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Original Article

Minimally Invasive Bariatric Surgery: Advancements and Techniques

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Background: Minimally invasive bariatric surgery has nowadays become a cornerstone in the treatment of obesity, offering effective weight-loss solutions with fewer complications, shorter recovery times, and reduced hospital stays compared to traditional open surgeries. This review provides an overview of the most commonly used minimally invasive techniques, including Laparoscopic Roux-en-Y Gastric Bypass (LRYGB), Laparoscopic Sleeve Gastrectomy (LSG), Mini Gastric Bypass (OAGB), Laparoscopic Adjustable Gastric Banding (LAGB), and emerging endoscopic procedures such as Endoscopic Sleeve Gastroplasty (ESG) and Intragastric Balloon (IGB) Therapy.

Materials and Methods: Additionally, it delves into each procedure's mechanism of action, benefits, challenges, and expected outcomes. It also focuses on the patients' selection criteria helping them determine the most appropriate approach. The review highlights that minimally invasive approaches can significantly reduce operative trauma, hospital stays, and postoperative complications, and also improve obesity-related comorbidities such as type 2 diabetes and hypertension.

Results: It is assumed that LRYGB and OAGB combine restrictive and malabsorptive mechanisms, leading to substantial weight loss and metabolic improvements, but require careful long-term nutritional monitoring. LSG, primarily a restrictive procedure, offers a favorable safety profile and is supposedly associated with significant appetite reduction due to hormonal changes.

Conclusion: The article further discusses the challenges and complications such as anastomotic leaks, nutritional deficiencies, and bile reflux, which are unique to each technique. Overall, advances in minimally invasive bariatric surgery have expanded treatment options, improved patient outcomes, and set the stage for further innovations in obesity management.

Keywords: bariatric surgery, Mini Gastric Bypass, Laparoscopic Sleeve Gastrectomy

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Introduction

Obesity has become a significant global health issue, affecting millions of individuals and contributing to an increased burden of chronic diseases such as type 2 diabetes, hypertension, cardiovascular disease, and certain cancers.[1] The prevalence of obesity has dramatically escalated over the past few decades due to sedentary lifestyles, high-calorie diets, and genetic

predispositions.[2] This condition is not merely a cosmetic concern but a complex metabolic disorder requiring effective long-term management strategies. While lifestyle modifications, including dietary changes and exercise, play a crucial role in weight management, these interventions often fail to provide sustained weight loss for individuals with severe obesity.[3] Pharmacological treatments have shown limited success, and adherence remains a significant challenge.[4] As a result, bariatric surgery has emerged as the most effective solution for not only achieving substantial and durable weight loss but also improving obesity-related comorbidities.[5] Traditional open bariatric surgeries, though effective, were associated with higher morbidity, prolonged recovery time, and increased postoperative complications. However, with the advancement of minimally invasive techniques, particularly laparoscopic and endoscopic bariatric procedures, patients now have access to safer and more efficient surgical options. Minimally invasive bariatric surgery offers several advantages, including reduced operative trauma, lower risk of complications, shorter hospital stays, and quicker recovery. In this article, we explore the evolution of minimally invasive bariatric surgery, discuss the key laparoscopic and endoscopic procedures, compare their effectiveness and safety profiles, and examine the future directions of these innovative techniques.[6, 7]

Laparoscopic Bariatric Surgery

Laparoscopy has revolutionized bariatric surgery by enabling complex procedures to be performed through small incisions, reducing trauma to surrounding tissues, and significantly lowering postoperative recovery time. Compared to open surgery, laparoscopic bariatric surgery leads to reduced postoperative pain, shorter hospital stays, faster recovery, and lower rates of wound complications such as infections and hernias.[8] Laparoscopic bariatric surgery is now considered as the gold standard for weight loss surgery, with multiple procedures available to suit different patient needs.[9] the primary laparoscopic bariatric procedures are as follows.

1. Laparoscopic Roux-en-Y Gastric Bypass (LRYGB)

Laparoscopic Roux-en-Y Gastric Bypass (LRYGB) is one of the most commonly performed and effective bariatric surgeries for patients with severe obesity. This procedure is particularly suitable for patients with a Body Mass Index (BMI) over 35 or those with a BMI over 30 who also suffer from obesity-related comorbidities such as Type 2 diabetes, hypertension, and sleep apnea.[10,11] During this surgery, a small stomach pouch, typically around 20-30 mL in size, is created and separated from the rest of the stomach. This pouch is then connected directly to the jejunum (the middle section of the small intestine), bypassing a large portion of the stomach and the proximal small intestine, including the duodenum. This alteration in the gastrointestinal anatomy results in reduced calorie absorption and triggers hormonal changes that promote weight loss and metabolic improvements. The procedure is typically performed laparoscopically, through which small incisions are made in the abdomen and a camera (laparoscope) is inserted to guide the surgical instruments.[12] Compared to traditional open surgeries, this laparoscopic approach offers significant advantages such as smaller incisions, reduced blood loss, shorter hospital stays, and quicker recovery time.

LRYGB works through two main mechanisms. The first is restriction, through which the creation of a small gastric pouch can help limit the amount of food that can be consumed, thereby reducing caloric intake. The second mechanism is malabsorption, entailing a bypass of a portion of the stomach and the duodenum, which can ultimately limit the absorption of calories and nutrients from food.[13] This bypass also leads to hormonal changes in the gut that affect hunger, satiety, and insulin sensitivity. Furthermore, the bypassing of the duodenum alters gut hormones such as ghrelin (the hunger hormone) and glucagon-like peptide-1 (GLP-1), which can help enhance insulin sensitivity. These hormonal changes can significantly contribute to weight loss and improvements in obesity-related comorbidities.[14] LRYGB typically leads to rapid and significant weight loss, with many patients losing 60-70% of their excess weight within the first 12 to 18 months after the surgery.[12] This weight loss is often sustained long-term. The surgery is highly effective in

resolving or improving obesity-related conditions such as Type 2 diabetes, hypertension, and sleep apnea.[15] many patients, especially those with Type 2 diabetes, experience complete remission. Studies have shown that the weight loss achieved through LRYGB is often maintained for several years. The procedure is particularly effective for patients with a BMI greater than 40 or those with significant comorbidities. While LRYGB is generally considered highly successful, it is not without risks. Some potential complications include anastomotic leaks, where the surgical connection between the small stomach pouch and the small intestine (anastomosis) can leak, leading to infection or peritonitis, which may require immediate intervention. Another potential issue is internal hernias, where the rerouted intestine may shift, causing internal hernias that may require additional surgical procedures.[16] Nutritional deficiencies are also a big concern since part of the intestine is bypassed, impairing the body's ability to absorb certain nutrients such as iron, vitamin B12, calcium, and folate. Patients will need lifelong supplementation and regular monitoring to avoid deficiencies. Dumping syndrome is another complication that occurs when food, especially sugar, moves too quickly from the stomach to the small intestine, leading to symptoms like nausea, dizziness, sweating, and diarrhea.[12] Psychological impact is also an important factor, as patients must undergo a comprehensive psychological evaluation before and after the procedure to ensure they are prepared for the significant lifestyle changes that follow. Patients who undergo LRYGB require careful follow-up to ensure their weight loss is progressing as expected and manage any potential nutritional deficiencies. Regular visits to see a bariatric nutritionist and a surgeon are also required. Additionally, patients are encouraged to maintain a healthy diet, engage in regular physical activity, and avoid high-calorie, high-sugar foods to prevent any potential weight regain.[17]

2. Laparoscopic Sleeve Gastrectomy (LSG)

Laparoscopic Sleeve Gastrectomy (LSG) is one of the most commonly performed bariatric procedures and has gained significant popularity due to its effectiveness and relatively lower risk profile compared to other bariatric surgeries. During this procedure, approximately 75-80% of the stomach is surgically removed, leaving behind a narrow, sleeve-shaped tube. This tube, or "sleeve," is the new stomach, which is significantly smaller than the original stomach, restricting the amount of food that can be consumed.[18] unlike gastric bypass, LSG does not reroute the intestines, making it a simpler procedure with fewer technical complications. The surgery is typically performed laparoscopically, meaning that small incisions are made in the abdomen, and a laparoscope (a small camera) is inserted to guide the surgeon in removing the majority of the stomach while preserving its function. The primary mechanism of LSG is restriction, as the newly created stomach is much smaller, limiting food intake. Additionally, LSG has a metabolic effect, as it involves the removal of the fundus of the stomach, which can produce ghrelin, the hormone responsible for hunger. As a result, patients often experience a significant reduction in hunger, which helps them maintain a reduced caloric intake. LSG also leads to changes in gut hormones, improving insulin sensitivity and contributing to weight loss.[19]

Unlike gastric bypass, there is no malabsorption of nutrients in LSG because the intestines are left intact, preserving nutrient absorption. This is one of the reasons LSG has a lower risk of nutritional deficiencies compared to other procedures like Roux-en-Y gastric bypass. LSG offers several advantages, including significant weight loss, typically ranging from 50-60% of excess weight within the first year after the surgery. Additionally, it is a simpler procedure with fewer long-term complications compared to gastric bypass, making it an appealing option for many patients. Many patients also experience improvements or complete resolution of obesity-related comorbidities, such as Type 2 diabetes, hypertension, and obstructive sleep apnea. Studies have shown that the weight loss achieved with LSG is often maintained long-term, though it may not be as dramatic as that achieved with gastric bypass.[20] However, like any surgery, LSG is not without risks and challenges. One of the most common complications is leaks at the staple line, where the newly created stomach sleeve is sealed with staples. If a leak occurs, it can lead to infection or peritonitis, requiring immediate intervention.[21] another potential

complication is gastroesophageal reflux disease (GERD), which may develop or worsen after the procedure. Some patients may also experience nausea or vomiting due to the small stomach size.[22] Although LSG does not cause malabsorption, patients may still experience some difficulty in consuming large meals due to the restricted stomach size.[23] Another key challenge is that LSG is irreversible; once a large portion of the stomach is removed, it cannot be restored. While this typically does not pose a problem for most patients, it does mean that the procedure is not suitable for everyone, and a thorough evaluation is necessary to determine whether it is the right option. Furthermore, LSG is a restrictive procedure, suggesting that it relies heavily on the patient's ability to adopt and maintain long-term lifestyle changes, such as healthy eating habits and regular physical activity, to achieve optimal results. Postoperative care for patients undergoing LSG includes regular follow-ups with a healthcare team or a nutritionist and monitoring weight loss, nutritional intake, and any potential complications. Patients are advised to adhere to a balanced diet, take necessary vitamin and mineral supplements, and engage in regular exercise to maximize their weight loss and maintain overall health. It is important for patients to receive psychological support, as the surgery requires significant lifestyle changes and adaptation.[24]

3. One Anastomosis Gastric Bypass (OAGB)

Mini Gastric Bypass, also known as One Anastomosis Gastric Bypass (OAGB), is a relatively newer bariatric procedure that has gained popularity due to its simplicity, effectiveness and at times lower complication rates compared to traditional Roux-en-Y gastric bypass.[25] In this procedure, a long, narrow gastric pouch is created by dividing the stomach, which is then connected to the jejunum (the middle part of the small intestine) with a single anastomosis (connection) rather than the two anastomoses used in Roux-en-Y. This significantly simplifies the surgical technique and reduces the operating time, making it an attractive option for both patients and surgeons. The single anastomosis eliminates the need for a complex re-routing of the intestines, which is often associated with higher complication rates. The procedure works primarily through two mechanisms: restriction and malabsorption.[26] the small gastric pouch restricts the amount of food that can be consumed, leading to reduced caloric intake. At the same time, by bypassing a portion of the stomach and the duodenum, the procedure can limit the absorption of calories and nutrients from food, contributing to faster weight loss. The bypass also alters gut hormones, including ghrelin, which is responsible for hunger, and GLP-1, which improves insulin sensitivity. These hormonal changes further support weight loss and help improve metabolic conditions like Type 2 diabetes, hypertension, and other obesity-related diseases.[26] Mini Gastric Bypass offers several advantages, including shorter operative time, lower complication rates, and significant weight loss.

Most patients can expect to lose approximately 60-70% of their excess weight within the first 12 to 18 months after the surgery.[27] In addition, many patients experience improvements in or even complete remission of obesity-related comorbidities, particularly Type 2 diabetes and hypertension.[28] One of the key benefits of OAGB is that it has a lower risk of internal hernias and bowel obstruction compared to traditional Roux-en-Y gastric bypass, which requires two anastomoses.[29] This makes it a less technically demanding surgery with a faster recovery time. However, despite its advantages, Mini Gastric Bypass is not without its challenges and complications. One of the major concerns is bile reflux, which can occur due to the single anastomosis. This condition happens when bile, which is normally released into the small intestine to aid in digestion, flows back into the stomach and esophagus, potentially leading to gastritis, ulcers, and long-term damage to the esophagus.[30] another potential complication is nutritional deficiencies, as the procedure reduces the amount of small intestine available for nutrient absorption. Patients who undergo OAGB will need to take lifelong vitamin and mineral supplements, including iron, vitamin B12, calcium, and multivitamins, to prevent deficiencies.[31] There is also a risk of marginal ulcers, which can form at the anastomosis site, causing pain and discomfort, and may require further treatment.[32] Although the risk of complications is generally lower with OAGB

compared to other bariatric surgeries, careful patient selection is essential to minimize the risk of adverse outcomes. Patients with a history of gastroesophageal reflux disease (GERD) or other gastrointestinal issues may not be ideal candidates for this procedure. Postoperative care for patients who undergo Mini Gastric Bypass involves regular follow-up visits to monitor weight loss, assess nutritional status, and detect any potential complications. Patients are typically advised to follow a balanced, nutrient-rich diet and avoid high-calorie, high-sugar foods to support their weight loss goals. Like other bariatric procedures, lifelong commitment to healthy eating habits, regular exercise, and consistent medical follow-up are essential to achieve the best possible outcomes.

4. Laparoscopic Adjustable Gastric Banding (LAGB)

Laparoscopic Adjustable Gastric Banding (LAGB) is a restrictive bariatric surgery that involves placing a silicone band around the upper portion of the stomach, creating a small pouch above the band. This small pouch limits the amount of food the stomach can hold, resulting in a feeling of fullness after consuming small amounts of food. The band is adjustable, suggesting that the tightness of the band can be modified postoperatively by injecting or removing saline through a port placed under the skin, allowing for individual adjustment based on the patient's progress. Compared to other bariatric surgeries, this adjustability makes LAGB a unique procedure. The procedure is performed laparoscopically, during which small incisions are made in the abdomen, and a camera (laparoscope) is inserted to guide the surgeon in placing the gastric band around the stomach.[33] The laparoscopic approach reduces the risk of complications such as infection and wound healing issues, which are typically associated with open surgery. This minimally invasive technique also leads to shorter recovery time, less postoperative pain, and smaller scars compared to traditional open surgery.[34] LAGB works primarily by restricting food intake. The small stomach pouch above the band limits the amount of food a person can eat, leading to early satiety (feeling full sooner). Because the band is adjustable, the size of the pouch can be fine-tuned over time to meet the patient's specific weight loss needs. Unlike other bariatric surgeries such as gastric bypass or sleeve gastrectomy, this procedure does not alter the stomach's digestive processes or reroute the intestines, implying that nutrient absorption remains intact. This preserves the body's ability to absorb nutrients properly, which reduces the risk of malnutrition and deficiencies, which are more likely to occur with more invasive procedures. The primary advantage of LAGB is its less invasive nature,

As it does not involve cutting or stapling of the stomach or rerouting the intestines. Additionally, the adjustable nature of the band allows for customized weight loss, and the procedure is reversible if necessary, as the band can be removed. Furthermore, LAGB has a relatively low complication rate compared to other bariatric surgeries and is associated with a quicker recovery, as many patients can easily return to normal activities within a week or two.[35] However, LAGB also has its share of challenges and potential complications. One of the most significant issues is the relatively lower rate of weight loss compared to other procedures such as gastric bypass or sleeve gastrectomy. Patients typically lose around 35% of their excess weight over the first year, which is less than the weight loss achieved with more invasive procedures.[36] additionally, long-term success depends heavily on the patient's adherence to dietary guidelines and lifestyle changes. Without commitment to healthier eating habits and regular physical activity, weight regain is common after the procedure. Other potential complications of LAGB include band slippage, where the band moves out of its position, or band erosion, where the band can erode into the stomach wall. Both of these complications may require revision surgery. Additionally, esophageal dilation or difficulty in swallowing can occur in some patients if the band is too tight, which may require adjustments or band removal.[34] some patients may also experience gastroesophageal reflux disease (GERD), which can be exacerbated by the presence of the band. Postoperative care for patients undergoing LAGB includes having regular follow-up visits, monitoring weight loss, adjusting the band, and assessing the potential complications. Patients must follow a strict diet after

the surgery, starting with liquids and gradually progressing to soft foods and solids. Regular exercise is also recommended to support weight loss and overall health. Lifelong dietary monitoring is essential to ensure that patients maintain healthy eating habits and avoid issues such as overeating, which can lead to stretching of the stomach pouch or band complications.[37]

Endoscopic Bariatric Procedures

Endoscopic bariatric procedures provide a non-surgical approach to weight loss by modifying the gastric anatomy through the gastrointestinal tract, offering an alternative for patients who are not suitable candidates for or prefer not to undergo traditional bariatric surgery. These minimally invasive techniques utilize endoscopic tools inserted through the mouth to perform the procedure, eliminating the need for any external incisions or traditional surgical methods. While they may not be as effective as surgical bariatric options like gastric bypass or sleeve gastrectomy, they provide a lower-risk option with quicker recovery time and reduced complication rates.

1. Endoscopic Sleeve Gastroplasty (ESG)

Endoscopic Sleeve Gastroplasty (ESG) is a minimally invasive, non-surgical procedure designed to help individuals with obesity achieve significant weight loss. ESG is performed using an endoscope, a flexible tube with a camera attached, which is inserted through the mouth and down into the stomach. The procedure involves the use of sutures placed inside the stomach to reduce its size and shape, effectively mimicking the impacts of a traditional sleeve gastrectomy. Unlike traditional bariatric surgeries, ESG does not require any incisions, making it a much less invasive option with a quicker recovery time and fewer risks.[38] the process begins with the insertion of the endoscope through the mouth, allowing the surgeon to visualize the stomach. Once the stomach is adequately examined, the surgeon uses specialized suturing tools to create a sleeve-like structure by folding and suturing the stomach into a smaller, tube-like shape. This significantly reduces the stomach's capacity, limiting the amount of food that can be consumed and promoting early satiety. As a result, patients feel full after eating smaller portions of food, which contributes to weight loss.

The procedure works primarily through restriction. By reducing the size of the stomach, ESG limits the volume of food the patient can ingest.[39] additionally, the surgery leads to hormonal changes in the gut, which can help reduce hunger and improve insulin sensitivity. The reduced stomach size also leads to a reduction in the production of ghrelin, the hormone responsible for hunger, which helps curb the patient's appetite and makes it easier for them to stick to a lower-calorie diet.[40] Unlike more invasive procedures such as gastric bypass or sleeve gastrectomy, ESG does not alter the digestive system or cause malabsorption of nutrients, making it a safer option for many patients. ESG offers several benefits, including a relatively low complication rate, minimal scarring, and a short recovery time.[41] most patients can resume normal activities within a few days, as there are no incisions involved. Additionally, ESG is a reversible procedure, implying that if needed, the sutures can be undone. This procedure is unlike traditional weight-loss surgeries such as sleeve gastrectomy or gastric bypass, in which the sutures are permanent. Another advantage of ESG is that it requires no cutting or stapling of the stomach, which reduces the risk of complications such as leaks, infections, or staple line failures that can occur with other types of surgery. Patients who undergo ESG typically experience significant weight loss, with many losing 17% of their excess weight within the first 12 months after the procedure.[42] This weight loss can lead to improvements in obesity-related comorbidities, such as Type 2 diabetes, hypertension, and sleep apnea.[43] However, while the weight loss achieved with ESG is often substantial, it tends to be less dramatic than that seen with more invasive bariatric surgeries. As a result, ESG may not be suitable for patients with extremely high BMIs or those who require a more aggressive weight-loss solution. One of the main challenges of ESG is that it requires the patient to commit to lifelong dietary and lifestyle changes.[39] while the procedure helps limit food intake, it does not address the underlying causes of obesity, such as poor eating habits, lack of exercise, and emotional factors. Therefore, patients must work closely with a

multidisciplinary team, including nutritionists, psychologists, and bariatric specialists, to ensure long-term success. Regular follow-up visits are essential to monitor weight loss progress, ensure that nutritional intake is adequate, and address any potential complications. While ESG has a lower risk of serious complications compared to traditional bariatric surgery, there are still some risks involved. These include stomach perforation, suture failure, infection, and gastroesophageal reflux disease (GERD), which may even be aggravated by the procedure.[44] some patients may also experience nausea or vomiting in the initial days after the procedure due to the stomach's smaller size.

2. Intragastric Balloon (IGB) Therapy

Intragastric Balloon (IGB) Therapy is a non-surgical weight loss procedure that involves the temporary placement of a silicone balloon inside the stomach to aid weight reduction. This minimally invasive procedure is designed for patients who have not had much success with diet, exercise, or other methods of weight loss and are looking for an alternative to more invasive bariatric surgery. The balloon is inserted endoscopically, suggesting that it is placed in the stomach through the mouth using an endoscope, a flexible tube with a camera at the end. Once in place, the balloon is inflated with saline solution or gas to occupy space in the stomach. This reduces the stomach's capacity, making the patient feel fuller more quickly and leading to a decrease in food intake. The balloon creates a sense of satiety by physically occupying space, thereby limiting the amount of food that can be consumed during meals. As a result, patients experience reduced hunger and are able to adhere to a calorie-restricted diet, which ultimately leads to weight loss. The balloon can remain in the stomach for up to six months, after which it is removed endoscopically.[45] one of the main advantages of the IGB procedure is its non-invasive nature. Since it does not involve cutting or modifying the stomach, there is no need for incisions or long recovery time. The procedure is performed under mild sedation or anesthesia, and patients are typically able to go home on the same day. In addition, because the balloon is reversible, it can be removed if necessary, which provides a flexible option for patients who may not achieve their desired results or experience significant discomfort.[46] Patients who undergo IGB therapy can expect to lose between 20-50% of their excess weight, depending on factors such as adherence to dietary changes and exercise routines.[47] In addition to weight loss, many patients experience improvements in obesity-related comorbidities, such as Type 2 diabetes, hypertension, and sleep apnea, although the procedure primarily addresses weight loss rather than metabolic changes.[48] However, despite its benefits, Intragastric Balloon therapy is not without its challenges and risks. Some patients may experience initial discomfort, nausea, or vomiting after the balloon is placed, especially in the first few days or weeks. These symptoms are typically temporary but can be bothersome. Additionally, there is a risk of gastric ulceration, balloon deflation, or migration, where the balloon moves out of position. If the balloon were to rupture, it would need to be removed promptly, but this complication is rare.[49] Another limitation of IGB therapy is that the weight loss achieved is often less than that seen with more invasive bariatric procedures, such as gastric bypass or sleeve gastrectomy.[50] As the balloon only helps limit the amount of food consumed, it does not address the root causes of obesity, such as emotional eating, poor eating habits, or lack of physical activity. For this reason, patients must be committed to making long-term lifestyle changes, including adopting healthier eating habits and incorporating regular exercise into their daily routines. Long-term success with IGB therapy depends largely on the patient’s commitment to these lifestyle changes. While the balloon itself helps control appetite, the weight loss is ultimately sustained through dietary discipline, exercise, and behavioral modification. If the balloon is not accompanied by these changes, patients may experience weight regain after the balloon is removed.

Comparison of Minimally Invasive Techniques

A comprehensive comparison of different minimally invasive bariatric techniques is provided, covering aspects such as invasiveness, mechanism of action, expected weight loss, advantages, challenges,

reversibility, and nutritional deficiencies. This detailed overview is summarized in Table 1. (51-54)

Table 1. A detailed comparison of Minimally Invasive Bariatric Techniques.

Procedure	Invasiveness	Mechanism of Action	Weight Loss(3)	Advantages	Challenges and Risks	Reversibility	Nutritional Deficiencies
Laparoscopic Roux-en-Y Gastric Bypass (LRYGB)	Moderate	Combination of restriction (small stomach pouch) and malabsorption (intestinal bypass).	High (6070% of excess weight lost)	Proven longterm weight loss, high success rate in remission of comorbidities like Type 2 diabetes and hypertension.	Risk of anastomotic leakage, internal hernias, nutritional deficiencies (iron, B12), and dumping syndrome.	Irreversible	High (Iron, B12, Calcium, Folate)
Laparoscopic Sleeve Gastrectomy (LSG)	Moderate	Restriction through stomach volume reduction (removal of 75-80% of stomach).	Moderate to High (50-60% of excess weight lost)	Simpler procedure, fewer longterm complications, improved metabolic outcomes.	Risk of staple line leaks, GERD, and limited reversibility.	Irreversible	Moderate (Iron, B12, Calcium)
Mini Gastric Bypass / One Anastomosis Gastric Bypass (OAGB)	Moderate	Restriction (small gastric pouch) and malabsorption (bypasses a part of the stomach and duodenum).	High (6070% of excess weight lost)	Shorter operative time, lower complication risk than Roux-en-Y, comparable weight loss to gastric bypass.	Risk of bile reflux, marginal ulcers, and potential nutritional deficiencies (B12, Iron).	Irreversible	High (Iron, B12, Calcium)
Laparoscopic Adjustable Gastric Banding (LAGB)	Low	Restriction (adjustable band around the stomach creating a small pouch).	Moderate (40-50% of excess weight lost)	Reversible, adjustable, least invasive, lower surgical risk.	Slower weight loss, higher failure rate, risk of band slippage, erosion, and less effective weight loss compared to other surgeries.	Reversible	Low
Endoscopic Sleeve Gastroplasty (ESG)	Minimally Invasive	Restriction (suturing stomach to create a sleeve-like structure).	Moderate (30-50% of excess weight lost)	Minimally invasive, no incisions, faster recovery, reversible, lower complication rates.	Less effective than surgical alternatives, durability of sutures remains a concern, potential for discomfort.	Reversible	Low
Intragastric Balloon (IGB)	Minimally Invasive	Restriction (balloon occupies space in the stomach, reducing capacity).	Low to Moderate (15-30% of excess weight lost)	Minimally invasive, reversible, outpatient procedure, relatively low complication rate.	Temporary effect, risk of nausea, balloon deflation, gastric ulceration, or migration.	Reversible	Low

Future Directions in Minimally Invasive Bariatric Surgery

The future of minimally invasive bariatric surgery is suffused with promising advancements in technology

and techniques aimed at improving patient outcomes and safety. One of the most significant developments is the use of robotic-assisted surgery, which offers enhanced precision, better visualization, and increased dexterity. These innovations are expected to improve surgical accuracy, reduce the learning curve for new surgeons, and ultimately provide more consistent results. In addition, the integration of artificial intelligence (AI) and machine learning will enable personalized surgical planning and real-time decision-making during the implementation of the procedures. AI can also assist in post-operative care by analyzing patient data and predicting potential complications, contributing to better long-term management of obesity and related comorbidities. Furthermore, the advancement of endoscopic techniques, such as endoscopic sleeve gastroplasty

(ESG) and intragastric balloons, will offer less invasive, non-surgical options for patients who are not ideal candidates for traditional bariatric surgery. Personalized medicine is also expected to play a key role in the future of bariatric surgery, with its focus on tailoring treatments based on genetic, metabolic, and microbiome profiles. This approach will help create more customized weight-loss solutions for individual patients, improving the effectiveness of bariatric procedures. Additionally, the development of hybrid surgical techniques that combine endoscopic and surgical methods could offer greater weight loss results with fewer risks. Advances in metabolic surgeries, which target the hormonal and metabolic causes of obesity, are likely to provide better solutions for patients with Type 2 diabetes and other metabolic disorders. Long-term management may also ensure improvements with the use of telemedicine and remote monitoring, helping patients maintain weight loss and prevent complications through continuous support and guidance.

Conclusion

In conclusion, minimally invasive bariatric surgery has revolutionized the treatment of obesity, offering patients safer, more effective, and less invasive options compared to traditional surgical methods. With continued advancements in technology, including robotic-assisted surgery, artificial intelligence, and endoscopic techniques, the field is poised for even greater improvements in patient outcomes. These innovations may lead to more personalized, precise, and efficient weight-loss treatments, enhancing both short- and long-term success rates. While challenges such as the need for lifestyle modifications and the management of potential complications remain, the future of bariatric surgery holds great promise in providing patients with more sustainable solutions for weight loss and paves the way for the better management of obesity-related comorbidities. As these techniques continue to evolve, they will play a crucial role in improving public health by offering a wider range of options for those struggling with obesity.

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