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Bariatric surgery and its role in obesity pandemic

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Obesity has grown to become a global pandemic, leading to higher medical costs and a lower quality of life. Progressively, there is a growing consensus that bariatric surgery is the optimal treatment option for individuals who are clinically morbidly obese and have failed medical treatment. It has proved to be effective in sustaining weight loss, providing remission of obesity-related comorbidities, improving quality of life and prolonging life expectancy. The number of bariatric surgery procedures have gradually increased over the past years. This not only attributed to the increasing global prevalence of obesity with the need for weight loss surgery but also in addition to the global increasing acknowledgement of the metabolic health benefits associated with it. With its recognition over the past decade, bariatric surgery has evolved tremendously, with most of these procedures are now performed laparoscopically. The minimally invasive techniques lower surgical risks and complications, providing minimal postoperative pain, faster recovery and therefore shorter hospital stays. At present, approximately 1% of eligible population with severe obesity receive bariatric surgery. Undoubtedly, better understanding of the mechanisms and the effects of bariatric surgery would aid physicians to select the optimal surgical approach for each patient. Herein, this review will summarize the historic and contemporary bariatric surgical techniques (Roux-en-Y gastric bypass, vertical sleeve gastrectomy and adjustable gastric banding) and their impact on obesity related metabolic diseases.

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Background

Obesity has grown to become a global pandemic, leading to higher medical costs and a lower quality of life [1–3]. The World Obesity Federation now identifies obesity as a relapsing, chronic progressive disease resulting from multiple environmental and genetic factors [4].

According to the World Health Organization (W.H.O.), 65% of the world's population lives in countries where overweight and obesity kill more people than underweight. Approximately 500 million adults in the world are affected by obesity and one billion are overweight, along with 48 million children [5]. Within the United States (U.S.), the National Health and Nutrition Examination Survey (NHANES) revealed that 39.8% of adults over 20 years old are affected by obesity with adults who are between aged 40–59 at highest risks. Overall, obesity is estimated to affect about 93.3 million of U.S. adults in 2016 [6].

There is a growing consensus that bariatric surgery is the optimal treatment option for individuals who are clinically morbidly obese and have failed medical treatment. It has proved to be effective in sustaining weight loss, providing remission of obesity-related comorbidities, improving quality of life and prolonging life expectancy [7]. The number of bariatric surgery procedures have progressively increased over the past years. The American Society for Metabolic and Bariatric Society (ASMBS) has estimated over 228 000 bariatric surgeries being performed in 2017 in the US, compared to 173 000 in 2012, a 132% increase [8]. The International Federation for the Surgery of Obesity and Metabolic Disorder (IFSO) has also shown an increased trend in bariatric surgery, estimating over 685 000 surgeries performed in 58 national IFSO members in 2016 [9]. Over the past decade, bariatric surgery has evolved tremendously, with the majority of these procedures are now performed laparoscopically, thus lowering surgical risks and complications, as well as providing minimal postoperative pain, faster recovery and therefore shorter hospital stays [10,11].

The National Institute of Clinical Excellence [12] and the American National Institute of Health [13] guidelines state that bariatric surgery should be offered to patients with a BMI of 35 kg/m^2 who have obesity related comorbidities such as diabetes mellitus, hypertension or obstructive sleep apnea and in patients with a BMI of 40 kg/m^2 or greater irrespective of weight related comorbidities.

The scientific evidence supporting bariatric surgery is rapidly expanding; yielding important short term and long-term data on efficacy and safety of surgical treatments for obesity and metabolic diseases. Hence, this review aims to provide an updated overview on the current state of bariatric surgery for obesity and its related metabolic disorders.

Evolution of bariatric surgery

The landscape of bariatric surgery has changed dramatically [10,14,15], with technical refinement, development of new surgical procedures and devices as well as the launch of a national accreditation system in the U.S., the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP), which helps standardize and improve bariatric surgical outcomes.

Bariatric surgery has been in existence since 1950's. The idea of weight loss surgery was first observed in patients who received bowel resections or procedures which restricted food intake. The prototype of malabsorptive procedures and the first operation performed specifically to induce weight loss was by Kremen in 1954 [16]. The jejuno-ileal bypass, removing 50–70% of mesenteric small bowel from the intestinal blood stream, created a blind loop of bowel with no active flow. Although producing significant results in weight loss, it was later abandoned and found to be associated with excessive diarrhoea and liver cirrhosis, most probably consequently to bacterial overgrowth in the excluded intestinal limb [17].

The first gastric bypass surgery is attributed to Dr Edward Mason, a surgeon from the University of Iowa, in 1966 [18]. He reported that weight loss can be achieved effectively by the means of a malabsorptive and restrictive gastrointestinal procedure, consisting of a horizontal gastric transection with a loop anastomosis. To minimize severe bile reflux, the procedure was later modified to a Roux-en-Y configuration which diverts the bile from stomach and oesophagus along with a smaller gastric pouch to limit weight regain.

Over the next decade, various types of gastric partitioning and small intestinal reconstruction were described including the biliopancreatic diversion in 1979 which was later modified with addition of a duodenal switch in 1993 by Marceau [19]. These surgeries are still being carried out today but rather infrequently and mostly reserved for patients with severe morbid obesity.

Purely 'restrictive' surgeries were also developed over the years as an alternative option to gastric bypass. These procedures, such as the horizontal gastroplasty and vertical banded gastroplasty, were found to be more 'physiological' without involvement of intestinal bypass, less surgical morbidity and simpler to perform. The vertical sleeve gastrectomy (VSG) was originally used as the first stage of biliopancreatic diversion, later found to be rather effective on its own and now commonly performed. The fundamental concept of restrictive surgery eventually led to the development of gastric banding system [10,14,15,20]. Gastric banding was first inaugurated by Wilkinson and Peloso in the U.S. in 1978 with further development of adjustable gastric bands in the early 1980s. The clinical application of gastric banding for weight loss became more popular in the mid-1990s as laparoscopic techniques flourished [21]. The LapBand received its FDA approval in 2001 and became a very popular weight loss operation in the US before a significant decrease in its use over the past decade due to suboptimal long-term weight loss results.

One of the most important advances that has revolutionized bariatric surgical care was the development of the laparoscopic technique. The first laparoscopic gastric bypass was performed in 1994 [10,14]. The growth of laparoscopic surgery with its reduced complications, shorter hospital stays, faster recovery, reduced morbidity has led to an ever-increasing patient demand [10,11]. By 2004, the number of laparoscopic bariatric operations in the USA exceeded the number of open bariatric operations. Currently, over 95% of all bariatric operations are performed using a laparoscopic approach [8,22].

Contemporary bariatric surgical techniques

The number of bariatric surgeries performed in the US and worldwide is currently <1% of the eligible population with severe obesity. The most common types of bariatric surgical techniques consist of laparoscopic Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (LSG) and laparoscopic gastric banding (LAGB) [8] (Table 1).

Laparoscopic Roux-en-Y gastric bypass

RYGB has evolved over the past 40 years following its initial description to include multiple modifications. It has remained as one of the most effective bariatric

Table 1

Bariatric surgical procedures and their characteristics

	RYGB	SG	LAGB
TBWL *(%)*	30–35	20–25	10–15
Length of operation *(mins)*	90–120	60	45–60
Length of hospital stay *(days)*	1–2	1–2	Day case
30-days mortality risk *(%)*	<0.2	<0.1	<0.01

Abbreviation: TBWL, total body weight loss; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; LAGB, laparoscopic gastric banding.

procedure and has been reported to achieve approximately 30% of total body weight loss (TBWL) at about two years. The size of the gastric pouch has gradually been reduced to the present 20–30-mL capacity (roughly size of an egg) and is commonly constructed by transection of the stomach using surgical stapling devices. The jejunum is divided usually 50–100 cm distal to the Ligament of Treitz with the distal end of the small bowel anastomosed to the gastric pouch. The proximal end of the divided jejunum is subsequently anastomosed to the distal jejunum forming a 100–150 cm alimentary limb, also known as the Roux limb. The common limb consists of the remaining length of the small bowel.

Historically, the weight loss achieved by RYGB has been attributed to a combination of restriction of food intake and malabsorption of oral consumption. However, we have now come to understand that this simplistic view to weight loss after surgery is incomplete and there are neurohormonal as well as other homeostatic effects at play. RYGB leads to profound changes in the secretion of gut hormones with effects on metabolism, appetite, and food intake. Changes in hormones such as incretins, glucagon-like peptide-1 (GLP-1), peptide YY (PYY) modulating glucose homeostasis and satiety and has been extensively studied post RYGB [23–26]. Reduced ghrelin, the hunger incretin, was found to decrease after RYGB and partially responsible for reduced hunger and the subsequent weight loss [23,25]. More recently, changes in circulating bile salt levels and alterations in intestinal microbiome have been proposed as a mechanism.

Gastric bypass surgery has improved significantly in safety, with a mortality rate of around 0.2%. Early surgical complications include anastomosis leak and post-operative infection, bleeding and thromboembolic evets (give rates and how leak rates are very low now). Later complications include mesenteric herniation, intestinal strictures and long-term vitamin B12, iron, calcium and folate deficiencies, requiring supplements. Although RYGB remains as the gold standard for obesity with metabolic disease, the complexity of surgery combined with a slightly higher surgical risk compared to sleeve gastrectomy has led to a slow decline in popularity. ASMBS has reported the percentage of RYGB being performed of all bariatric operations, has decreased from 37.5% in 2012 to 17.8% in 2017 [8].

Laparoscopic vertical sleeve gastrectomy

The vertical sleeve gastrectomy is rapidly increasing in popularity and has been reported to achieve 20–25% TBWL. It consists of an 80% vertical gastric resection, which creates a long and narrow tubular gastric reservoir without intestinal bypass. This procedure works by several mechanisms, including neuro-hormonal changes such as decreased concentration of ghrelin. Ghrelin is mainly produced in oxyntic glands by endocrine cells localized in the gastric fundus which is resected during sleeve gastrectomy.

Surgical complications include anastomosis leak, worsening of gastric reflux symptoms, post-operative bleeding and infection. In the past five years, laparoscopic sleeve gastrectomy has become increasingly popular and is now the most common bariatric surgery in the US, and the world. The percentage of LSG has increased remarkably from 33.0% in 2012 to 59.4% of all bariatric cases in 2017 performed in the US [8].

Laparoscopic gastric banding

The adjustable form of laparoscopic gastric banding (LAGB) creates a small superior gastric reservoir with an adjustable outlet. It consists of a silicone belt with an inflatable balloon in the lining that is buckled into a closed ring around the upper stomach 1–2 cm below the gastroesophageal junction, thereby creating an approximatively 30 mls upper gastric pouch. The degree of constriction of the stomach is variable and may be adjusted by modifying the amount of saline injected into a port embedded in the abdominal subcutaneous tissue which is linked to the inflatable band. The small pouch size induces early satiety which reduces food consumption. However, suboptimal weight loss (15% total body weight loss at two years, which is decreased to around 10% at five years) have reduced enthusiasm for this procedure. There are several potential serious late complications, such as band slippage and band erosion which may lead to gastric ischemia, requiring urgent surgical removal. A retrospective study reviewing over 19 000 LAGB placements in New York revealed a revision rate of 34.2% over a seven-year period [27]. This has led to the decline in popularity of LARB at most bariatric centers. The percentage of LAGB performed has fallen from 20.2% in 2012 to 2.77% of all bariatric procedures in 2017 within the US [8].

In the past decade, bariatric surgery continues to evolve with a constant shift in the most favored type of surgery being performed for weight loss. Recently, the Patient-Centered Outcomes Research Institute funded the National Patient-Centered Clinical Research Network (PCORnet) Bariatric Study compared the safely and effectiveness of RYGB, LSG and LAGB. This sizable longitudinal study involving over 40 000 patients showed RYGB as being most effective at weight lost at 25.5%, LSG at 18.8 and 11.7% for LAGB by five years. However, RYGB was also found to have the highest 30-day rate of major adverse events, at 5.0% when compared to 2.6% for LSG and 2.9% for LAGB [28].

Improvement in metabolism

In addition to weight loss, bariatric surgery has been known to improve several components of the metabolic

syndrome [29,30]. In a meta-analysis comprising of 22 094 patients, by Buchwald *et al.*, 77% of T2D patients has achieved remission, hyperlipidaemia improved in 70% or more of patients, hypertension was resolved in 61.7% of patients whilst 86% of patients no longer suffer from obstructive sleep apnoea [31]. The five-year results from the STAMPEDE (Surgical Treatment And Medications Potentially Eradicate Diabetes Efficiently) trial also concord similar outcomes. The STAMPEDE trial concluded that at five years, patients who underwent RYGB and SG experienced sustained improvement in glycemic control and hence require less medication when compared to patients who received intensive medical therapy alone [32].

More recently, a multicentre Longitudinal Assessment of Bariatric Surgery (LABS) study assessed the seven-year weight and comorbid health changes following RYGB and LAGB. This large database including 2348 patients showed a clear reduction in the prevalence of dyslipidaemia following both LAGB and RYGB. While diabetes and hypertension prevalence were reduced after RYGB only, with 60.2% of patients achieving diabetes remission at seven years. Over the years, much research has been conducted to establish the mechanisms by which bariatric surgeries achieve these metabolic benefits [33].

Most notably, it is well established that bariatric surgeries improve insulin sensitivity or even lead to type 2 diabetes (T2D) remission [23,29,34,35]. However, the mechanisms by which they facilitate their improvement in glycaemic control remain much debated. The weight loss effect of these procedures clearly contributes to the long-term improvement in glucose handling. However as glycaemic control often improves within days after bariatric surgery, there is increasingly more evidence pointing to immediate, weight loss–independent mechanisms related to surgery-induced changes in gastrointestinal anatomy, gut transit, microbiome, altered secretions of bile acids and neuro-hormonal changes (such as GLP-1 [24–26] and PYY [23,25,36]).

Other positive outcomes – cancer and mortality

It is important to recognize that bariatric surgery has been shown to decrease overall mortality in obese patients who have surgery when compared with their weight-matched controls. Patients with obesity were followed for an average of 11 years in a Swedish longitudinal study that enrolled >2000 patients who underwent bariatric surgery and equivalent case-matched controls. It showed patients who received surgical intervention had a lower hazard ratio (HR) of 0.76 for mortality [37]. Whilst Christou *et al.* found a sustained 67% weight loss and a reduced relative risk of death by 89% during the five-year study when comparing over 1000 patients who underwent bariatric surgery [38]. Furthermore, a large retrospective cohort study reviewed the long-term mortality risk specifically among patients who had undergone RYGB to control subjects who were matched for age, sex and BMI. Including over 8000 subjects in each group, adjusted long-term mortality from any cause in the RYGB group decreased by 40%. The study also reported an immense decrease in cause-specific mortality; with a 56% reduction in mortality secondary to coronary artery disease, 92% reduction for T2D and 60% for cancer after RYGB [39]. As bariatric surgery is known to reduce inflammatory markers and genomic injury, its plays an important role in decreasing obesity-related cancers risk after bariatric surgery [40,41]. A meta-analysis of four observational studies from Afshar *et al.* involving 105 187 individuals followed up to 12.3 years revealed that bariatric surgery is associated with a 27% reduced risk of colorectal cancer [41]. Interestingly, the prospective Swedish Obese Subjects (SOS) study showed that this benefit reduction in cancer risk may vary between gender. Within their mixed gender cohort involving over 2000 obese patients, bariatric surgery was associated with reduced cancer risk in obese women (HR 0.58) but not in obese men (HR 0.97) [42]. A more specific study conducted by the same group, including 1420 women who had under undergone bariatric surgery matched with 1447 controls found a significantly reduced risk of overall cancer in the surgical group. The study showed a much lowered HR of 0.68 in female-specific cancers in the surgical group [43]. In addition, within breast cancer patients, bariatric surgery was found to be associated with better prognostic factors and cancer specific-mortality [44].

Adolescents obesity surgery

Overall prevalence of childhood obesity has quadrupled in the past 40 years [3], and 18.5% of adolescents now meet the criteria of obesity within the US [45].

With the rapidly increasing adolescent obesity prevalence, the ASMBS has recently published their revised pediatric metabolic and bariatric surgery guidelines [46]. The acknowledgement that obesity is modulated by a concoction of metabolic and genetic influences rather than solely under volition control, leads to the need to offer practical and effective obesity management to adolescents with obesity. There is an increasing amount of recent research providing data to support the use of bariatric surgery in adolescents with severe obesity [47–49]. Current guideline suggests either the LSG or the LRYGB should be considered for adolescents with a BMI > 35 with serious comorbidity or a BMI > 40 along with vigorous support provided by a multidisciplinary team. Contrary to the former recommendations, prior weight loss attempts, Tanner stage, and bone age should no longer be barriers to definitive surgical treatment [46].

Conclusion

Over the years, bariatric surgery has established itself as a highly efficacious option in managing obesity and its

comorbidities. Undoubtedly, better understanding of the mechanisms and the effects of bariatric surgery would aid physicians to select the optimal surgical approach for each patient. Further research on this area not only unravel the mechanisms on how these surgeries define their benefits, but also allow further development in less invasive therapies.

Conflict of interest statement

Nothing declared.

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