The History and Evolution of Bariatric Surgical Procedures

Matthew T. Baker, MD

Although the origins of surgery to treat obesity can be traced back to the 1950s, its practice remained in obscurity until 2 things happened. First, obesity became recognized as a disease state with life-threatening comorbidities such as diabetes, hypertension, sleep apnea, dyslipidemia, and venous stasis, resulting in a higher risk for premature death.1,2 Second, obesity became an epidemic. Recent data show that up to 35% of Americans are now considered obese, whereas that number was only 12.8% in 1962.3 Given these developments, a renewed interest in surgical procedures to treat obesity led to a large increase in the number of operations performed annually in the past decade. In an attempt to find the best weight loss operation, many procedures have been tried, with varying results and outcomes. This article reviews the history of bariatric surgical procedures and discusses why some survived to the present day and others became less popular.

All bariatric procedures can be categorized as restrictive, malabsorptive, or a combination of the two. Restrictive procedures are designed to decrease the amount of caloric intake by reducing the volume of food able to be consumed. Malabsorptive procedures bypass a large portion of the nutrient absorptive circuit, thereby reducing the amount of caloric absorption. Other procedures combine restriction and malabsorption in varying amounts.

MALABSORPTIVE PROCEDURES
Jejunoileal Bypass

Given the fact that all nonsurgical attempts at weight reduction have involved limiting or reducing caloric intake, it is interesting that the first surgical attempts involved malabsorption, not restriction. Dr Viktor Henrikson4 of Sweden is credited with being the first to perform surgery for inducing weight loss and improving comorbidities. His 1952 article describes a case report in which he resected a 105-cm segment of small

KEYWORDS
• Bariatric surgery • Outcomes • Obesity
bowl in a 32-year-old woman suffering from obesity, constipation, slowed metabolism, and the inability to complete a weight loss program successfully. The idea apparently came to him after becoming aware of a couple of reported cases in which “favorable side-effects concerning weight and intestinal function occurred” after small bowel resection. He does not mention why he chose the length of 105 cm, or which segment of bowel was removed, but it apparently was not enough to induce significant weight loss because, at 14 months after her operation, the patient not only had failed to lose weight, but had gained 2 kg. Despite this numerical failure, the patient was “content, subjectively felt healthier and more energetic. Her intestines were functioning without problem and her metabolism was somewhat higher than before the operation.”

The first attempts at surgical weight loss in the United States were similar in concept, but different in design. In 1954, Kremen and colleagues, from the University of Minnesota, published the results of their elaborate experiments on dogs followed by a jejunoileal bypass (JIB) in a human subject on April 9, 1954. The procedure involved joining the proximal small intestine to the distal ileum, thereby bypassing a large segment of small bowel, instead of resecting it as described by Henrikson. Around the same time, Dr Richard Varco, also of the University of Minnesota, independently performed a JIB, but the case was unpublished and the patient record was lost. Variations of the JIB procedure were introduced during the next 2 decades. In the early 1960s, Payne and colleagues published a case series involving 10 patients in whom a segment of proximal jejunum 38 to 51 cm long was anastomosed to the transverse colon. The jejunocolic shunt procedure (Fig. 1), as it was termed, resulted in considerable weight loss with comorbidity resolution, but the associated debilitating diarrhea, dehydration, and severe electrolyte imbalances led to either complete reversal of the procedure or conversion to a JIB. This latter procedure involved anastomosing the proximal 36 cm of jejunum to the distal 10 cm of ileum in an end-to-side fashion (Fig. 2). Payne and colleagues eventually advised against the jejunocolic

![Fig. 1. Initial intestinal bypass operation with jejunocolic anastomosis. (From Payne JH, Dewind LT, Commons RR. Metabolic observations in patients with jejunocolic shunts. Am J Surg 1963;106:274; with permission.)](image_url)
shunt and recommended the JIB procedure. However, it was eventually noted that approximately 10% of patients having JIB either did not experience satisfactory weight loss or developed significant weight regain. This finding was caused by reflux of nutrients back up the defunctionalized limb of small bowel, allowing absorption of the refluxed material, and led to other JIB variations in which an end-to-end anastomosis was performed and the defunctionalized, or bypassed, limb was drained into the cecum, transverse colon, or sigmoid colon (Fig. 3).8

Despite the popularity and weight loss success of the JIB procedure in the late 1960s and early 1970s, it was also associated with serious complications. The so-called blind loop syndrome was believed to be caused by bacterial overgrowth in the defunctionalized limb. The syndrome was characterized by abdominal bloating, migratory arthralgias, and, eventually, liver problems. The severity of liver dysfunction ranged from mild, in about 25% of patients, to full-blown cirrhosis in up to 5%, and liver failure in 1% to 2%.9,10 Significant diarrhea became synonymous with the jejunoileal bypass. The associated anal burning, electrolyte abnormalities, and dehydration compromised quality of life and led to frequent physician visits and hospitalizations. Other malabsorptive sequelae included protein depletion, calcium and vitamin D deficiencies, nephrolithiasis, cholelithiasis, and vitamin B12 deficiency. Only about one-third of patients having JIB had a benign course. By the mid-1970s, other less morbid bariatric procedures were being developed and the jejunoileal bypass became less popular.11

**COMBINED MALABSORPTIVE AND RESTRICTIVE PROCEDURES**

**Biliopancreatic Diversion**

Because of the morbidity associated with the defunctionalized limb in the jejunoileal procedures, Scopinaro and colleagues12 of Genoa, Italy developed the biliopancreatic diversion (BPD) procedure in the mid-1970s. The procedure involved a partial distal
gastrectomy with closure of the duodenal stump. The jejunum was divided 250 cm proximal to the ileocecal valve. The distal limb (Roux limb) was then anastomosed to the proximal stomach. The proximal limb (biliopancreatic limb) was anastomosed to the ileum 50 cm proximal to the ileocecal valve (Fig. 4). The result was a Roux-en-Y version of the JIB. Although the biliopancreatic limb was not part of the alimentary channel, conveyance of bile and gastropancreatic juices prevented bacterial overgrowth and thus eliminated the blind loop syndrome of the JIB. The resulting 200-cm Roux limb and 50-cm common channel allowed for rapid transit of food and minimal contact time with digestive enzymes, thereby greatly reducing caloric and nutrient absorption. The partial gastrectomy introduced a restrictive component to the procedure that was believed to enhance the overall initial weight loss achieved. The long-term maintenance of weight loss was attributed to the jejunileal bypass portion of the procedure.

The BPD proved to be effective. In 1998, Scopinaro and colleagues reported their long-term outcomes in 2241 patients in a 21-year period. The excess weight loss achieved after 1 year averaged 75% and most patients were able to maintain most

Fig. 3. Jejunoileal bypass, end-to-end.
of this throughout the follow-up period. These results are the best, in terms of initial and maintained weight loss, reported in the bariatric surgical literature to date. The effect on glycemic control in patients with diabetes was equally impressive, with a 98% cure at 10 years. The effect of BPD on hypertension and hyperlipidemia was also favorable. However, the long-term side effects were significant. The main complications were diarrhea, foul-smelling stools, flatulence, anemia, stomal ulceration, protein malabsorption, dumping syndrome, peripheral neuropathy, Wernicke encephalopathy, and bone demineralization secondary to poor calcium and vitamin D absorption.\textsuperscript{14} The incidence of most of these side effects were greatly reduced with close lifelong follow-up, early detection, intervention, and even prevention. There was a particular problem with protein malnutrition (PM), which was characterized by hypoalbuminemia, anemia, edema, asthenia, and alopecia. The cause was multifactorial, including insufficient intake from gastric restriction and insufficient absorption from deficient alimentary limb length. Attempts to increase weight loss led to drastic reductions in gastric pouch size. Although the weight loss was excellent, it was associated with a 30% incidence of PM. Treatment typically involved 2 to 3 weeks of parenteral feeding. PM was rare, but did occasionally recur. Larger gastric volumes were associated with less PM but also less weight loss. To maximize weight loss and minimize PM, alimentary limb lengths were increased from between 200 and 250 cm to between 300 and 350 cm. This increase led to further reduction of PM without significantly compromising weight loss. Scopinaro\textsuperscript{15} eventually adopted a tailored approach to the BPD and altered gastric pouch size and alimentary limb length according to specific patient characteristics and risk factors.

**BPD with Duodenal Switch**

To reduce some of the morbidity associated with the BPD, Hess and Marceau developed a variation of that procedure in the late 1980s.\textsuperscript{16,17} By preserving the pylorus,
gastric emptying control was maintained and the dumping syndrome was eliminated. Preservation of the proximal duodenum helped to neutralize gastric acid and therefore minimize the risk of stomal ulcerations. Gastric restriction was maintained as in the BPD, which not only decreased parietal cell mass but also preserved the restrictive component of the operation. However, to keep the pylorus intact, the partial gastrectomy was converted to a 70% to 80% greater curve gastrectomy (sleeve configuration). The entire small bowel was measured from the ligament of Treitz to the ileocecal valve. Forty percent of this distance was calculated and measured from the ileocecal valve in a retrograde fashion. The jejunum was divided at this distance and the distal (Roux) limb was brought up and anastomosed to the proximal duodenum. The long biliopancreatic limb was anastomosed to the ileum, 75 to 100 cm proximal to the ileocecal valve, creating a longer common channel than the classically described 50-cm common channel of the BPD. The resulting alimentary limb, which includes the Roux limb and common channel, usually became 250 to 300 cm (Fig. 5).

Hess and colleagues\textsuperscript{17} developed the procedure while addressing the problem of weight regain in patients with prior failed restrictive operations. In their attempts to revise the failed procedures, they adopted the BPD as the revisional procedure of choice. However, frustrated with dense adhesions in the upper abdomen, the associated difficulty of creating the gastrojejunostomy on a scarred, previously stapled

![Fig. 5. BPD with DS. (From Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. Obes Surg 1998;8:269; with permission.)](image-url)
stomach, along with the trouble with marginal ulcerations, they began to look for alternative solutions. They came across an article by DeMeester and colleagues\textsuperscript{18} about a duodenal switch (DS) procedure for duodenogastric reflux, and adapted it to their use. With time, they noticed the success of the procedure in their revisional patients and soon began using the procedure as a primary operation for both morbidly obese and supermorbidly obese patients. In 1998, Hess and Hess\textsuperscript{17} published their experience with the BPD/DS procedure in 440 patients with follow-up data available for some patients up to 9 years. They reported weight loss outcomes similar to those of the BPD procedure. As expected, comorbidity resolution was also similar. The main differences between the 2 procedures were found in the lack of marginal ulcers and dumping syndrome in patients who had BDP/DS. Because of the slightly longer common channel, there was also less liver failure, renal failure, and severe electrolyte abnormalities. However, revisional procedures were required to lengthen the common channel for PM and excess weight loss in 8 patients and for excess diarrhea in 2 patients. The common channel was shortened in 7 patients for poor weight loss.

**Gastric Bypass**

In search of a weight loss operation without the detrimental side effects of the JIB, Dr Edward E. Mason, of the University of Iowa developed the gastric bypass. As opposed to the previously mentioned operations, this procedure introduced gastric restriction as the main force driving weight loss. The concept was based on observations in patients who had undergone partial gastrectomy with Billroth II gastrojejunostomy for peptic ulcer disease. These patients were noted to lose weight after surgery and had difficulty regaining weight long term. The first gastric bypass was performed by Mason and Ito\textsuperscript{19} on May 10, 1966, on a 50-year-old woman with a body mass index (BMI) of 43 kg/m\textsuperscript{2}. She had undergone multiple failed ventral hernia repairs and the gastric bypass was performed in hopes of helping her achieve a more manageable, less morbid weight. Nine months later, she was 27 kg lighter and her hernia was successfully repaired.\textsuperscript{19} The procedure consisted of dividing the stomach horizontally and connecting a loop gastrojejunostomy to the proximal gastric pouch (Fig. 6). Small pouch size to force smaller portions and small diameter anastomosis to delay gastric emptying and enhance satiety was emphasized.

As the popularity of the JIB waned, more surgeons began to perform the gastric bypass, each adding different modifications to improve weight loss, avoid weight regain, or to lessen the morbidity, mortality, or detrimental side effects of the procedure. Initially, the pouch size was not measured or calibrated. In 1977, Alder and Terry\textsuperscript{20} published a study that correlated pouch size with observed long-term weight loss. Implementing the law of Laplace, they argued that the larger the pouch, the more the wall tension, which would lead to more dilatation. Based on their findings, they concluded that an adequate size for the gastric pouch was less than 30mL. In the same year, Alden\textsuperscript{21} published a study in which, instead of dividing the stomach in pouch creation, he proposed just stapling a partition without division to decrease the incidence of gastric leaks. However, the frequent failure of staple lines led to restoration of stomach and pouch continuity and subsequent weight regain. The technique was eventually abandoned.

Also in 1977, Griffen and colleagues\textsuperscript{11} introduced the Roux-en-Y configuration to replace the loop gastrojejunostomy (Fig. 7). This modification improved the technique in 3 ways: it lessened tension on the jejunal loop, eliminated bile reflux into the pouch, and added a malabsorptive component to the operation. With the Mason bypass, bringing up a loop of jejunum to reach the proximal stomach was often difficult to do without tension. Subsequent leaks led to the escape of gastric, duodenal, biliary,
Fig. 6. Mason loop gastric bypass. (From Deitel M. A Synopsis of the development of bariatric operations. Obes Surg 2007;17:708; with permission.)

Fig. 7. Griffen Roux-en-Y gastric bypass. (From Deitel M. A synopsis of the development of bariatric operations. Obes Surg 2007;17:708; with permission.)
and pancreatic secretions, which was morbid and often fatal. Less tension with the Roux-en-Y decreased anastomotic leak risk. Moreover, if a leak did occur at this anastomosis, the escaping fluid was mainly saliva and patients were more likely to survive.\textsuperscript{22}

In 1983, Torres and colleagues\textsuperscript{23} introduced another modification. Creating an anastomosis to the upper greater curve of the stomach was technically challenging because of exposure problems in the obese patient. Furthermore, mobilizing the upper fundus for pouch creation often left the lateral segment, to which the jejunum was anastomosed, potentially ischemic. In addition, many cases of pouch dilatation and weight regain were reported. To overcome these factors, Torres and colleagues\textsuperscript{23} created a pouch based on the lesser curve of the upper stomach, in which blood supply could be better preserved, the wall was more muscular and less prone to distention, and exposure was less cumbersome (\textbf{Fig. 8}). The late 1980s brought additional modifications to prevent dilatation of the pouch and its outlet. Salmon\textsuperscript{24} added a banded gastroplasty and Fobi\textsuperscript{25} used a silastic ring. Other surgeons began experimenting with Roux limb length and found that additional weight loss could be achieved if the Roux limb was longer than 150 cm, compared with the traditional limb lengths of less than 100 cm. This finding was mainly significant in superobese patients (BMI> 50 kg/m\textsuperscript{2}).\textsuperscript{26}

Although the gastric bypass offered advantages compared with the JIB and BPD, with less diarrhea, PM, and liver disease, it came at the expense of poorer weight loss and weight regain.\textsuperscript{11} In addition, the issues with dumping syndrome and marginal ulcers, not encountered with the JIB, could be problematic. Also, like the BPD, bypassing the distal stomach and duodenum leads to calcium, iron, and B\textsubscript{12} malabsorption, and lifelong supplementation and monitoring is crucial to prevent bone demineralization and anemia.

\section*{PURELY RESTRICTIVE PROCEDURES}
\textbf{Gastroplasty}

In search of a bariatric operation without the morbidity of intestinal or gastric bypass, several surgeons began developing gastroplasty procedures in the 1970s and 1980s. Gastroplasty procedures altered gastric anatomy to restrict caloric intake and induce

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{The Torres and colleagues\textsuperscript{23} variation with stapled lesser curvature pouch. (From Deitel M. A synopsis of the development of bariatric operations. Obes Surg 2007;17:708; with permission.)}
\end{figure}
early satiety, but avoided intestinal bypass and the associated long-term morbidity. The first attempts by Printen and Mason\textsuperscript{27} were performed in 1971. This procedure consisted of horizontal division of the upper stomach, creating a small upper pouch connecting to the larger lower pouch through a small channel along the greater curvature of the stomach (Fig. 9). The unsatisfactory weight loss and/or weight regain was believed to be secondary to staple line dehiscence and/or dilatation of the pouch and connecting channel.

In the late 1970s, Gomez\textsuperscript{28,29} advocated modifications to avoid these problems. He added a second staple line application to the partition to avoid staple line dehiscence, and reinforced the channel with an external mersilene mesh collar to avoid channel dilatation. This latter modification was associated with excessive fibrosis and gastric obstruction, so he abandoned the mesh for a running polypropylene seromuscular suture ring. However, the suture ring was complicated by suture erosion into the stomach and subsequent stomal dilatation.\textsuperscript{29} About the same time, Pace and colleagues\textsuperscript{30} and Carey and Martin\textsuperscript{31} described gastric partitioning but, in contrast with the procedures described earlier, the 1-cm stoma was created midway between the lesser and greater curvatures by removing 3 of the middle staples from a TA-90 stapling device (Fig. 10). Despite attempts to reinforce staple lines and stomas, such as those by Gomez,\textsuperscript{28,29} failures continued. Moreover, none of these modifications addressed pouch dilatation. To address this shortcoming, Long and Collins\textsuperscript{32} in 1978 began using an oblique staple line from the fundus, just lateral to the angle of His, to a stoma based on the lesser curvature of the stomach. This technique was based on the idea that the lesser curvature has thicker muscle and would therefore be less prone to dilatation. The stoma was reinforced with polypropylene suture to prevent dilatation (Fig. 11). Recognizing that polypropylene suture reinforcement of stomas frequently led to suture erosion and subsequent stomal dilatation, Laws\textsuperscript{33} introduced a silastic ring threaded over a suture and around the stoma to prevent this problem.

Fig. 9. Horizontal gastroplasty (Mason). (From Saber AA, Elgamal MH, McLeod MK. Bariatric surgery: the past, present, and future. Obes Surg 2008;18:124; with permission.)
Subscribing to the theory that lesser curvature–based pouches are more resistant to dilatation, as did Long and Collins,\textsuperscript{32} Mason\textsuperscript{34} developed the vertical banded gastropasty (VBG) procedure and began performing it in 1980. Disillusioned by the increased operative risks and undesirable side effects of the gastric bypass, Mason\textsuperscript{34} was in search of a better bariatric procedure. His strict criteria included “effectiveness, safety, freedom from undesirable side effects, and reversibility.” He believed that gastric restriction, if performed appropriately, could meet these ideal criteria by

Fig. 10. Horizontal gastroplasty.

Fig. 11. Closure of defect in stomach wall. (From Long M, Collins JP. The technique and early results of high gastric reduction for obesity. Aust N Z J Surg 1980;50(2):147; with permission.)
“eliminating the stomach’s reservoir function without disturbing digestion and absorption.” The procedure consisted of creating a vertical pouch oriented along the proximal lesser curve separated from the fundus by a stapled partition. The size of the pouch was precisely calibrated using a standardized hydrostatic pressure measurement. The ideal pouch size was determined to be less than 50 mL. The outlet of the pouch was reinforced by a narrow band of polypropylene mesh passed through a window created by a circular stapler. The stoma was also carefully calibrated using a bougie to assure a diameter of between 10 and 12 mm (Fig. 12). The VBG proved to be less technically challenging than the gastric bypass and eliminated the problems of dumping, ulcers, and anemia. Its popularity increased during the next decade as short-term outcomes proved to be favorable, with excess weight loss at 1 year of 60% or more. By 5 years, however, only 50% of patients were maintaining a 50% excess weight loss and this decreased to 40% of patients by 10 years. The failures were in part caused by staple line dehiscence in up to 48% of patients, depending on the technique used. This problem allowed ingested food to reenter the main body of the stomach, thereby negating effective restriction of the proximal gastric pouch. Mason and colleagues reported only a 10% dehiscence rate, and many of these were only partial breakdowns allowing maintenance of some weight loss success. Although less common, stomal stenosis from excessive scarring from the mesh wrap requiring revision was also occasionally seen. Direct comparisons with the gastric bypass showed the VBG to be associated with less sustained weight loss over time and was less successful at controlling type 2 diabetes. With the development of new technologies and laparoscopic techniques, many surgeons began performing laparoscopic VBGs and gastric bypasses. Although favorable reports of comparable long-term outcomes were published, reports of high revision rates and conversions of VBG to gastric bypass became more prevalent. VBG popularity subsequently waned and it is used less and less by bariatric surgeons.

**Gastric Band**

Gastric banding, which does not involve any transection or stapling of the stomach, was developed to be the least invasive bariatric procedure. Like the VBG, drastic volume reduction of the stomach inlet reservoir was the goal to limit food intake.
without altering the continuity of the gastrointestinal tract. In 1978, Wilkinson and Peloso\(^\text{42}\) of New Mexico were the first to place a nonadjustable band in a human. The band consisted of a 2-cm wide strip of Marlex mesh around the upper part of the patient’s stomach (Fig. 13). About this same time, Molina and Oria\(^\text{43}\) of Houston performed similar operations using a nonadjustable Dacron graft to encircle the upper stomach. Other surgeons, like Kolle\(^\text{44}\) of Norway\(^\text{44}\) and Naslund and colleagues\(^\text{45}\) of Sweden, also used mesh to perform their versions of the nonadjustable band procedures in the early 1980s, and this was soon followed by the use of silicone as a safer alternative to nonadjustable gastric banding.\(^\text{46,47}\)

These early gastric bands and grafts were unsuccessful. It was nearly impossible to create an ideal stoma diameter during surgery or to revise it later. Slippage was common and the stomach would prolapse either anteriorly or posteriorly up through the band, especially with the silicone variety. Band erosions and strictures led to intractable vomiting, severe food intolerances, and esophageal dilatation. In time, the proximal pouches would gradually dilate and lead to weight regain.\(^\text{48}\) However, important developments were occurring during this period. Austrian surgeon Szinicz and colleagues\(^\text{49}\) described experiments in rabbits in which the upper stomach was encircled with a ring of silicone, lined with a balloon on its inner surface. This balloon was attached to a subcutaneous port that could be accessed (Fig. 14). By adding, or removing saline, the balloon volume could be adjusted, thereby adjusting the stoma size.\(^\text{49}\) Other researchers were quick to develop and bring this concept into clinical practice. Hallberg and Forsell\(^\text{50}\) of Sweden described their experience with an inflatable gastric band in 1985, and Dr Lubomyr Kuzmak,\(^\text{47}\) a Ukrainian surgeon working

![Fig. 13. Placement of a nonadjustable band with Marlex mesh (Wilkinson and Peloso\(^\text{42}\)). (From Steffen R. The history and role of gastric banding. Surg Obes Relat Dis 2008;4(Suppl 3):S8; with permission.)](image-url)
in the United States, published his experience in 1986. Kuzmak showed improved weight loss and reduced complications when comparing the inflatable band with the nonadjustable version.

It soon became evident that the adjustable bands were superior to their nonadjustable counterparts. The stoma could be sized appropriately to maximize the effect for patients individually. The bands created and developed by Forsell and Kuzmak underwent numerous modifications and were eventually commercialized. With the advent of laparoscopic placement, this led to an increase in banding procedures, first in Europe and Australia, then later in the United States. Forsell’s band became known as the Swedish Adjustable Gastric Band and was approved for use in Europe in 1996, although it had been available in Sweden since 1987. It was eventually approved for use in the United States in late 2007 as the Realize Band (Ethicon Endo-Surgery, Inc, Cincinnati, OH, USA). Kuzmak’s band came to be known as the LAP-BAND system (Allergen, Inc, Irvine, CA, USA) and was accepted for use in Europe and Australia in the mid-1990s, but did not receive approval from the US Food and Drug Administration (FDA) until 2001.

Like all the bariatric procedures mentioned earlier, outcomes and complication rates improved as experience with the banding procedures grew. Early studies, all performed outside the United States, reported favorable results. However, similar outcomes were not seen in early reports from US centers. This was likely because of the relative inexperience with advanced laparoscopic techniques and variability in surgical procedures. One of the main complications was band slippage and upward gastric prolapse through the band causing either gastric obstruction or proximal gastric pouch dilatation. The incidence of this complication was greatly reduced by altering the placement technique. The band was originally introduced through the lesser sac and placed perigastrically. This technique has largely been replaced by the pars flaccida technique, which places the band higher on the stomach, resulting in a smaller pouch less vulnerable to dilatation. The posterior gastric attachments are also preserved in this technique, further securing the band posteriorly. In addition, gastrogastric imbricating sutures around the band anteriorly provide additional support and resistance to slippage. Other observed complications include band erosion, esophageal dilatation, and problems related to the reservoir and tubing.
There are many studies documenting outcomes in thousands of patients having adjustable gastric bands with long-term follow-up. Although technically safer and less challenging, with favorable weight loss and comorbidity reduction, it has not achieved the outcomes seen with the other bariatric procedures. Excess weight loss percentage, although variable among studies, averages around 50%, but in general takes 2 to 3 years to achieve, compared with 12 to 18 months with other bariatric procedures. Closer follow-up for adjustments is also required for optimal results. Reoperation rates also vary and have improved with time, but approach 5% per year. Many of the reoperations include band removal, replacement, or conversion to a different bariatric procedure.

**Sleeve Gastrectomy**

Another purely restrictive procedure involving only the stomach is sleeve gastrectomy. However, compared with other gastroplasty procedures in which partitioning, or dividing, is involved, this procedure resects the excluded, or divided, part of the stomach, thereby eliminating reversibility, one of the proposed advantages of gastroplasty. The procedure involves a vertical gastrectomy that excises the most compliant, or distensible, part of the stomach, the fundus and lateral 80% of the body, leaving a narrow, sleevelike gastric tube that preserves the antrum and an intact pylorus (Fig. 15). The procedure was originally described by Marceau and colleagues in the early 1990s as the restrictive component of the BPD/DS. However, its true origins as a standalone procedure began in the late 1980s as the magenstrasse and mill procedure.

Disappointed with the results of the VBG procedure and the morbidity of the gastric bypass, Johnston and colleagues of Leeds, United Kingdom, sought to develop a simpler procedure that would avoid the use of implanted foreign material such as bands and reservoirs. The new type of gastroplasty they developed was to create a narrow tube along the lesser curvature of stomach, longer than that of the VBG. A circularly stapled hole in the stomach was created that differed from that of the VBG in that it was located more distally, just beyond the incisura angularis. The outlet into the antrum was not wrapped in mesh to avoid erosion or stenosis, as seen in the

Fig. 15. Sleeve gastrectomy.
VBG. The tube was then created by stapling just lateral and parallel to the lesser curve from the doughnut hole up to the angle of His around a prepositioned bougie (Fig. 16). The magenstrasse, or “street of the stomach”, conveyed the restricted volume of food from the esophagus to the antral “mill”, where normal antral grinding of solid food would take place. Normal gastric emptying was then regulated by an intact and functioning pylorus. At first, a 40-French bougie was used, but, because of unsatisfactory weight loss, the size was reduced incrementally, and they found that a 32-French bougie resulted in a 63% excess weight loss at 3 years.

Modifications were made to the original procedure in subsequent years to simplify the technique, improve weight loss maintenance, and to facilitate adaptation to the laparoscopic approach. To overcome the challenges of creating the circular hole, this step was omitted by starting the staple line on the greater curve, 5 to 6 cm proximal to the pylorus, stapling up to and then along the bougie. This method also addressed the rare, but troubling, complication of gastric fistula formation from the staple line on the greater curved side of the stomach, as well as weight regain from food refluxing up into the lateral stomach reservoir. This modification required removal of the resected part of the stomach and division of the short gastric vessels, which became less risky with the advent of laparoscopic techniques, instrumentation, and improved visualization. After implementing these changes, new outcomes showed an increased leak rate, almost always high on the staple line near the gastroesophageal junction. Because a 32-French bougie is smaller in diameter than the lumen of the esophagus, it was believed that encroachment of the staple line onto the esophagus compromised staple line integrity. To overcome this shortfall, surgeons began swinging the last staple load application to the left, thereby leaving a small triangular pouch of stomach near the esophagus. This modification resulted in a large decrease in leaks.63

With the shift from open surgery to laparoscopy in bariatric surgery, the sleeve gastrectomy has also been used as part of a staging approach in the massively obese patient, preceding either a DS or gastric bypass. These complex procedures in such large patients often pose significant technical challenges for laparoscopic surgeons. Because the sleeve gastrectomy is technically less challenging to perform, surgeons began performing this procedure, waiting a year or two for adequate weight loss, then returning to the operating room for the definitive procedure within a more friendly environment. Many of these patients lost enough weight with the sleeve that the secondary procedure was often not pursued or thought to be unnecessary.64 The sleeve gastrectomy as a standalone procedure has become more popular in the last decade. It is technically less demanding than the gastric bypass or DS, is associated with minimal morbidity, avoids the use of foreign material like the VBG or gastric band, and has

Fig. 16. The magenstrasse and mill procedure. (From Johnston D, Dachtler J, Sue-Ling HM, et al. The magenstrasse and mill operation for morbid obesity. Obes Surg 2003;13(1):11; with permission.)
fewer long-term problems such as dumping, marginal ulcers, internal hernias, and malabsorptive deficiencies. Complications associated with the sleeve procedure include staple line leaks and strictures. This latter complication usually occurs at the incisura angularis and can be avoided with added attention to detail when constructing the sleeve at this area. Staple line leaks can be troubling because the gastric tube is a high-pressure cylinder, making it resistant to spontaneous healing. Long-term weight loss data are lacking, but intermediate-term follow-up data up to 5 years show an overall 55% excess weight loss, with a range from 33% to 85%. Weight regain, or insufficient weight loss, has led to conversion of the sleeve to either a gastric bypass or DS.65

LAPAROSCOPY IN BARIATRIC SURGERY

The introduction, development, and refinement of laparoscopic techniques have been the biggest contributor to the increase in the number of bariatric procedures performed in the last decade. The associated shorter length of stay, quicker recovery, less pain, and large reduction in wound-related problems such as infections and incisional hernias, with similar results in other outcomes, has led to increased patient demand.66

The first laparoscopic procedures for obesity were performed in the early 1990s. Broadbent and colleagues67 first successfully placed a nonadjustable gastric band in a patient on September 10, 1992, in Australia, and published their preliminary results in 1993. After initial animal experiments in 1992, Belachew and colleagues68 placed the first laparoscopic adjustable band in a human on September 1, 1993, in Belgium. The first laparoscopic VBG was performed by Hess and Hess69,70 on July 29, 1993, in Bowling Green, Ohio. However, only 2 laparoscopic VBGs were performed before changing to the DS procedure they were developing. Just 3 months later, Wittgrove and Clark71 performed the first laparoscopic Roux-en-Y gastric bypass procedure in October, 1993, and published their results on 500 patients in 2000. Gagner performed the first laparoscopic DS procedure in 1999.72

Early outcome comparisons between laparoscopic procedures and their open counterparts showed that a learning curve existed to achieve similar results.73,74 Young surgeons eager to overcome this learning curve and to learn the advanced, minimally invasive techniques required to perform these procedures began enrolling in newly developed fellowship training programs. With time, mortality, anastomotic leak rates, operative times, and other outcomes have improved to equal, or surpass, those associated with the open era.75,76 Currently, more laparoscopic bariatric procedures than open procedures are performed annually.

SUMMARY

The search for the ideal weight loss operation began more than 50 years ago when obesity was rare, but its detrimental health effects were coming to light. Surgical pioneers, recognizing the growing need to help these patients, developed innovative, but unproven procedures that initially created malabsorption, then restricted volume intake, and eventually combined both techniques. Variations, alterations, and modifications of these original procedures, combined with intense efforts to follow and document outcomes, have led to the evolution of bariatric surgery as it is known today. Hundreds of thousands of patients have benefited from their work. No single procedure is right for every patient and no single patient is right for every procedure. Patient factors such as preference, risk tolerance, co-morbid conditions, and surgical history all play a role in determining which procedure is suitable. More recent research
has focused on the hormonal and metabolic effects of these procedures. These discoveries at the cellular level will help develop possible mechanisms of weight loss and comorbidity reduction beyond the traditional explanation of reduced food consumption and malabsorption. As more lifelong data become available, further modifications and recommendations will surface. Until then, what Dr Edward E. Mason said in 2004 is still true today: The best lifelong surgical treatment of severe obesity remains to be developed.77

REFERENCES


