Chapter 4
Primary Single Anastomosis Duodenal Switch: Perspective from a Lengthy Experience

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4.1 Historical Perspective of Weight Loss Procedures

There is no consensus regarding the ideal bariatric procedure. Although different surgeries have gained popularity at points in bariatric history, all procedures have side effects and complications. It can be argued that side effects are an inherent issue with weight loss surgery. In comparison to the majority of surgical procedures that remove or repair damaged tissue, bariatric surgery creates a controlled abnormality. Thus, by design normal anatomy is distorted. The goal of bariatric surgery is finding the appropriate balance between lasting weight loss and unpleasant side effects or nutritional complications. To achieve this goal, either the stomach alone, or the stomach and intestine are altered.

Procedures that only manipulate the intestine, such as the jejunoileal intestinal bypass (JIB), were fraught with complications, often required reversal, and have been abandoned. However, both weight loss and lasting resolution of diabetes was achieved in numerous patients. Realizing the dangers of short bowel syndrome, Mason described the vertical banded gastroplasty (VBG) in 1982 [1]. He hypothesized that targeting the stomach was safer and with decreased risk for anemia, bone loss, and other issues that result from intestinal manipulation. Although true, other issues became apparent with this procedure. The fixed outlet and vertical staple line creates a high-pressure system resulting in staple line dehiscence, gastroesophageal reflux disease (GERD), and maladaptive eating of calorically dense foods which pass with less effort [2]. A study published by the Mayo Clinic in 2000 demonstrated that fewer than 25% of patients who underwent VBG were content with their long-term results [3].

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In the late 1990s and early 2000s, bariatric surgery gained popularity with annual case numbers in the United States increasing from under 20,000 to over 200,000. Numerous factors accounted for this growth including the development of laparoscopy, the growing severity of the obesity epidemic, increasing awareness of the complications of morbid obesity and improved outcomes with surgery, as well as the absence of alternative effective therapies. Roux-en-Y gastric bypass (RYGB) became the second most prevalent operation during this period to VBG. Sugerman compared open RYGB to VBG in a single center randomized trial. He concluded that RYGB offered greater weight loss especially in patients that were identified as "sweet eaters." He justified this finding secondary to adverse dumping symptoms seen after carbohydrate ingestion following RYGB.

With the introduction and approval of laparoscopic adjustable gastric banding (LAGB) in 2004, the debate between gastric only or combined procedures was reignited. Many opined that LAGB was preferred for "bulk eaters" and RYGB for "sweet eaters." These theories were difficult to prove because characterization of eating patterns is fraught with subjectivity. With increased usage of LAGB, complications became more apparent including intractable GERD, weight loss failure, and novel issues such as prolapse and erosion. Although once on pace to be a disruptive technology representing 40% of domestic procedures, in 2009, that trend started to wane. LAGB now accounts for less than 5% of bariatric cases.

As LAGB declined, another gastric only procedure emerged, the laparoscopic sleeve gastrectomy (LSG). Initially proposed by Dr. Gagner as part of a staged duodenal switch in patients with high BMI, it was observed that LSG alone provided lasting weight loss. Introduced in 2004, LSG has since become the most prevalent world-wide procedure. Advocates of LSG highlight weight loss results that rival gastric bypass but with lower surgical risk, decreased rate of anemia, and bone loss. Antagonists of LSG highlight increased weight regain without manipulation of the intestine, higher rate of GERD, and inferior diabetes resolution compared to RYGB. Additionally, there have been reports of de novo Barrett's esophagus following LSG, with an incidence as high as 18.8% [4].

With the increasing popularity of LSG, RYGB numbers declined. According to the American Society for Metabolic and Bariatric Surgery (ASMBS) database, RYGB represented 36.7% of all bariatric procedures performed in 2011. In 2018, that number decreased to 17%. The reasoning behind this decline is unclear but theories include physician preference for what is perceived as a simpler procedure (i.e., LSG) as well as negative patient perception of bypass procedures.

4.2 The Next Frontier

Traditionally, there has been little correlation between the physiology of obesity and the mechanisms of surgical correction. Bariatric procedure development was observational and based on the realization that with gastric volume reduction (i.e., gastrectomy) and bowel resection, patients lost weight. The overall understanding was that a caloric deficit was created by gastric restriction, malabsorption, or both. The detailed physiologic derangements that cause obesity, as well as how surgical procedures improve these derangements, is only just beginning to be deciphered. It is conceivable that with an improved understanding of these two aforementioned variables, operations can now be designed with improved results.

4.3 To Treat Obesity, It Is Necessary to Understand the Cause

Historically, weight loss education was centered around calories in and calories out. In fact, LuLu Peters first described calorie counting as a form of weight management over 100 years ago. This dogmatic approach to weight loss cited success with simply burning more calories than consumed. Unfortunately, we now realize that weight loss is much more complex. First, all calories are not absorbed (created) equally. For example, a pretzel digested primarily via oral amylase is not the same mechanism as a piece of asparagus. Second, the accounting theory of weight loss assumes all individuals process calories in an identical manner. Yet, by experience we know this not to be the case. Theoretically, if one were to reduce input and increase expenditure, they would continue to lose weight indefinitely. Instead, we see many individuals reach a weight plateau after altering intake for a period of time. In truth, caloric intake influences caloric expenditure and caloric expenditure impacts caloric intake. Reduction of caloric intake is countered by the body improving metabolic efficiency and resisting weight loss. Increasing activity promotes appetite. Importantly, energy regulation is centrally controlled. This is made clear by the increased consumption during pregnancy and the observation that many drugs including insulin, anti-seizure, and anti-psychotic medications result in weight gain. Short-term caloric deprivation may lead to early weight loss, however this is rarely maintained. The simplistic approach of severe caloric restriction combined with increased activity is flawed and outdated with little evidence to support sustainable weight loss.

More likely, obesity is a hormonal disease resulting in an alteration of energy regulation. Two hormones that invariably cause weight gain are insulin and cortisol. Insulin is an anabolic hormone essential for glucose control as well as promoting lipogenesis and inhibiting lipolysis. Unfortunately, increased fat and insulin levels lead to insulin resistance. Thus once resistance develops, additional insulin secretion is necessary to maintain blood sugar. When fat stores are increased, they secrete another hormone called leptin. Leptin signals the brain that adequate adipose stores exist in the body. Similar to the pathophysiology of insulin resistance, obese individuals become leptin resistant. Few interventions are effective in breaking this hormonal imbalance especially once class III obesity (BMI > 40 kg/m^2) develops. To date, the most effective therapy is bariatric surgery. Although the improvement in diabetes is more often touted, bariatric procedures such as RYGB profoundly improve insulin resistance and reduce overall insulin secretion. Many mechanisms account for the effects of bariatric surgery on insulin, including reduced intake, reduction in hepatic insulin resistance, and increased incretins, which delay gastric emptying and increase insulin sensitivity.

Little about obesity was understood when RYGB and duodenal switch (DS) procedures were developed. It was believed fat was the cause of obesity and cardiac disease, a hypothesis titled the “heart health hypothesis” and popularized by an American physiologist Ancel Keys in the late 1950s. It seemed logical that since fats were more calorically dense, and calories were all that mattered, a low fat diet was optimal. Therefore, the most effective bariatric procedures would inhibit fat absorption by incorporating a diversion of bile and pancreatic juices with a short common channel. Today, many obesity experts have a strikingly different opinion. They opine that the reduction of fat in the diet resulted in the replacement with carbohydrates leading to reduced satiety and increased insulin resistance. It seems that at least in part, the obesity epidemic dates back to the heart health hypothesis. The replacement of whole foods with increased processed food, based primarily on carbohydrates, is another major factor. However, if massive fat malabsorption is not needed and potentially can be maladaptive, then it is imperative we take a fresh look at the construction of our bariatric procedures and abandon the traditional biases based on disproven assumptions.

4.4 The Next Domain: Glucose Variability and Matching Bariatric Surgery to Modern Obesity Treatment

The fundamentals of current obesity management center around glucose regulation with reduced insulin secretion. Although the specifics of paleo, whole 30, keto, and intermittent fasting differ, they all seek to reduce glucose spikes and the resultant insulin surge. Many have considered RYGB to be the gold standard bariatric procedure. Advocates state it offers the best balance of sustained weight loss and improvement in comorbid conditions while having an acceptably low long-term complication rate. Contrarily, opponents such as Dr. Mason argued that bypass leads to anemia, osteoporosis, and other long-term maladies [1]. In support of RYGB, Dr. Sugerman conducted a randomized trial between RYGB and VBG. This single center study strongly supported the use of RYGB for patients that were categorized as “sweet eaters.” Although flawed, this became dogma and RYGB became the preferential procedure for patients who “snacked.” It was suggested that a possible reason for this was sugar ingestion following RYGB can cause dumping syndrome with its symptoms thus deterring further consumption.

The question remains whether dumping is advantageous for weight loss. Dumping correlates with hypoglycemia and increased glucose variability. This is contrary to medical weight loss experts who seek to prevent glucose fluctuations and the resultant hunger stimulation [5]. It was this phenomenon of glucose variability that prompted our bariatric group to pursue alternative surgical interventions. Initially, glucose tolerance testing was performed in RYGB patients. These tests confirmed increased glucose variability with frequent hypo- and hyperglycemia events. Next, glucose tolerance was compared in patients who underwent LSG, RYGB, and DS. DS provided the greatest degree of glucose stability while RYGB had the greatest degree of glucose variability. Interestingly, despite the maintained anatomy, LSG patients had only intermediary variability. A finding that implies pyloric preservation is not the sole mechanism for glucose stability [5]. More than absolute values, it is the fluctuations in glucose that results in oxidative stress [6]. Further studies demonstrate that patients with increased glucose variability are less likely to have resolution of diabetes [7].

Despite the observation that DS offers superior lasting weight loss and resolution of diabetes, it remains a rarely performed procedure. According to the ASMBS database, DS accounts for only 1% of primary bariatric procedures. Reasons for this paucity include the technical challenges of the duodenal switch and concerns for micronutrient deficiencies. There have been multiple case matched studies comparing duodenal switch and gastric bypass, demonstrating similar patient satisfaction and complication rates [8–11]. Despite these, the DS has never reached comparable popularity to RYGB.

There persists a need for a bariatric procedure with less glucose variability than the RYGB and lower risk of micronutrient deficiencies than the DS. In Spain, Dr. Antonio Torres and Dr. Sanchez-Pernaute described a single anastomosis duodenal switch, which they named the single anastomosis duodeno-ileal (SADI) [12]. In their modification, Dr. Torres and Dr. Sanchez-Pernaute performed a sleeve gastrectomy over a 54-French bougie and anastomosed the transected post-pyloric duodenum to the jejunum (approximately 200 cm from the ileocecal valve). This procedure was further modified to a common channel of 250 cm in an effort to decrease diarrhea. In 2012, Dr. Roslin and Dr. Cottam began the US experience with single anastomosis duodenal switch. They designed an operation called stomach intestinal pylorus sparing surgery (SIPS), which included a sleeve gastrectomy over a 42 bougie and a post-pyloric anastomosis 300 cm from the ileocecal valve. In 2015, they presented their initial 1-year data suggesting an average BMI weight loss of approximately 21 units [13]. Further publications have cited weight loss following SIPS to be 30% greater than weight loss following LSG [14]. Despite initial concerns for micronutrient deficiency following DS, studies demonstrate that postoperative iron, vitamin A, and vitamin D levels are similar in DS and RYGB patients [15]. Given these positive findings, both the International Federation for the Surgery of Obesity and Metabolic Disease (IFSO) and the American Society of Bariatric Metabolic Surgery (ASMBS) added single anastomosis duodenal switch (SADI/SADS) to the endorsed list of bariatric procedures in 2018 and 2019, respectively [16].

4.5 Rationalization for Patient Selection

Although there are many benefits for bariatric surgery, weight loss is often the primary objective. Often patients' unstated goal is to no longer be viewed as obese, thus a realistic discussion of probable results is mandatory prior to any surgical intervention.

Commonly cited, LSG offers 60% excess weight loss, RYGB 70%, and DS 80%. However, analysis of results obtained in over 600 LSG patients demonstrate that historical figures for weight loss following LSG are inaccurate as BMI increases. In fact, the majority of patients with BMIs greater than 45 who undergo LSG will remain obese [17]. For those with a BMI >50, the probability of reaching a BMI < 30 following LSG is approximately 5%. Additionally, obesity-recidivism also increases with increasing BMI [13]. Consequently, patients with increased BMI (i.e., > 45) should be recommended more aggressive procedures that include intestinal bypass to improve long-term success [18].

Another issue mitigating the success of LSG is insulin resistance. Whereas there have been several randomized controlled trials that have compared LSG, RYGB, and medical therapy for individuals with Type 2 diabetes, Mingrone first compared BPD, RYGB, and medical therapy in 2012 [19]. BPD, an obsolete version of the modern DS, was shown to be superior especially in patients with the increased homeostatic model assessment (HOMA) and increased degree of insulin resistance. Therefore, patients managed on home insulin therapy with persistently elevated HbA1c should be considered for a SADI-type procedure [12].

An increasing number of bariatric patients experience weight regain or inadequate initial weight loss following a gastric only procedure (i.e., LAGB or LSG). Initial assessment of these patients includes an understanding of current anatomy. If tests fail to document anatomic flaws, attempts to further restrict are unlikely to result in long-term success. Bariatric surgery is far more than just mechanical. Success involves altering the gut–brain interaction. Thus, activating an additional mechanism of action such as an intestinal conduit is the most logical approach.

In patients with a high BMI, severe insulin resistance or metabolic syndrome and those who have failed a previous weight loss procedure, an aggressive approach combining a gastric resection and intestinal bypass is necessary. Several principles have emerged. Stomach restriction promotes early weight loss, but the intestinal malabsorption maintains weight loss. Both reduction in weight and metabolic control correlate directly with the length of the biliopancreatic limb or degree of malabsorption. Unfortunately, micronutrient deficiency and hypoalbuminemia also correspond with length of the biliopancreatic limb. When designing an operation, consideration must be given to pylorus preservation, the importance of a bile-free roux limb and the ideal biliopancreatic limb length.

4.6 SADI/SADS vs. Traditional Roux DS

The major difference between SADI/SADS modification and the traditional DS is a single anastomosis in the former. So instead of biliopancreatic limb, a digestive roux limb and a common channel, there is an afferent and efferent limb without a bile-free digestive limb.

A roux construction eliminates bile reflux and the DS was initially proposed as a treatment for bile reflux gastritis. Bile is produced in the liver and secreted into the proximal duodenum. In SADI, bile enters into the bypassed duodenum and travels through a long afferent limb without food particles. In the normal digestive tract, the majority of bile salts are reabsorbed in the distal intestine as part of the entero-hepatic digestive cycle. Studies have shown that binding to lipids is a major inhibitor of bile reabsorption [20]. In the long afferent limb following SADI, where there are no lipids acting as inhibitors, the majority of bile is reabsorbed prior to the anastomosis. The combination of this situation and the fact that fats are not the primary culprit of obesity explains the similarity in weight loss following traditional DS and SADI/SADS modification-type procedures. Cottam et al. have shown no significant weight loss at 3 years between these procedures [21]. A randomized trial from Spain also demonstrated no significant difference in weight loss with the caveat that there may be a trend toward higher weight loss in those with BMI > 60 following DS.

Another advantage of a Roux limb is that it allows for a shorter common channel while preserving adequate bowel length to prevent fluid and electrolyte disturbances. The Roux limb maintains the ability to digest virtually all simple carbohydrates and alcohol. Additionally, the Roux limb also absorbs most protein. A short common channel mainly limits fat absorption. Although there are no essential carbohydrates, there exists essential amino acids and fats that must be consumed via dietary sources and the importance of proper dietary fat is often underappreciated. Poor dietary fat intake correlates with decreased cognitive function. Therefore, if fats do not cause obesity, and fat absorption to some degree is key to homeostasis, then a short common channel is not mandatory.

Another obvious advantage of SADI is lack of a distal anastomosis and subsequent decreased perioperative risk of bleeding or leak. Although issues at the distal anastomosis are less common than the proximal anastomosis, they are often difficult to diagnose and can be lethal. Overall compilations following SADI were compared to RYGB. SADI procedures were found to have a lower risk of internal hernia, marginal ulceration, and anastomotic complications when compared to Roux procedures [22].

A cardinal principle of medicine states that every intervention should be justified by science. There must be a rationale beyond traditional bias to divide the small bowel and perform an entero-enterostomy. For the majority of patients undergoing metabolic surgery, performing an entero-enterostomy is not necessary and carries more risk than benefit. Flaws at the entero-enterostomy, although rare, are associated with a high morbidity and mortality. Interrupting bowel continuity disrupts the intestinal pacemaker mechanism and creates mesenteric windows that must be closed. However, some clinical conditions exist where the creation of a bile-free Roux limb is advantageous. One of these is a patient with Barrett's esophagus and a history of dysplasia, where any bile exposure could be deleterious. Another condition pertains to anastomotic complication following SADI. In this event, conversion to a traditional roux DS diverts bile and pancreatic juices from the proximal anastomosis and prevents reflux into the stomach. A final condition pertains to the rare patient that is referred for bile gastritis, for whom a traditional roux DS is a better approach. It is our anticipation that, with time, SADI will become more common, and DS reserved for few patients. Some have suggested that in the case of weight regain following SADI, conversion to DS might be a viable option. While further data must be collected, the benefit of such a conversion is debatable. The majority of patients with weight regain following SADI are consuming processed carbohydrates rather than excess fat from animal or plant-based sources.

4.7 SADS vs. RYGB

There are essential anatomic differences between SADS and RYGB. In SADS, the gastric pouch is a long tube that preserves the pyloric valve but the procedure includes resection of the majority of the stomach. Alternatively, in RYGB, the gastric pouch is generally 4–6 cm and based on the lesser curvature. The remnant is separated from the pouch, but not removed. The gastric pouch is then anastomosed to the jejunum.

There are several advantages of gastric resection in SADS procedures. Reducing gastric volume decreases acid production and subsequent risk of marginal ulceration. Both Hess and Marceau separately designed the concept of DS, with reduced gastric cell mass, in an effort to replace Scopinaro's BPD given the high incidence of marginal ulcers. Powerful data demonstrates that DS type procedures have a lower risk of marginal ulcer. Besides acid reduction secondary to resection, Brunner's glands in the duodenum secrete bicarbonate that neutralizes acid gastric secretions. Preservation of a 3–4 cm duodenal cuff is desirable. Further, gastric resection results in the reduction of hunger hormones produced in the fundus, including ghrelin. Finally, although rare, resection eliminates the possibility of pathology in the gastric remnant that can be difficult to assess via traditional endoscopy.

Conversely, there are advantages for gastric preservation in RYGB. A major benefit includes the ability for future conversion if necessary. The persistence of the gastric remnant allows for access to the biliary tree via percutaneous or laparoscopic cannulation and endoscopic retrograde cholangiopancreatography (ERCP) if indicated. Since the blood supply to the remnant is not altered, the stomach remains viable as a reconstructive conduit if esophageal cancer occurs. Although this is not a common scenario, one must be aware that the risk of esophageal cancer is increased in obesity and cases of de novo Barrett's esophagus following LSG have been documented.

In SADS, the pyloric valve is preserved. Under normal conditions, the pylorus controls the release of solid foods from the stomach. Although the degree of pyloric function following fundectomy is unknown, improved glucose regulation and high pressures detected following LSG demonstrate ongoing efficacy. RYGB patients exhibit a crescendo-decrescendo glucose response following carbohydrate ingestion. A fast rise in glucose correlates with a spike in insulin and resulting rapid decline in glucose. Use of continuous glucose monitoring following RYGB reveals that patients are frequently both hyper- and hypoglycemic. Hypoglycemia is perhaps the strongest stimulus for appetite. Increasing numbers of RYGB patients complain of weight regain secondary to inter-meal hunger. Alternatively, procedures that have lower glucose variability, including SADS, may have more advantageous long-term outcomes. Again, decreased glucose variability is demonstrated following a duodenal switch-type procedure.

While pyloric preservation has benefits in terms of decreased glucose variability, it is not without side effects. An active pylorus results in a higher resting pressure within the sleeved stomach. Sequelae of this increased pressure include increased risk for GERD, hiatal hernia formation, and intrathoracic migration of the stomach. Additionally, if a complication (i.e., leak) does occur in the sleeved portion it can be difficult to treat non-operatively due to the pressurized stomach. RYGB procedures should be suggested when a low pressure system is desirable, these circumstances include large hiatal hernias, esophageal dysmotility, Barrett's esophagus, and esophageal strictures.

4.8 SADS vs. OAGB (One Anastomosis Gastric Bypass)

The major differences between SADS and OAGB is the pylorus, which is preserved only in the former and the bypassed stomach remnant that is present only in the latter. Pyloric preservation in SADS reduces the rate of marginal ulcer and decreases glucose variability. Pyloric preservation also prevents bile reflux, which is a major drawback of OAGB [23]. An advantage of OAGB is relative technical ease compared to the SADS. OAGB does not require duodenal dissection and can be performed via a stapled approach versus the handsewn duodenal-enterostomy required in SADS.

4.9 Surgical Technique

Multiple techniques have been described to perform the single anastomosis duodenal switch [12]. Several of the key points that are utilized in our practice are highlighted below. Additionally, Fig. 4.1 is visual demonstration of the single anastomosis duodenal switch with the key anatomic points mentioned below.

- The initial action includes identifying the cecum and terminal ileum. We measure 300 cm of small bowel from the ileocecal junction. 300 cm is our suggested length as data cites 250 cm as an adequate amount, however there exists a 20% error when measuring. When 300 cm is reached, a marking stitch is placed between the efferent limb and the mesentery of the transverse colon.
- It is imperative that a proper sleeve gastrectomy is performed. The sleeve should be of a greater diameter than a primary sleeve gastrectomy. A major source of morbidity following duodenal switch is an overly narrowed sleeve (previously published papers have used as small as a 32-Fr bougie) [24]. A narrowed sleeve prevents adequate oral intake and results in rapid gastric emptying with increased malabsorption. Conversely, a less restrictive sleeve decreases risk of stricture and leak and reduces incidence of GERD. We prefer a 42-Fr bougie and start 5 cm proximal to the pyloric valve.
- Division of the duodenum and subsequent anastomosis represents major technical hurdles for surgeons learning SADS. Transection of the duodenum should be

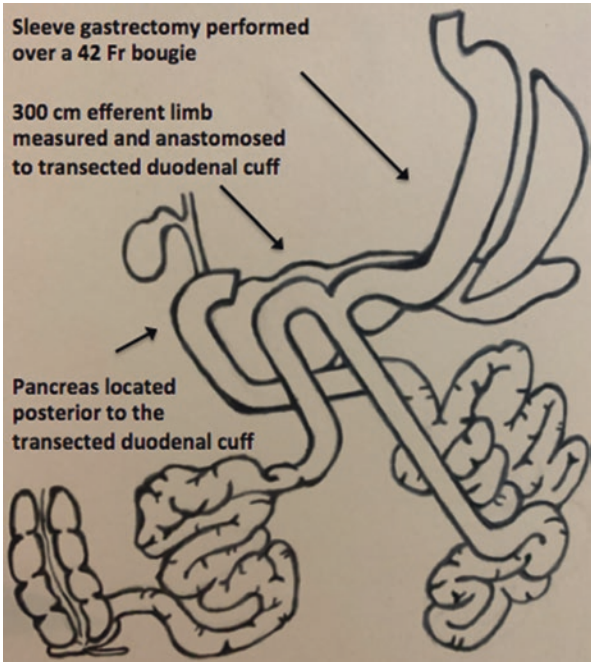

Fig. 4.1 SADS anatomy: visual representation of SADS anatomy including transected duodenal cuff anastomosed to efferent loop at 300 cm proximal to the ileocecal valve. Sleeve gastrectomy is performed over a 42-Fr bougie, a slightly larger bougie than traditional sleeve gastrectomy. Figure Source—Original artwork by one of the authors (Michael Marchese)

done at the level of the gastroduodenal artery. To accurately perform this, dissection is initiated down the greater curvature of the stomach with all posterior adhesions taken down and the stomach mobilized preserving only the blood supply to the lesser curvature. The dissection continues beyond the pyloric valve and the peritoneum is lysed on the superior aspect of the duodenum. Once in the correct plane, the gastroduodenal artery is visualized. This dissection should occur with ease and the pancreas should never be encountered. An articulating grasper encircles the duodenum past the pyloric valve. This is replaced by a linear stapler. Traction is placed on the stomach, pulling toward the patient's left to increase duodenal cuff length. The duodenum is transected.

- We perform a hand-sewn termino-lateral duodenal enteral anastomosis using a 2–0 pds on an SH needle. We place a single stay stitch between the top corner of the duodenum and the mesentery of the small bowel. A 2 cm duodenotomy and enterotomy are made. The posterior layer of the anastomosis is performed inside-outside on the duodenum and outside-inside on the small bowel, initiating at the superior corner. At the inferior corner, the suture is brought outside on the duodenum. An oral gastric tube is placed over the posterior wall and into the efferent limb. At the inferior corner, a stitch is taken outside-inside on the duodenum and inside-outside on the small bowel along the anterior wall. This is tied to both itself and the posterior wall suture. Starting at the superior corner, a suture is taken on the anterior wall and carried to and secured to the previous anterior suture. After completion of the anastomosis, both limbs of the small bowel are occluded and 60 cc of methylene blue infused, demonstrating distension of the sleeve and both limbs of the bowel. Several Lembert sutures are placed. Lastly, a stitch from the antrum to the omental fat and then afferent limb is placed to prevent torsion.

4.10 Issues in Complication Management

Early leaks (<5 days postoperatively) at the duodenal-enteral anastomosis are unusual [22]. An early leak is best treated with laparoscopic exploration. Anastomotic repair can be performed laparoscopically with endoscopy to confirm viability. Anastomotic tension must be ruled out. Because digestive enzymes from the pancreas will traverse the leak, consideration for conversion to traditional DS with a Roux limb should be undertaken. Conversion to DS offers the additional advantage of a feeding jejunostomy near the ligament of Treitz such that feeds do not traverse the area of concern. If extensive inflammation precludes anastomotic repair, resection of the pylorus and distal antrum with reconstruction of the small bowel and creation of a BPD at the level of the angularis is a viable option.

Delayed leaks (>5 days postoperatively), without systemic sepsis or peritonitis are best treated via percutaneous drainage, IV antibiotics, nothing per oral (NPO), and total parenteral nutrition (TPN). After initial therapy, endoscopy is performed. If a small leak is visualized, we recommend a 7-Fr double tailed pigtail for internal drainage. The drain is left in place for several weeks and a clamp trial performed prior to removal. If a large leak is visualized, the management algorithm is more complex. Adequate drainage parenteral nutrition is paramount. Endoscopic stenting can be performed, however the stent cannot travel across both limbs. Use of an endoscopic vacuum is technically challenging. In these complex cases, we advise sepsis control, natural healing, and delayed reconstruction. After 3 months the area is contained and reconstruction more feasible.

Fortunately, anastomotic complications following SADS are rare. In a multi-institute study with 6 years of patients undergoing SADI, the incidence of marginal ulcers, anastomotic strictures, and small bowel obstructions was lower than following RYGB and DS [22]. Torsion of the afferent limb and herniation posterior to the anastomosis has been reported but was managed successfully with laparoscopic reduction. There have been no reports of bowel ischemia following SADI [25].

4.11 Malnutrition: Input and Output Issues

Bypassing the intestine comes with the substantial risk of increased bowel movements, flatulence, anal rectal pathology, micronutrient and divalent cation deficiencies, and hypoproteinemia. Preserving 300 cm of small bowel, proper patient education, diet compliance, and nutritional supplementation mitigates the risk of these complications. Long-term follow-up with regular blood work checking protein, iron, calcium, fat-soluble vitamins, and parathyroid hormone (PTH) is mandatory. Morbidly obese patients are commonly nutrient deficient secondary to years of abusing food with limited nutritional value [26]. Following SADS, gastric volume is reduced and the proximal half of the small intestine bypassed, a combination that predisposes patients to further malnutrition. Exacerbating the issue, poor intake leads to edema, reducing the absorptive capacity of the sleeved stomach. Following any bariatric procedures that contain a malabsorptive element, complaints of weakness and fatigue must be investigated thoroughly. One critical deficiency is thiamine secondary to poor intake and/or increased emesis. The human body has limited reserves of thiamine and the half-life is only 7 days [27]. Deficiency is potentiated by an impulse for consumption of high dextrose, high osmotic solutions (i.e., sports drinks). Thiamine promotes glucose utilization and should be administered prior to dextrose rich solutions [27]. Acute thiamine deficiency can manifest with Wernicke's syndrome and irreversible neurological damage. Additional factors that predispose SADS patients to malabsorption include altered pH of gastric contents, bypassed duodenum, and the site of cholecyctokinin (CCK) stimulation and small intestinal bacterial overgrowth (SIBO).

Hypoproteinemia following SADS can lead to clinically apparent edema [28]. When diagnosed, treatment is mandatory. The hallmark of malabsorption is weight loss despite adequate intake, however more often bariatric patients have both poor absorption and intake. In all cases of malnutrition, correction of deficiencies is the first step. Extensive blood work should be performed. Anemia due iron deficiency is frequently present. Electrolyte abnormalities are common and should be repleted. If fat malabsorption is present, calcium and magnesium bind to unabsorbed fat leading to depletion. Vitamin D levels are low exacerbating calcium deficiency. Management of malnutrition begins with thiamine repletion, followed by a programmed feeding regimen [27]. Intake should be titrated responsibly to prevent refeeding syndrome. TPN is often necessary. It is our practice to administer TPN gradually when indicated, utilizing low dextrose containing solutions to minimize steatosis. Adequate amino acids and essential fatty acids should be included in the TPN. TPN is continued until laboratory values normalize and PO intake improves or surgical revision is undertaken. Endoscopy and CT scan are utilized to rule out a mechanical etiology for malnutrition, however generally intake issues are difficult to solve with surgery alone. Mental health providers are important support. Appetite stimulants can be tried. Regardless, continued alimentation must persist until the patient is capable of resuming adequate feeding autonomously.

Following SADS, frequent bowel movements are a common complaint. Assessment of oral intake and bowel movements is key. Steatorrhea presents with abundant and dense floating stool. Lactase deficiency, which is potentiated by gastric restriction, presents with frequent and watery diarrhea. Watery diarrhea following bariatric surgery is more often associated with malabsorption of carbohydrates rather than fat. Poorly absorbed carbohydrates enter the colon and undergo fermentation by bacteria. Methane is produced presenting with bloating and flatulence and potentiating small intestinal bacterial overgrowth.

Output issues present later in the postoperative course. Laboratory abnormalities can occur, however this is not always the case. For patients with normal nutritional parameters despite frequent bowel movements, management is focused on control of diarrhea. As mentioned previously, carbohydrate abuse is often the etiology of diarrhea. Small intestinal bacterial overgrowth (SIBO) should be ruled out by a breath test. Treatment involves alteration of diet, the use of motility agents such as imodium and lomotil. An H2 blocker and PPI should be prescribed. Dietary modification with minimization of carbohydrate and fat is necessary (the so-called FODMAP diet). Fiber and probiotics should be encouraged through diet and supplemented. Cholestyramine, a bile acid binding agent, is often effective but poorly tolerated by many patients. Other medications include clonidine, octreotide, and GLP-1 agonists. GLP-1 agonists delay gastric emptying. The GLP-2 analogue teleglutitide is rarely used following bariatric surgery. Although its use leads to short-term gut hypertrophy, it is expensive and must be used regularly or the effect dissipates. If surgical revision is practical to reduce output it is often necessary given the paucity of alternatives.

If chronic diarrhea and poor nutritional parameters persist, liver failure may occur. Although more common following jejunoileal bypass in the past, liver failure can occur following modern bariatric surgery when the majority of usable calories are via simple sugars. Liver failure can be accelerated if bacterial overgrowth is present. Consideration should be given to surgical reconstruction following nutritional repletion whenever malnutrition is present. The primary goal of surgery is to increase the length of bowel taking part in absorption. Insertion of a jejunal feeding tube to augment postoperative oral feeding at the time of reconstruction should be considered.

4.12 Electrolyte and Micronutrient Deficiencies

Early findings of poor nutrition following bariatric surgery include hypokalemia and decreased BUN. These values are evident before hypoalbuminemia, as albumin has a half-life of 21 days [29]. Chronic patients can often compensate for these deficiencies, but may present with persistent hypokalemia and metabolic acidosis secondary to diarrhea. Iron, magnesium, and calcium can also be abnormal. Iron is absorbed predominantly in the duodenum. Anemia secondary to iron deficiency and chronic disease is common. B12 and folic acid levels can be diminished, however a microcytic anemia is more common. Calcium is also preferentially absorbed in the proximal intestine. Hypocalcemia is exacerbated by decreased vitamin D levels and via binding to unabsorbed fatty acids in the GI tract. Magnesium, although preferentially absorbed in the distal GI tract, can also be deficient due to binding to unabsorbed fatty acids as well as increased excretion.

4.13 Fat Soluble Vitamins

Decreased bile salts and absorptive capacity following SADS presents with a persistent deficiency of fat-soluble vitamins (ADEK) despite supplementation. Vitamin A deficiency can present with visual impairment and night blindness. Vitamin D deficiency worsens hypocalcemia and increases bone turnover via osteoclasts. Vitamin K deficiency can present with clotting disorders. All oral supplements given must be water-soluble versions to maximize absorption.

4.14 Vitamin B12

B12 is a water-soluble vitamin, absorbed primarily in the ileum. Absorption of B12 requires the presence of intrinsic factor. Intrinsic factor activity is dependent on gastric acid levels, which are decreased following SADS. If bacterial overgrowth is present, bacteria compete for B12 further decreasing absorption. B12 deficiency can present with megaloblastic anemia and neurologic symptoms. Supplementation is best given nasally, sublingually, or intradermally.

4.15 Trace Elements

Critical deficiencies of trace elements including zinc, copper, and selenium can occur following SADS. In general, they rarely occur in isolation and are representative of chronic malnutrition. Zinc deficiency is most common and can present with hair loss, diarrhea, and dermatosis. Copper deficiency can present with peripheral neuropathy and weakness. Selenium deficiency can cause heart failure. Trace elements are usually administered along with parenteral nutrition.

4.16 Metabolic Bone Disease

All bariatric procedures that bypass the proximal intestine increase the incidence of osteomalacia, osteoporosis, osteopenia, and secondary hyperparathyroidism secondary to decreased calcium absorption. Vitamin D absorption is also compromised. Supplements can be effective. However, in the presence of fat malabsorption, calcium binds to fatty acids increasing excretion. In response to hypocalcemia, increased parathyroid hormone recruits osteoclast mediated bone resorption. Elevated PTH leads to hypophosphatemia. The risk of hungry bone syndrome is decreased with adequate calcium and vitamin D supplementation. Routine bone density scans are suggested [30].

4.17 Nephrolithiasis

Another sequelae of malabsorption is nephrolithiasis, exacerbated by increased oxalate intake. Fat malabsorption leads to hypocalcemia secondary to calcium binding to free fatty acids. Subsequently, free oxalate is absorbed via the colon. Oxalate in the bloodstream is filtered by the kidney and binds calcium within the urinary tract. Calcium oxalate crystals precipitate causing nephrolithiasis. Management includes a low oxalate diet, increased calcium, and adequate hydration.

4.18 SADS Surgical Correction for Malabsorption

For patients with a single anastomosis, there are several options to lengthen the BP limb. The first is to take down the duodenal enteral anastomosis. We advise firing a transverse staple line. Another anastomosis can then be performed 150 cm proximally in the standard fashion. Figure 4.2 demonstrates this technique for correcting malabsorption via lengthening the BP limb.

Another option includes the creation of two small bowel anastomoses. The small bowel is transected proximal to the anastomosis and reattached 50 cm distally with conversion to a Roux. 150 cm of the BP limb is attached to the now proximal Roux limb. A feeding jejunostomy can be placed to supplement oral feeding. Figure 4.3 demonstrates this technique for correcting malabsorption via creation of two small bowel anastomoses.

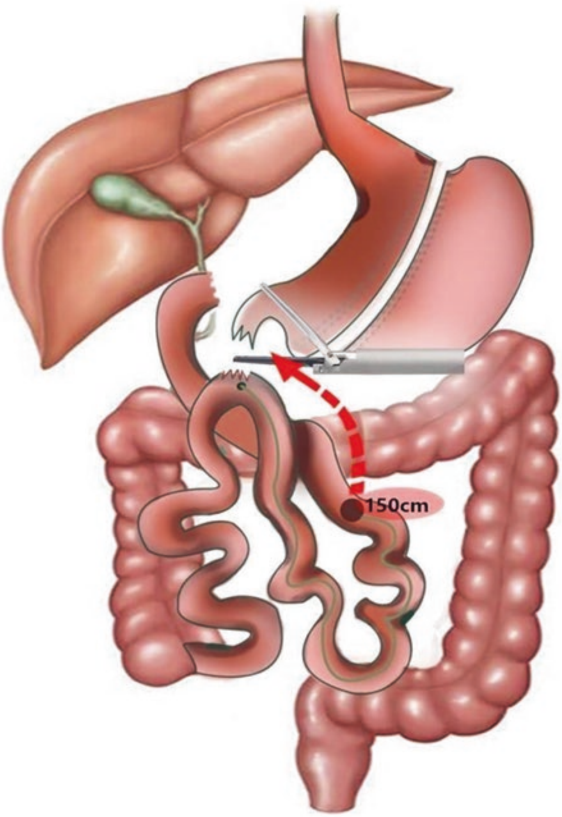

Fig. 4.2 SADS surgical correction #1: visual representation of lengthening the BP limp via transection of proximal duodenal enteral anastomosis and recreation of subsequent anastomosis 150 cm proximal. Figure source—Roslin et al.

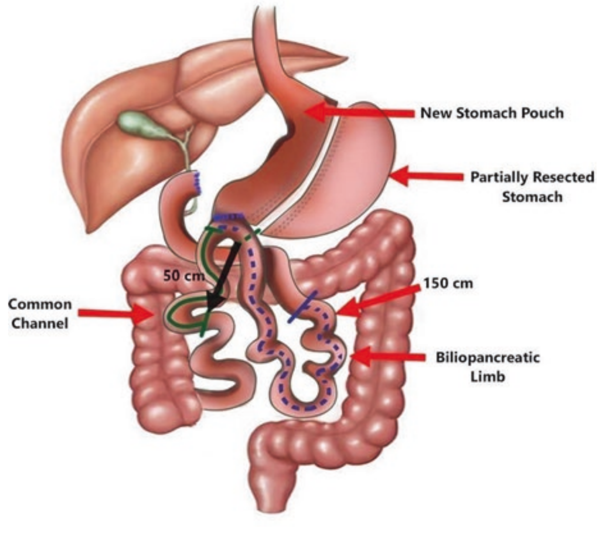

Fig. 4.3 SADS surgical correction #2: visual representation of the creation of two small bowel anastomoses via transection of small bowel proximal to anastomosis and creation of second distal anastomosis. Figure source—Roslin et al.

4.19 Additional Complications of SADS: Gastroesophageal Reflux Disease (GERD)

Another issue that can mandate surgical revision following SADS is refractory GERD. Similar to LSG, SADS involves a longitudinal gastrectomy. The degree of GERD is often inversely proportional to the size of the gastrectomy (i.e., 36-Fr for VSG and 42-Fr for DS). Patients with GERD symptoms are often managed effectively with medicine. However, for patients with GERD refractory to medical management, numerous options exist including endoscopic procedures, such as STRETTA and LINX [31].

STRETTA is an endoscopic radiofrequency procedure, which increases lower esophageal sphincter (LES) tone and therefore reduces esophageal acid exposure. A meta-analysis of controlled and cohort studies of patients with GERD demonstrated a significant reduction in erosive esophagitis and esophageal acid exposure, as well as a subjective improvement in heartburn symptoms and decreased proton pump inhibitor use following STRETTA [32]. Another approach is LINX, which includes placement of a magnetic ring around the esophagus to augment LES and decrease reflux [33]. A retrospective review of 7 patients following LINX placement demonstrated subjective improvement in GERD symptoms.

A surgical approach to refractory GERD includes hiatal hernia repair [34]. A recent experimental approach includes usage of the round ligament to provide a pseudo-plication [35]. However, without true fundoplication the long-term efficacy of this surgical repair is debatable.

For patients with severe esophagitis following SADS, conversion to an RYGB is a viable option. To accomplish this, the sleeved stomach is divided to form a pouch and the roux limb constructed from the previous BP limb. The distal sleeve is resected and an entero-enterostomy is performed where to loop was to prevent distal obstruction. This procedure is also indicated if chronic stricture or asymmetry of the sleeve is the etiology of GERD symptoms.

4.20 Conclusion

SADI/SADS offers many advantages. A larger sleeve is more compliant and allows for easier oral intake and reduces gastroesophageal reflux and other complications. Combining a sleeve gastrectomy with an anastomosis 300 cm from the ileocecal valve promotes lasting weight loss while maintaining adequate small bowel length for nutritional absorption. Weight loss following SADI/SADS has been demonstrated to be superior than that following sleeve gastrectomy and gastric bypass. Early data suggests similar weight loss following traditional DS and SADI/SADS. The increasing popularity of this procedure led to approval by the ASMBS. As awareness of this procedure expands, there will be an unmet need. We anticipate that SADI/SADS will be the fastest growing bariatric procedure in the

United States. Patients offered SADI/SADS include those with inadequate following LSG and those unlikely to meet their goals following a gastric-only procedure. While not without its previously mentioned complications, SADS is a robust procedure with a safety profile that can match RYGB.

The purpose of this review article was to highlight our experience with the SADS. Bariatric surgery is an imperfect method to treat a fatal and debilitating disease that works by creating a controlled abnormality. With proper technique, patient selection and education, and early detection of complications, SADS is an excellent weight loss option.

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