flow Diagram

5.1 PRISMA CRITERIA

In total, 313 records were identified from PubMed and Cochrane searches. Out of these, four records were removed prior to the screening process due to being duplicates. Following this, 309 records were screened, of which 257 were excluded for not fulfilling the predetermined inclusion criteria. Subsequently, 52 reports were sought for retrieval, of which 12 reports could not be retrieved, leaving us with a total of 40 reports, which were then assessed for eligibility. Upon assessing these records, 11 studies were excluded for the following reasons: Narrowly defined comorbidities (focus on psychiatric disorders, malnutrition), low sample size, and median follow-up duration of less than 10 years. Ultimately, 29 studies met all inclusion criteria and were considered eligible for inclusion in this systematic review.

5.2 CHARACTERISTICS OF STUDIES

The 29 articles that met the inclusion criteria comprise various study types, underlining the comprehensive nature of the review. Out of the included articles, 22 were retrospective cohort studies, four were prospective cohort studies, two were previous randomized controlled trials, and one was a retrospective data analysis, as detailed in Table 2.

The studies initially included 11,435 patients who underwent RYGB as the initial surgery method. With a 10-year follow-up rate of 44%, 4,995 patients were included in the analysis, providing a fundamental and robust dataset for the review. The median follow-up duration ranged from 10 to 16.5 years, with an average of 11 years across all studies.

5.3 WEIGHT LOSS PARAMETERS

The baseline BMI was evaluated in 25 articles. Out of the 25 articles, only 20 reported the BMI 10 years post RYGB surgery To further evaluate long-term effects of RYGB surgery on weight 10 years post-surgery, the following additional weight reduction parameters were taken into account: %TWL from 23 articles, %EWL from 15 articles, and %EBMIL from 14 articles. All studies have listed at least one weight-reduction value ten years after the bariatric RYGB surgery. The BMI at baseline averaged 49.1 (±3.4) kg/m2. After ten years, the BMI has decreased to an average of 35.9 (±4.1) kg/m2. The % TWL results showed a reduction of 28.9 (±3.8) %, the %EWL 60.9 (±7.6) %, and the %EBMIL 57.8 (±9.8) %, ten years after the surgery.

Numerous studies have noted a significant weight reduction two years post-surgery, highlighting the procedure's primary impact. In 15 articles, the results of 2-year and 10-year follow-ups have been assessed. The evaluation of these two follow-up intervals is shown in Table 3. The results show the same baseline BMI since they originate from the same studies. The BMI assessed 2 years after the surgery was 30.1 (±1.6) kg/m² [Table 3]. In comparison with the BMI, which was evaluated 10 years after the surgery, the BMI has increased by 19.0 %. This difference in change was highly statistically significant (p-value <0.001**). The %TWL 2 years after RYGB initially showed a peak reduction of 35.7 (±4.6) %; however, at the ten-year mark, the TWL has decreased by 6.8 % compared to the 2-year mark [Table 3]. These values were also highly statistically significant (p-value: <0.001**).

Two years after the RYGB surgery, the %EWL was considered to be 75.2 (±11.4) %, whereas after 10 years, it has decreased to 60.9 (±7.6) % [Table 3]. This change corresponds to a difference of 14.2 %, indicating a statistical significance (p-value 0.004*). The most significant percentile difference was observed for the %EBMIL [Table 3]. Notably, there was a reduction of 18.2 % from the peak value of 75.9 (±4.4) % 2 years after the surgery to 57.8 (±9.8) % 10 years after the surgery [Table 3]. With a p-value of <0.001**, this reduction is highly statistically significant [Table 3].

Table 3- Comparison of weight reduction 2 years and 10 years post-RYGB

Weight reduction parameter	2 years after RYGB	10 years after RYGB	*Difference (%)*	*P-value*
BMI at Baseline (kg/m²)	49.08 ±3.37	49.08 ±3.37	-	-
BMI (kg/m²)	30.14 ±1.61	35.88 ±4.05	19.04	**<0.001****
%TWL	35.67 ±4.63	28.92 ±3.77	-6.75	**<0.001****
% EWL	75.16 ±11.38	60,93 ±7,58	-14.23	**0.004***
% EBMIL	75.94 ±4.40	57.75 ±9.79	-18.19	**<0.001****

* significant change (P<0.05); ** highly significant change (P<0.001)

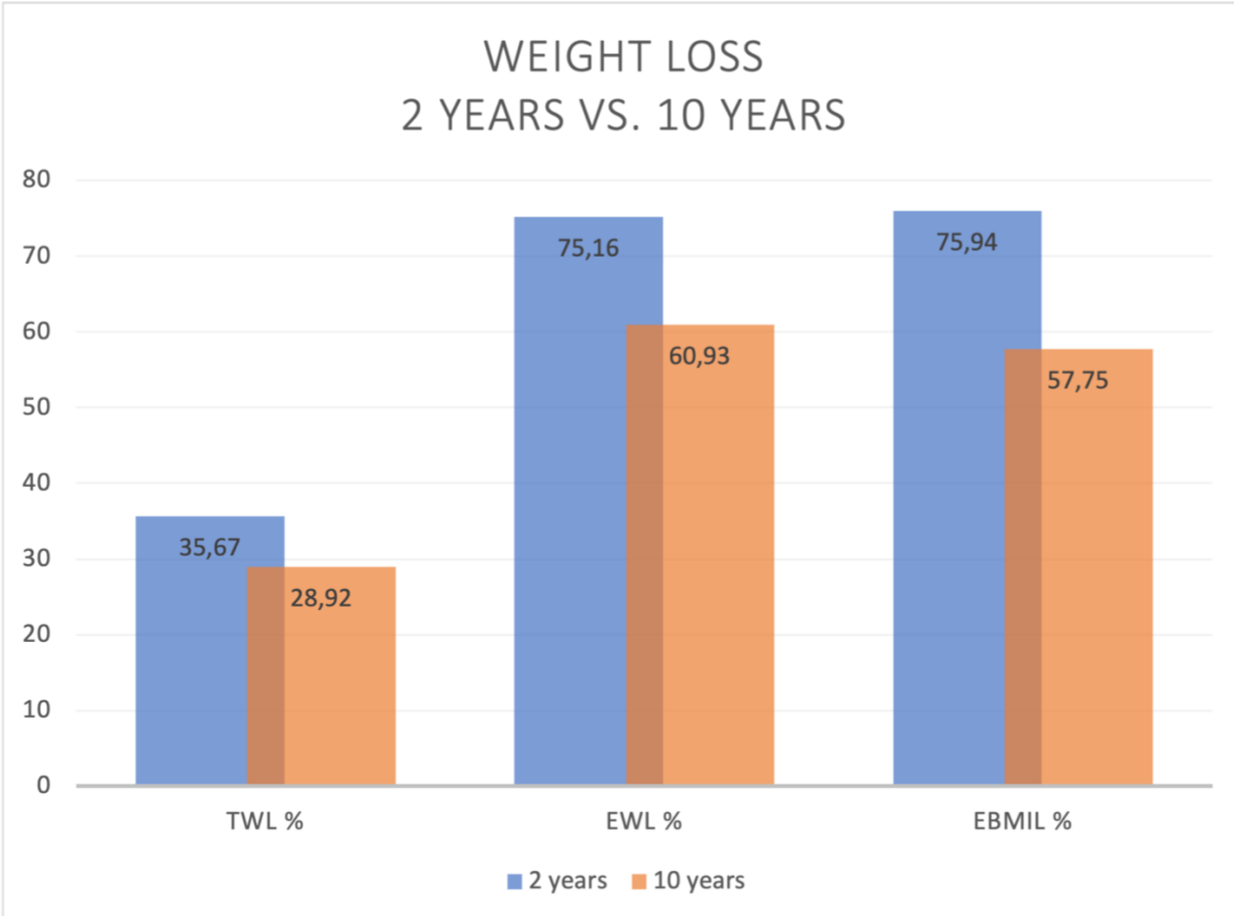

Figure 4 – Comparison of weight loss 2 years and 10 years post RYGB based on; TWL%; EWL%; EMBL%

5.4 COMORBIDITY PARAMETERS

23 studies stated the effect of RYGB 10 years after the procedure on comorbidities. 23 articles evaluated the outcomes of T2DM, 15 articles on Hypertension, 12 studies on Hyperlipidemia, 7 articles on GERD, and 9 articles on OSAS, as presented in Table 4.

Out of the 23 studies, 22 provided the criteria for improvement or remission. Most studies defined remission as achieving normal clinical parameters without needing medication, while a reduction in medical therapy characterized improvement .

An average of 29.1% of the patients which received bariatric RYGB surgery were previously diagnosed with T2DM. The remission of these patients ten years after the procedure accounted for 61.9% [Table 4]. The percentile of patients diagnosed with Hypertension criteria was 55.5% pre-surgery and showed a remission rate of 49.5% ten years after [Table 4]. 43.7% of the included patients showed hyperlipidemia criteria and had a 10-year post-operative remission rate of 61.3% [Table 4]. In around 43.8% of the patients, symptoms of GERD were present and had improved by 54.4% of the patients [Table 4]. The baseline of patients who showed symptoms of OSAS was 30.4% [Table 4]. After ten years, remission was observed in 66.1% of the patients [Table 4].

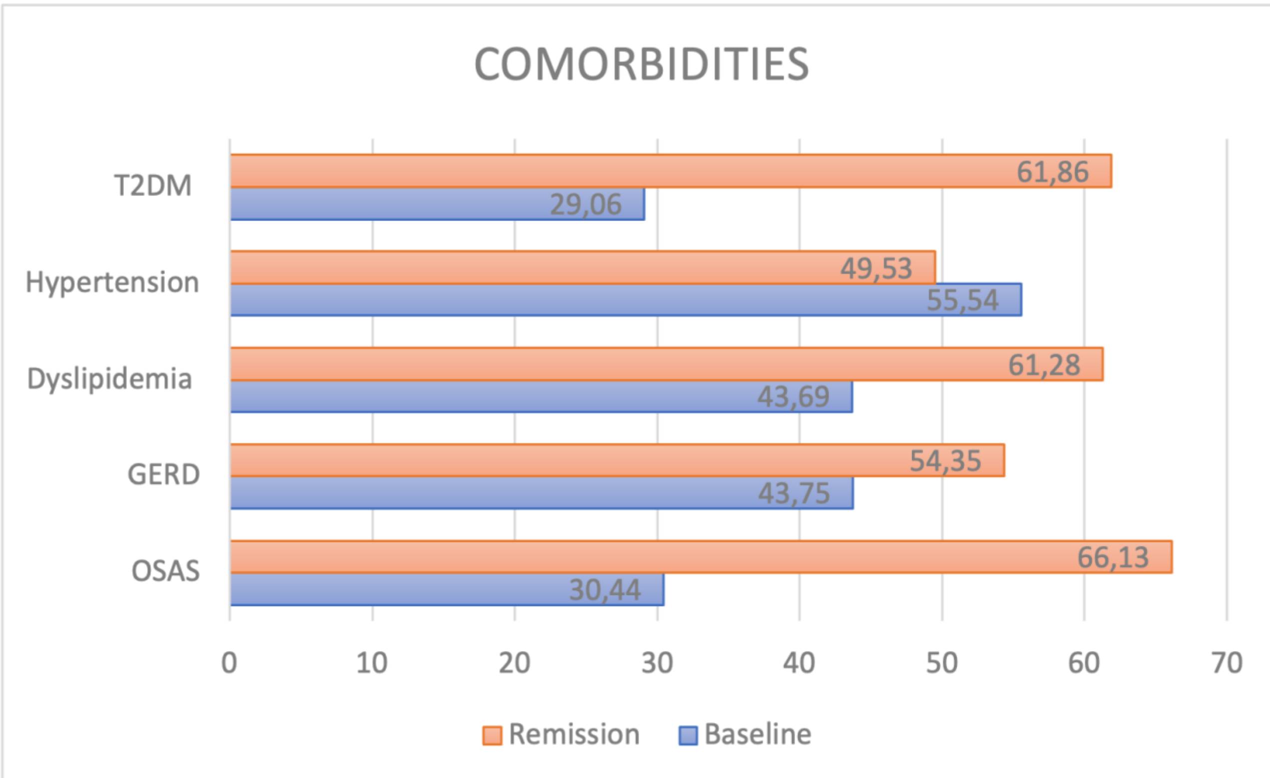

Figure 5 - Baseline and remission rates of the following OR-NCDs: T2DM, Hypertension, Dyslipidemia, GERD, and OSAS

6 DISCUSSION

In the past, bariatric surgery was indicated for obesity class II with one or more OR-NCDs or obesity class III with or without the diagnosis of OR-NCDs (8,43,44). The ASMBS has updated recommendations from 2022 stating that class I obesity with exacerbation or severe OR-NCDs should be considered for MBS, as for Class II obesity even without OR-NCDs if conservative treatments are utilized (14). For the Asian population, even lower BMI ranges are recommended due to the advanced risk of developing cardiac diseases or complications. Surgery should, therefore, be adjusted to a BMI range of 25 - 27.5 kg/m² (14). These new recommendations show a shift towards surgery with a lower BMI range due to prognostic better weight reduction outcomes (14). High-risk patients are considered those who are “super obese” or ”super-super obese,” as well as patients older than 70 years (19). These groups of patients have been found to be more susceptible to complications and mortality, on the one hand, due to difficult operative conditions and, on the other hand, due to severe comorbidities (19).

RYGB remains the second most often conducted bariatric surgery after SG (5). The laparoscopic procedure, with a commanding 99.1% dominance in MBS techniques, provides a series of advantages (22). These comprise more abbreviated hospital stays, fewer complications, faster recovery and mobilization, and less post-operative pain, surpassing the open procedure (21). While the RYGB techniques may vary from surgeon to surgeon, the method is standardized, involving four steps that bypass food content from a small gastric pouch directly to the small intestines, thereby disabling the remaining stomach for absorption (8). An alimentary limb, comprising the remnant stomach and the duodenum, is anastomosed with the distal jejunum, facilitating the emptying of gastric, biliary, and pancreatic secretions into the small intestine while preserving the enzymatic absorption of food (8,21-23).

Complications can be classified as “early” and “late” and are differentiated by the days after surgery. Early compilations that occur <30 after MBS include DVT, PE, anastomotic leaks, and gastrointestinal bleeding (29). Immediate action is required to prevent severe complications or mortality. Late complications, while they may have relatively less severe and acute complications, underscore the importance of post-operative care and follow-ups as they may need further treatment, such as supplements, surgical procedures, or revisions (29).

This systematic review has revealed the long-term success of weight loss after RYGB (10 years and more). By comparing 29 recent studies that have evinced the results of retrospective cohort studies and prospective cohort studies, the outcome has shown that weight reduction was effective. However, the comparison of the weight outcomes two years and ten years post-surgery reveals a significant decrease in weight loss. The results have shown a rise in BMI and a notable reduction in the percentile weight loss measures in the long-term follow-up beyond ten years after the surgical procedure.

The systematic review shows that the remission of OR-NCDs, such as T2DM, Hypertension, Hyperlipidemia, OSAS, and GERD, has also been successful. Therefore, improving OR-NCDs reduces diseases that can eventually lead to early mortality in obese patients.

6.1 WEIGHT LOSS

The results of the included studies revealed an average TWL% of 28.92% after 10 years. Comparing this finding with a meta-analysis by Georgis-Ioannis Verras et al., which examined common bariatric surgeries like SG, RYGB, and GB, the outcomes showed a higher TWL% value of 37.6% (45). This difference in number could be attributed to the smaller sample size of 322 patients for RYGB in the meta-analysis (45). In our review, the overall sample size was 4995 individuals who received RYGB and were followed up for 10 years.

The average of our analyses shows a value of 60.93% for the % EWL after 10 years. A systematic review by Paul E O'Brien et al. (46) elaborated on similar but slightly lower values. This review compared all bariatric surgery procedures and stated an %EWL of 56.7% after 10 years or more (46).

The results of our analyses have also revealed the outcomes after 2 years, which have been stated as the plateau of weight loss but gradually decreased after this breaking point. An increase in BMI values with a simultaneous reduction in %EWL, %TWL, and %EBMI indicates a trend of weight regain among patients. Further, this trend bears significant challenges for the long-term sustainability of bariatric outcomes, emphasizing the need for further research and intervention.

Possible reasons for this tendency include many factors that can impact the patient's body and, therefore, the weight changes over time. On the one hand, physiological factors such as metabolic adaptation can cause a diminished resting metabolic rate (RMR) post-MBS, known as adaptive thermogenesis. An article from the *Journal of Clinical Endocrinology & Metabolism* (47) published a study observing a reduction in RMR and diminishing the caloric deficit determined by the surgical procedure.

Further suggestions of physiological factors that could influence weight changes after surgery include a shift in hormone secretion that regulates eating drive and satisfaction (48). After surgery, there is a decrease in ghrelin, a hormone that causes hunger, and an increase in leptin, which induces satiety and promotes weight loss (48). However, over time, there may be an adaptation of hormonal changes, causing a rise in ghrelin and a drop in leptin (48). A study conducted by Marco Santo et al. stated that in patients who regained weight, the pattern of secretion of these specific intestinal hormones is different compared to patients who did not regain weight (48). In contrast, continuous weight loss might be possible for other individuals due to stable hormone secretion, highlighting the complexity of weight regain factors (48).

Further, a possible explanation is the adaptation of the gut after RYGB by increasing its absorptive capacity, which counterbalances bariatric surgery's malabsorptive effect. A review in the Journal of *Endocrinological Investigation* (49) discussed these factors, which could further influence the long-term weight loss outcomes of RYGB.

Another aspect of weight regain can be behavioral factors, which play a significant role in the success of weight loss after RYGB. Patients can fall back into old patterns and prefer a high-calorie diet instead of a high-fiber and healthy diet. Poor understanding and implementation of nutritionists' advice can lead to weight regain (50). Equally important is physical activity, which is crucial for the success of adequate weight loss. The lack of physical activity can be associated with less favorable outcomes after MBS (51). Psychological challenges can also be a component of weight regain over time. Stress eating habits or psychological disorders, such as binge eating, can, without further long-term treatment and support, lead to unwanted weight regain.
A lack of nutritional adaptation, physical activity, and psychological factors accounts for almost 50% of the patients experiencing weight regain after RYGB. Maladaptive eating behaviors, including junk food and frequent snacking, statistically decreased %TWL by around 20-30% (50). Therefore, critical dietary adherence can significantly increase the success of MBS in the long term (52).

Surgical and anatomical factors can be one of the reasons why weight loss might stagnate. Dilation of the gastric pouch volume or the enlargement of surgical connection points, such as the gastrojejunal stoma diameter, can diminish the effectiveness of RYGB (52).

This triad of physiological, behavioral, and anatomical factors affecting long-term bariatric success should be stressed from the beginning of the MSB procedure. Comprehensive patient support, such as individualized follow-up care, lifestyle interventions, and potential surgical revisions, can collectively influence the long-term success of weight loss.

6.2 COMORBIDITIES

Weight loss, as a primary indicator in determining MBS success, is of great significance. Moreover, the course of the most common OR-NCDs, such as T2DM, hypertension, hyperlipidemia, GERD, and OSAS is also a crucial indicator in determining the overall success of MBS.

In our analysis, a remission of T2DM was observed in 61.9% of the patients diagnosed before the bariatric procedure of RYGB. Slightly lower but similar remission rates were observed in other studies conducted by M. Chahal-Kummen et al. and Marza Guimarães et al., with remission of T2DM in 56.8% and 54.2% of the patients (53,54). These differences could be due to unclearly defined criteria for the improvement and/or remission of T2DM, which might differ from study to study in this review. M. Chahal-Kummen et al. also observed higher remission rates of T2DM 5 years after RYGB, with 64.7% (54). However, after the 10-year follow-up, lower values were shown (54). In a meta-analysis of Zhiqing Yu et al., a relapse rate of 30.0% was described after initial remission after RYGB (55). A possible explanation discussed in the article by M. Chahal-Kummen et al. could be weight regain, which is a prevalent issue post MBS that can impact the long-term outcomes of the procedure regarding T2DM (54).

A major problem remains the divergence of criteria for defining T2DM remission. The need for more unified values for improving and/or remitting T2DM is especially important when evaluating and comparing different study results. In literature, terms such as *resolution, reversal, remission* (partial and complete), and *cure* of T2DM define the patient's disease state (43). An international consensus report from the *American Diabetes Association* in 2021 aimed to standardize the definition and interpretation of remission in Type 2 Diabetes (43). They evaluated the various terms used in the definitions, questioning whether they line up with the current state of the disease, ultimately concluding that only the term "remission" was appropriate (43). The consensus of the *American Diabetes Association* (2021) stated the following clarification:

1.) *"The term used to describe a sustained metabolic improvement in T2D to nearly normal levels should be remission of diabetes."* (43)

2.) *"Remission should be defined as a return of HbA_{1c} to <6.5% (<48 mmol/mol) that occurs spontaneously or following an intervention and that persists for at least 3 months in the absence of usual glucose-lowering pharmacotherapy."* (43)

3.) *“When HbA1c is determined to be an unreliable marker of chronic glycemic control, FPG <126 mg/dL (<7.0 mmol/L) or eA1C <6.5% calculated from CGM values can be used as alternate criteria.”* (43)

The need for regular glycemic monitoring and the unified definition and implementation of study protocols is essential for the evaluation of the outcomes of MBS. The analysis of M. Chahal-Kummen et al., along with others (54–56), has observed a reduced remission rate over time (10 years or more). This could be due to weight regain and, therefore, should be accounted for in the overall long-term success rate of RYGB. Nonetheless, it is worth mentioning that 10 years after the RYGB procedure, great remission rates were achieved, which consequently impacts the patient’s health outcomes and quality of life significantly. These findings can guide future studies in this field, potentially leading to more effective analysis.

In this analysis, 55.54% of the patients were diagnosed with hypertension before they underwent RYGB surgery. Remission was observed in an average of 49.53% of these patients 10 years post-MBS, ranging between 20% and 85%. Similar results came from a retrospective observational cohort study among 585 subjects, which revealed a 54.2% remission rate of HTN 10 years post-RYGB. This improvement is based on two mechanisms, which are decreased body weight and hormonal secretion changes. Decreased body weight positively impacts the course of HTN due to reduced vascular resistance in the vessels (57).

In terms of hormonal changes, a decrease in leptin secretion in the gut contributes to an improvement in the renin-angiotensin-aldosterone system’s regulation (58). However, if weight regain remains a significant issue, this can affect the outcomes of HTN remission in the long term by impacting both mechanics, vascular resistance, and hormonal changes that regulate blood pressure (57,58).

Obesity is closely related to dyslipidemia, which is characterized by elevated triglycerides, low high-density lipoprotein (HDL) cholesterol, and increased low-density lipoprotein (LDL) cholesterol. These changes in the lipid panel heighten the risk of cardiovascular diseases. Short-term effects can be seen within the first year post-RYGB and have shown a reduction in LDL and an increase in HDL cholesterol (59). This trend is seen even more in long-term results, gradually improving cholesterol and triglycerides (53). The comparison by M. Chahal-Kummen et al. of 5-year and 10-year follow-up results has shown increased remission rates from 42.3% to 46.0% over time (54). In a different analysis, the 10-year results reached 52.4% (53). Out of 12 studies included, our results revealed a remission rate of 61.28%. These findings show significant outcomes for treating HL. Around 43.69% of the patients initially presented with dyslipidemia; these results are essential and could possibly result in a reduced risk of developing cardiovascular diseases. Weight loss and, therefore, a decrease in free fatty acid release promotes the enhancement of lipid profiles. Hormonal changes, such as increased glucagon-like peptide-1 (GLP-1), produced in the gut, are crucial in regulating lipid metabolism (60). Another aspect can be the post-operative dietary adjustments that include reduced fat intake and healthier nutrition (60).

The long-term results of GERD symptoms after the RYGB surgery show substantial remission rates of 54.35%. The improvement in symptoms may be attributed to weight loss, consequently reducing intra-abdominal pressure, or due to anatomical changes by forming a smaller stomach pouch, which can bypass food (61,62). The anatomical changes plus the pressure relief on the esophageal sphincter, can, therefore, diminish acid exposure in the esophagus (61). Additionally, by decreasing gastric volume, fewer acid-producing cells lead to reduced acid levels (61). Another advantage of reconstructing the gastric pathway is the diversion of bile and pancreatic secretions into the distal jejunum (61). These factors can influence acid production and thus significantly reduce reflux symptoms in post-RYGB patients (61).
However, there are discrepancies in how remission of GERD has been defined. Remission is frequently defined by symptom relief after MBS rather than being combined with pH monitoring or endoscopy investigations (63). This approach can be problematic since the perception of symptoms can vary from person to person and may be either over- or underestimated (64,65). Some patients may report no symptoms despite esophageal changes, such as erosive esophagitis or Barrett's esophagus (65). The lack of standardized remission criteria remains crucial for accurately assessing and comparing study results.

The results of obstructive sleep apnea syndrome (OSAS) remission rates have shown successful long-term outcomes of 66.13%. A prospective multicenter trial published in the *Obesity Surgery Journal* revealed long-term outcomes at 5 years post-RYGB, with a remission rate of 55% (66). Furthermore, another literature study states a 45% remission rate 10 years post-surgery (67).
On the one hand, these differences in results can be attributed to the variance in study populations, with milder OSAS severity leading to a higher remission rate due to less progressive airway alterations, as well as the exclusion of high-risk groups with advanced pulmonary or cardiovascular conditions, which contributes to higher remission rates. On the other hand, differences in the remission criteria can

influence outcomes. The definition of remission in OSAS varies between studies; whereas some studies rely solely on symptom improvement, others include the discontinuation of continuous positive airway pressure (CPAP), a reduced apnea-hypopnea index (AHI) below a defined threshold, or objective measures such as polysomnography (68). This discrepancy can result in varied remission rates, suggesting higher success rates. An article from the Journal of *Surgery for Obesity and Related Diseases,* 2021, has highlighted that reliance on self-reported data without polysomnography can lead to inaccurate evaluations (69). The current absence of standardized OSA criteria and definitions leads to either overestimation or underestimation of remission rates, complicating a uniform assessment.

6.3 FOLLOW-UP

The analysis of the 29 included studies revealed a 10-year follow-up rate of 43.68%, which is similar to a retrospective survey by Georgios-Iannis Verras et al. that evaluated the follow-up rates 10 years post-surgery for different bariatric procedures, reporting a follow-up rate of 40.9% among patients who underwent RYGB (45). This relatively low participation and, consequently, a diminished sample size present challenges in determining the statistical significance of long-term outcomes, which may lead to inconclusive or misleading findings. Low follow-up rates can introduce selection bias, wherein patients experiencing complications or less favorable outcomes do not participate in long-term follow-up studies. This is particularly relevant for patients who may struggle with implementing behavioral changes such as dietary adjustments and/or physical activity, as discomfort may result in rejecting study participation. The issue of selection bias may subsequently lead to overestimated success rates of RYGB outcomes.

Comprehensive follow-up strategies should be included in the bariatric program to achieve better long-term outcomes and, hence, increased statistical power. These strategies may compose regular meetings with flexible scheduling and frequent educational sessions. This approach does not only enhance outcomes by increasing adherence with healthcare providers, nutritionists, and specialized bariatric nurses but also improves retention rates.

6.4 LIMITATIONS

This systematic review is significantly limited by variations in the definition of a successful outcomes regarding the long-term results of the RYGB procedure. The results showed an overall reduction in weight loss values 10 years post-RYGB. However, in the majority of studies, there has been no accurate percentile value for tracking weight regain. If noted, the inconsistent definitions of weight regain have made assessing these outcomes challenging.

Furthermore, there has been a variability in how the success of bariatric surgeries is defined. Inconsistency in success measures, such as weight loss only, improvement of quality of life, and remission of comorbidities, has made it complicated to draw robust conclusions. Patient-reported outcomes, such as satisfaction or psychological well-being, have rarely been evaluated in terms of the success rate of outcomes.

The issue of a low follow-up rate for long-term outcomes 10 years or more after primary surgery reflects the questionable validity of the study results.

The lack of unified criteria for evaluating comorbidities further impedes the assessment of results across studies. Differences in the definition of improvement/remission in OR-NCD, as well as varying thresholds and degrees of diagnostic intervention for evaluating improvement, limit the unified comparison of results.

Some included studies exhibited methodological issues, including small sample sizes and conflicts of interest. Bariatric surgeries are in the financial interests of hospitals and medical companies, which may favor positive study outcomes. This situation may limit the reliability of specific study outcomes involving conflicts of interest.

7 CONCLUSION

This review provides an in-depth analysis of the long-term outcomes of the RYGB bariatric procedure over a period of 10 years or more. The findings confirm the highly effective outcomes of RYGB, including success in weight loss measures and the remission rates of OR-NCDs.

However, when comparing two-year and ten-year weight loss results, a gradual reduction in weight loss values along with a rise in the BMI values is visible. This indicates challenges with weight maintenance and even weight regain over time. Further investigation is necessary to evaluate the degree of weight regain and to determine the leading factors that cause regression after successful weight loss. This can help develop prevention strategies accurately.

The long-term outcomes of several obesity-related comorbidities demonstrate high remission rates and, therefore, indicate beneficial health outcomes in managing metabolic and cardiovascular diseases and conditions. However, a consensus in OR-NCD definitions and internationally established thresholds for interpreting improvements or remission of comorbidities is crucial for further evaluation of bariatric outcomes, especially in the long term.

Low follow-up rates a decade after surgery hampered the evaluation and significance, indicating difficulties in developing selection bias and, thus, diminished generalizability of the findings. To facilitate future research, it is of great importance to increase the overall follow-up duration as well as improve follow-up rates. Adherence to bariatric health care providers and outpatient facilities is necessary to increase the follow-up rate and success in weight loss.

Additionally, various criteria are used to define the success of RYGB outcomes, making it difficult to evaluate the operation's overall success. Therefore, further studies should implement more unified criteria for defining MBS success outcomes.

8 ADMINISTRATIVE AND ETHICAL DECLARATIONS

8.1 CONSENT FOR PUBLICATION

Not applicable.

8.2 STANDARDS OF REPORTING

PRISMA guidelines and methodology were followed in this study.

8.3 FUNDING

None.

8.4 CONFLICTS OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

8.5 ACKNOWLEDGEMENTS

Declared none.

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10 TABLES

Table 2- Characteristics of included studies

Author	Year	Type of Study	Surgical Technique	Number of Patients at Baseline (A), After 10 Years (B)	BMI at Baseline (kg/m2)	BMI at 10 Yrs. (kg/m2)	%TWL at 10 Yrs.	%EWL at 10 Yrs.	%EBMIL at 10 Yrs.
Obeid NR, et al. (70)	2016	retrospective cohort study	LRYGB	A: 294 B: 134	47.5	31.8	31.6	58.9	70.7
Chen Y, et al. (71)	2016	retrospective cohort study	RYGB	A: 173 B: 78	49.9	-	-	-	-
Sjöholm K, et al. (72)	2016	prospective cohort study	RYGBP	A: 265 B: 159	-	43.06	25.1	-	-
Mehaffey JH, et al. (73)	2016	retrospective cohort study	RYGB; LRYGB	A: 1087 B: 651	53.1	-	27.7	-	52.5

Hunter MJ, et al. (74)	2016	retrospective cohort study	RYGB; LRYGB	A: 1087 B: 151	-	-	26.3	-	52.2
Mehaffey JH, et al. (75)	2017	retrospective cohort study	RYGB	A: 489 B: 31	-	48	-	-	-
Artero A, et al. (76)	2017	retrospective cohort study	RYGB	A: 79 B: 63	55	38.1	29.8	50.6	56.1
Nguyen NT, et al. (77)	2018	retrospective cohort study	RYGBP	A: 111 B: 48	46.5	-	29.1	61.4	65.8
Duvoisin C, et al. (78)	2018	retrospective cohort study	LRYGB	A: 554 B: 273	45.9	32.7	28.6	65.8	63.2
Rolim FFA, et al. (79)	2018	retrospective cohort study	RYGBP	A: NA B: 42	50.8	36.3	-	-	-
Carden A, et al. (80)	2019	retrospective cohort study	RYGBP	A: 108 B: 83	-	-	-	-	57.8

Jiménez A, et al. (81)	2019	retrospective cohort study	RYGBP	A: 390 B: 330	46.3	34.5	25.3	56	-
Shah K, et al. (82)	2019	retrospective cohort study	RYGBP	A: 671 B: 209	50.6	34.1	32.5	63.3	-
Suter M, et al. (83)	2019	retrospective cohort study	RYGBP	A: 820 B: 638	45.8	32.5	28.8	-	66.1
Etienne JH, et al. (84)	2020	retrospective cohort study	LRYGB	A: 415 B: 32	44.1	32.0	29.4	71.0	-
Major P, et al. (85)	2020	retrospective cohort study	LRYGB	A: 31 B: 19	52.6	33.3	36.5	62.2	72.7
Elshaer AM, et al. (86)	2020	retrospective cohort study	RYGBP	A: 217 B: 192	47.0	-	27.0	-	-
Chahal-Kummen, et al. (54)	2020	prospective cohort study	LRYGB	A: 194 B: 121	45.6	36	24.1	53	46.6

Freire CC, et al. (87)	2021	retrospective cohort study	RYGBP	A: 96 B: 46	50.4	-	-	63.6	-
Gorecki P, et al. (88)	2021	retrospective cohort study	LRYGB	A: 576 B: 145	48.3	34.3	28.4	-	-
Angrisani L, et al. (89)	2021	retrospective cohort study	LRYGB	A: 105 B: 97	47.2	32.8	27.5	62.1	-
Järvholm K, et al. (90)	2021	prospective cohort study	RYGBP	A: 60 B: 10	55.7	40.2	32.4	-	50.1
Moriconi D, et al. (91)	2022	retrospective cohort study	LRYGB	A: 88 B: 88	46.7	32.8	-	-	-
Chang SH, et al. (92)	2022	retrospective cohort study	LRYGB	A: 1104 B: 250	54.7	37.1	31.0	-	59.8
Salminen P, et al. (67)	2022	retrospective cohort study	LRYGB	A: 119 B: 95	48.4	36.5	26.9	51.9	58.2

Bjerkan KK, et al. (93)	2022	retrospective cohort study	LRYGB	A: 959 B: 497	44.4	35.2	21.35	50.9	-
McClelland PH, et al. (94)	2023	prospective cohort study	LRYGB	A: 71 B: 20	49.5	-	31.8	-	-
Verras GI, et al. (45)	2023	retrospective cohort study	LRYGB	A: 786 B: 322	52.7	-	37.6	76.8	36.7
McClelland PH, et al. (94)	2023	prospective cohort study	RYGBP	A: 486 B: 171	48.4	36.5	26.5	-	-

Table 4 - Comorbidity rates at baseline and remission rates 10 years after bariatric RYGB surgery

Author(s)	Diabetes Mellitus		Hypertension		Hyperlipidemia		GERD		OSAS	
	Baseline %	Remission Rate %	Baseline %	Remission Rate %	Baseline %	Remission Rate %	Baseline %	Remission Rate %	Baseline %	Remission Rate %
McClelland PH, et al.	24.3	63.2	44.7	41.9	24.9	61.5	60.7	75.0	32.5	69.6
Etienne JH, et al.	12.5	90.6	34.4	78.1	9.4	96.8	18.8	25.0	15.6	87.5
Salminen P, et al.	41.0	33.0	73.0	24.0	38.0	35.0	71.4	84.0	29.4	31.0
Shah K, et al.	23.2	75.8	50.3	60.3	34.6	84.2	-	-	28.8	80.2
Mehaffey JH, et al.	41.3	57.4	59.2	20.4	-	-	38.4	25.5	35.8	54.7
Hunter MJ, et al.	36.8	60.6	56.4	18.1	-	-	35.9	30.9	35.9	57.1
Artero A, et al.	26.6	80.0	29.1	17.3	13.9	36.4	-	-	24.1	73.7
Duvoisin C, et al.	27.7	73.0	52.7	64.0	65.8	65.0	31.5	54.0	-	-
Obeid NR, et al.	20.0	58.0	56.0	46.0	60.0	46.0	-	-	-	-

Suter M, et al.	61.4	91.7	62.2	85.3	54.1	-	49.6	-	55.7	75.2
Nguyen NT, et al.	-	86.4	-	78.8	-	73.9	-	86.0	-	-
Jiménez A, et al.	29.7	62.3	58.3	40.2	51.9	71.0	-	-	-	-
Chahal K, et al.	31.9	56.8	82.5	41.4	83.3	46.0	-	-	-	-
Angrisani L, et al.	8.6	50.0	18.1	61.1	14.3	58.3	-	-	-	-
Rolim FFA, et al.	9.5	50.0	59.5	66.0	-	-	-	-	-	-
McClelland PH, et al.	9.6	64.7	-	-	-	-	-	-	-	-
Mehaffey JH, et al.	32.0	58.0	-	-	-	-	-	-	-	-
Gorecki P, et al.	26.0	59.4	-	-	-	-	-	-	-	-
Elshaer AM, et al.	45.6	36.0	-	-	-	-	-	-	-	-
Major P, et al.	64.5	-	96.8	-	74.2	-	-	-	16.1	-

Sjöholm K, et al.	-	48,3	-	-	-	-	-	-	-	-
Chen Y, et al.	-	52.6	-	-	-	-	-	-	-	-
Moriconi D, et al.	-	53.0	-	-	-	-	-	-	-	-