Taxonomy and Imaging Spectrum of Small Bowel Obstruction After Roux-en-Y Gastric Bypass Surgery

Abhijit Sunnapwar[1]
Kumaresan Sandrasegaran[2]
Christine O. Menias[3]
Mark Lockhart[4]
Kedar N. Chintapalli[1]
Srinivasa R. Prasad[1]

OBJECTIVE. For most patients with morbid obesity, bariatric surgery is the only effective method to achieve sustainable weight loss. Small bowel obstruction (SBO) after bariatric surgery is a major complication that affects postoperative course and management. Knowledge of the types of and imaging findings for SBO is essential to prompt diagnosis.

CONCLUSION. We discuss different types of SBO and a taxonomic schemata of bowel obstruction (ABC classification) and present a review of imaging findings that facilitates optimal patient management.

Keywords: bariatric surgery, CT, hernias, management, postoperative complications, small bowel obstruction

DOI:10.2214/AJR.09.2840

Received April 2, 2009; accepted after revision June 19, 2009.

[1]Department of Radiology, UT Health Science Center San Antonio, 7703 Floyd Curl Dr., San Antonio, TX 78229. Address correspondence to S. R. Prasad (prasads@uthscsa.edu).

[2]Department of Radiology, Indiana University Medical Center, Indianapolis, IN.

[3]Mallinckrodt Institute of Radiology, St. Louis, MO.

[4]Department of Radiology, University of Alabama at Birmingham, Birmingham, AL.

AJR 2010; 194:120–128

0361–803X/10/1941–120

Obesity is a major global health problem that primarily affects the Western world. The prevalence of obesity in the United States has shown a steady upward trend and now affects up to one third of the adult population [1]. Between 2000 and 2005, obesity and morbid obesity in the United States showed growth rates of 25% and 50%, respectively [2]. At least 300,000 annual deaths in the United States are thought to be related to obesity, and the estimated health care costs of caring for obese American adults amount to approximately $100 billion [3].

Roux-en-Y gastric bypass surgery, a combined restrictive and malabsorptive technique, is considered to be a standard procedure for achieving consistent sustainable weight loss. Since it was first described in 1994, laparoscopic Roux-en-Y GBP has gained widespread acceptance, with high success rates in long-term weight loss [4, 5]. Currently, more than 170,000 bariatric surgeries are performed annually in the United States [1]. A varied spectrum of complications may occur in 3–20% of patients after Roux-en-Y gastric bypass surgery. Along with the exponential increase in the volume of bariatric surgical procedures, there has been an increase in the reported incidence of procedure-related complications, including small bowel obstruction (SBO) [6]. This article provides a contemporary review of the incidence, cause, mechanism, clinical presentation, and imaging findings of SBO after bariatric surgery.

Roux-en-Y Gastric Bypass Procedure and Normal Postoperative Anatomy

Knowledge of the surgical procedure is critical for understanding the normal postoperative anatomy and for diagnosing complications. Roux-en-Y gastric bypass is performed with either an open or a laparoscopic technique. Because of the manifold advantages of the laparoscopic technique, including faster recovery, short hospital stay, reduced perioperative complications, and weight loss achievement that is comparable with that associated with the open surgery, most surgeons perform laparoscopic Roux-en-Y gastric bypass procedures. Either technique generally involves formation of a 20- to 30-mL gastric fundal pouch to exclude the remainder of the stomach, duodenum, and proximal jejunum from the food path. The jejunum is transected 45–50 cm distal to the ligament of Treitz, creating the biliopancreatic limb. The transected distal jejunal loop (alimentary limb) is anastomosed to the gastric fundal pouch with a narrow gastrojejunal anastomosis (0.8–1.5 cm in diameter) or stoma. The anastomosed jejunal loop, also called the "Roux limb" or the "efferent limb," is placed in either retrocolic position (by creating an opening in the transverse mesocolon) or antecolic position (anterior to the transverse colon). The biliopancreatic limb (also called the "afferent limb") is then anastomosed to the alimentary limb ≥ 100 cm distal to the gastrojejunostomy, and a common channel is created (Figs. 1A and 1B). The Roux-en-Y gastric bypass serves a dual purpose: early satiety resulting from a

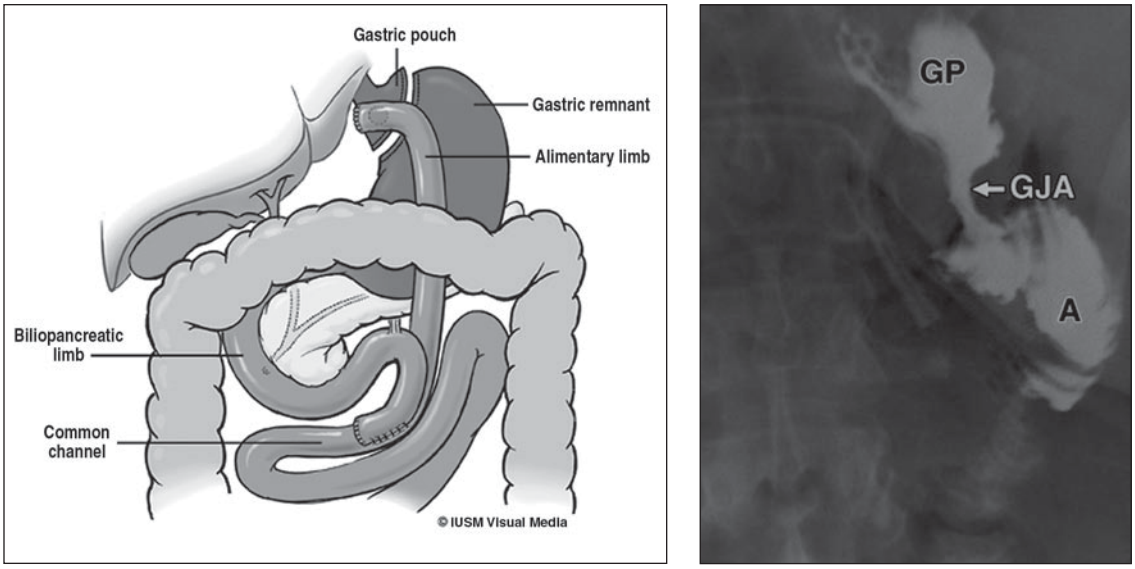


Fig. 1—Normal postoperative anatomy after Roux-en-Y gastric bypass surgery.
A, Diagram shows alimentary limb, biliopancreatic limb, and common channel. Alimentary limb can be placed in antecolic or retrocolic position. (Used with permission from Office of Visual Media, Indiana University School of Medicine)
B, Upper gastrointestinal contrast (diatrizoate meglumine and diatrizoate sodium solution [Gastrografin, Bracco]) study shows normal postoperative anatomy in 45-year-old woman. A = alimentary limb, GJA = gastrojejunostomy anastomosis, GP = gastric pouch.

small gastric pouch and reduced absorption due to bypass of a segment of jejunum [7]. Increasing or decreasing the length of the Roux limb will alter the malabsorptive component of the surgery [8].

SBO After Gastric Bypass Surgery

Epidemiology, Nomenclature, Causes, and Clinical Manifestations

SBO after Roux-en-Y gastric bypass is a major postsurgical complication that contributes to increased morbidity and mortality. The incidence of SBO varies from 0.4% to 7.45%, and the variation is primarily attributable to differences in surgical techniques and the volume of procedures performed in a particular institution [9]. Podnos et al. [10] reported increased incidence of early and late bowel obstruction after laparoscopic Roux-en-Y gastric bypass, compared with open gastric bypass surgery. Specifically, the incidence of late bowel obstruction was significantly higher after laparoscopic Roux-en-Y gastric bypass than after open gastric bypass (3.15% vs 2.11%). With the laparoscopic approach, there has been a decrease in postoperative SBO secondary to adhesions and incisional hernias. However, a higher incidence of SBO secondary to internal hernias is seen with the laparoscopic technique than with the open procedure [11] (Figs. 2A and 2B).

Patients with SBO most commonly manifest abdominal pain, nausea, vomiting, and bloating [12]. The presence of significant gastroesophageal reflux with vomiting indicates obstruction to the alimentary limb or the common channel. Abnormal liver function tests and hyperamylasemia may occur because of obstruction of the biliopancreatic limb or the common channel [13]. However, the symptoms may be nonspecific, thus rendering the clinical diagnosis difficult. In this scenario, imaging signs, such as localization of the small bowel loops in the left upper quadrant, segmental bowel dilatation, mural thickening, increased Roux limb redundancy, or transit time, may help to diagnose SBO [6].

SBO after bariatric surgery may be classified according to the timeline of presentation after surgery, anatomic site of obstruction, or underlying cause. SBO that occurs within

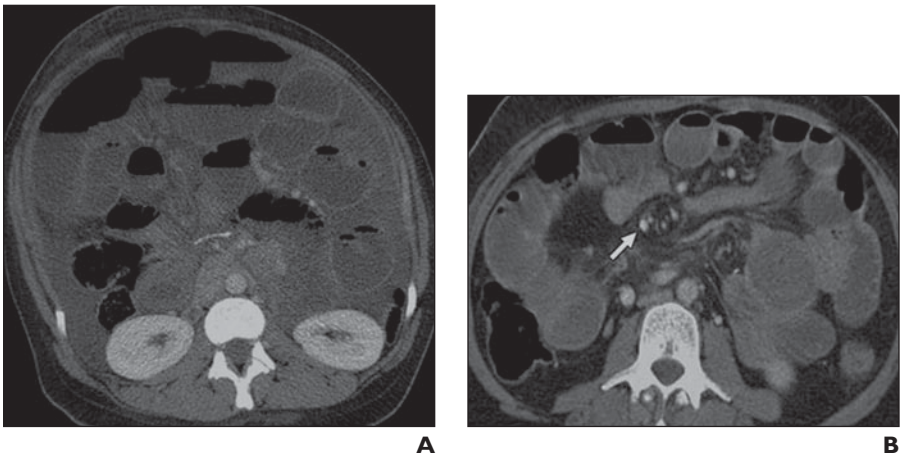


Fig. 2—Small bowel obstruction (SBO) after Roux-en-Y gastric bypass (GBP).
A, Axial contrast-enhanced CT scan in 50-year-old woman who presented 4 years after open Roux-en-Y GBP with late SBO due to adhesions.
B, Transmesenteric hernia in 44-year-old woman who presented with SBO secondary to internal hernia 1 year after laparoscopic Roux-en-Y GBP. Note swirling of mesenteric vessels (*arrow*).

TABLE 1: ABC Taxonomic Schemata of Small Bowel Obstruction After Roux-en-Y Gastric Bypass Based on Site of Obstruction

Alimentary Limb		Biliopancreatic Limb		Common Channel	
Acute	Chronic	Acute	Chronic	Acute	Chronic
Petersen hernia	Internal hernia	Jejunojejunostomy stenosis	Internal hernia	Incarcerated abdominal wall hernia (trocar site or incisional)	Internal hernia
Intussusception of the Roux limb	Mesocolic constriction of the Roux limb	Intussusception	Anastomotic stricture	Volvulus around the roux limb	Adhesions
Intraluminal or intramural hematoma		Intraluminal or intramural hematoma		Intraluminal or intramural hematoma	
Jejunojejunostomy stricture		Mesenteric hematoma			
Tight mesocolic stricture		Volvulus			
Mesocolic hematoma					

Note—Modified from Tucker et al. [13].

30 days of surgery is termed "early," whereas SBO that manifests 30 or more days after surgery is referred to as a "late" event. A simplified classification of SBO depending on the anatomic site has been proposed by Tucker et al. [13]. The ABC taxonomic system is based on the anatomic site involved in SBO as follows: alimentary limb (A), biliopancreatic limb (B), or common channel (C). SBO in each of the limbs is further categorized as either acute or chronic. The ABC classification of SBO after Roux-en-Y gastric bypass is presented in Table 1 with examples (Figs. 3A–3C). Tucker et al. also suggested classification of SBO according to the timing of the onset of obstruction as follows: acute early (≤ 30 days), acute late (between 30 days and 12 months), and chronic (≥ 12 months). SBO may also be classified according to the cause of bowel obstruction (summarized in Appendix 1).

Early SBOs, seen within 30 days after surgery, are primarily due to technical problems with the Roux limb, whereas late-presenting obstructions usually result from adhesions or internal hernias. The incidence of SBO after open Roux-en-Y gastric bypass is lower than that after laparoscopic Roux-en-Y gastric bypass, and SBO after open Roux-en-Y gastric bypass is most commonly an open loop obstruction due to adhesions. SBO due to adhesions may be managed conservatively. Thin and loose adhesions that are characteristic of open surgeries, however, may play an important role in preventing bowel obstruction by stabilizing the small bowel loops. The lack of adhesions after laparoscopic Roux-en-Y gastric bypass allows free displacement of small bowel into surgically created defects, with resultant internal hernia and closed loop obstruction [14]. Some operative techniques that are thought to minimize postoperative bowel obstruction include closure of all three mesenteric defects, placement of an antiobstruction suture, and suture closure of the jejunojejunostomy enterotomy defect [15].

Postoperative Imaging in Patients After Bariatric Surgery

The radiologic evaluation of patients after Roux-en-Y gastric bypass is institution specific, with imaging paradigms and protocols that vary among hospitals. Although routine radiologic evaluation is performed in some centers during the immediate postoperative period, to exclude leaks and early obstruction, many institutions now perform upper gastrointestinal examination in select patients who show specific symptoms [16]. Upper gastrointestinal examination is invaluable in the evaluation of symptomatic patients af-

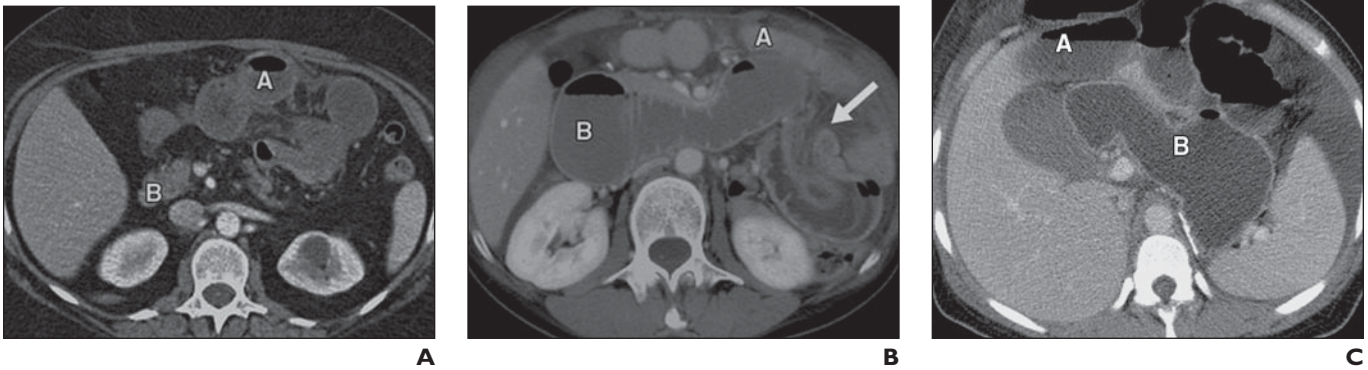


Fig. 3—ABC classification system (modified from Tucker et al. [13]) of small-bowel obstruction (SBO) after Roux-en-Y gastric bypass.
A, 43-year-old man. Dilated alimentary limb (A) without dilatation of biliopancreatic limb (B) with SBO due to internal hernia is suggestive of type A obstruction.
B, 62-year-old woman. Obstructed biliopancreatic limb (B) secondary to intussusception (*arrow*) is suggestive of type B obstruction. Alimentary limb (A) is not distended.
C, 35-year-old woman. Dilated alimentary limb (A) and dilated biliopancreatic limb (B) secondary to adhesions causing obstruction to common channel are suggestive of type C obstruction. Bypassed stomach (not shown) was also distended.

TABLE 2: Representative 16-MDCT Protocol for Scanning Morbidly Obese Patients

Imaging Parameter	Setting
kVp	140
mAs	500; automatic mAs
Gantry rotation time	1 rotation/s
Pitch	0.375–0.6
Slice thickness	5 mm

ter Roux-en-Y gastric bypass for the detection of anastomotic leaks and SBO, particularly within 4 months after surgery [3]. MDCT is the primary technique in the evaluation of patients with abdominal pain with a high suspicion of SBO and in symptomatic patients 4 months after surgery [12, 17]. MDCT after oral and IV administration of contrast material permits optimal evaluation of the postoperative anatomy and complications, including SBO. MDCT is invaluable in the confirmation of the presence, location, and associated complications of SBO. However, several studies have indicated that missed diagnoses of SBO, particularly cases of SBO due to internal hernias, occur with CT [12, 18].

Radiologic evaluation (both fluoroscopy and MDCT) of morbidly obese patients after Roux-en-Y gastric bypass presents significant technical challenges. A subset of patients may not fit within a standard MDCT scanner (table weight limit, 450 lb [204.1 kg]; available vertical gantry diameter with the table in position, 52–55 cm). Even when patients can physically fit within the scanner, they may exceed the standard field of view of 50 cm, resulting in artifacts. Slowing the table speed and the gantry rotation speed, decreasing the pitch, and increasing the kilovoltage and the milliamperes per second are some of the techniques used to optimize image quality while scanning morbidly obese patients [17]. A representative 16-MDCT protocol for morbidly obese patients is presented in Table 2. Different types of SBO that occur after Roux-en-Y gastric bypass are presented below.

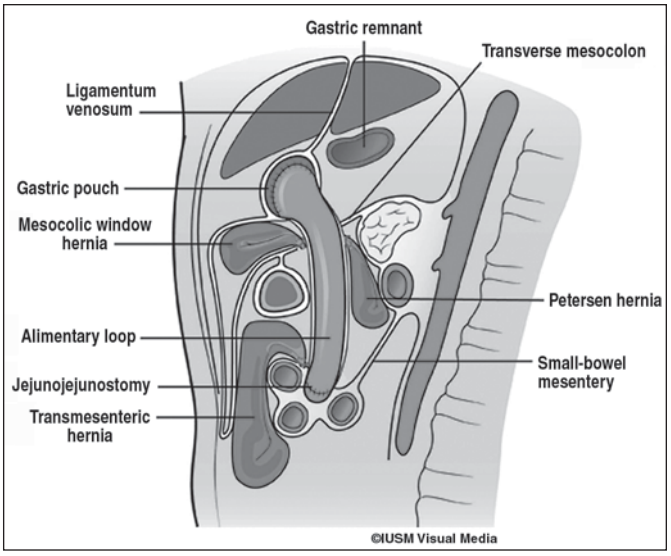


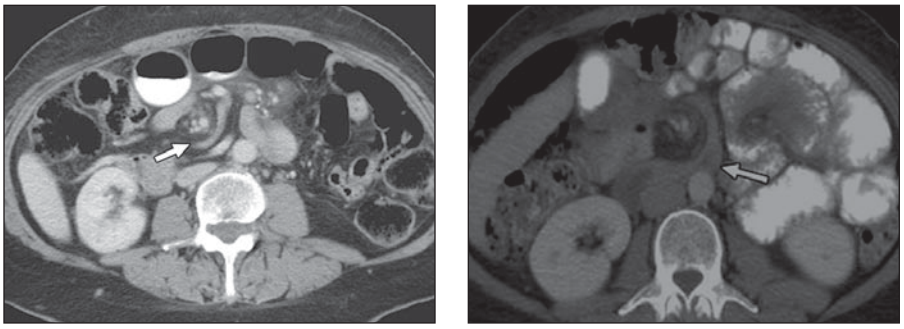
Fig. 4—Diagram illustrates appearances of three types of internal hernias in sagittal plane after Roux-en-Y gastric bypass surgery. (Used with permission from Office of Visual Media, Indiana University School of Medicine)

Internal Hernia

The presence of defects in the bowel mesentery after Roux-en-Y gastric bypass predisposes patients to the development of internal hernias, which are an important cause of postoperative morbidity and mortality. Laparoscopic Roux-en-Y gastric bypass appears to be associated with a relatively higher incidence of internal hernias, compared with open Roux-en-Y gastric bypass [15]. Most internal hernias occur within 2 years after laparoscopic Roux-en-Y gastric bypass. The incidence of internal hernias after laparoscopic Roux-en-Y gastric bypass is approximately 3%, compared with < 0.5% for open surgery, at a mean follow-up of 2 years [19]. Indeed, internal hernias are the most common cause of SBO after laparoscopic Roux-en-Y gastric bypass procedures. Prompt diagnosis and management of internal hernias is of paramount importance because of the potential for the development of catastrophic complications, such as anastomotic dehiscence, staple line disruption, small bowel ischemia and infarction, and septicemia [20].

The increased incidence of internal hernias after laparoscopic Roux-en-Y gastric bypass has been attributed to various causes, including reduced incidence of postoperative adhesions, which may help to "fix" the bowel, difficulty in closing all mesenteric defects meticulously, and excessive mobility of the bowel loops [15]. Although > 50% of patients with internal hernias acutely present with signs of complete obstruction, others manifest intermittent postprandial abdominal pain, nausea, and vomiting [15]. There are three potential sites for internal hernias after Roux-en-Y gastric bypass (Fig. 4): through the defect in the transverse mesocolon (mesocolic window); through enteroenterostomy mesenteric defect (transmesenteric); and through the space between the mesentery of the Roux limb and the transverse mesocolon, also known as Petersen hernia.

Mesenteric swirl is considered a very helpful CT sign of internal hernia, with high sensitiv-



A B

Fig. 5—Transmesenteric type of internal hernia after Roux-en-Y gastric bypass (GBP).
A, 54-year-old man who presented with intermittent pain 3 years after laparoscopic Roux-en-Y GBP. Axial contrast-enhanced CT image shows swirling of mesenteric vessels (*arrow*), which is a sign suggestive of internal hernia. Transmesenteric type of internal hernia was found at surgery.
B, 48-year-old woman who presented with postprandial nausea after Roux-en-Y GBP due to transmesenteric type of internal hernia. Note abnormally placed distal small-bowel loop behind mesenteric vessels (*arrow*); this finding is a highly specific sign for internal hernia.

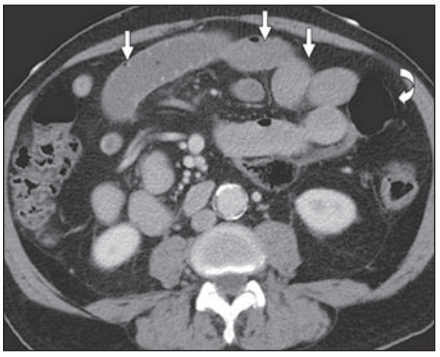


Fig. 6—52-year-old man who developed transmesocolic hernia after laparoscopic Roux-en-Y gastric bypass surgery. Axial contrast-enhanced CT image shows that dilated small-bowel loops including Roux limb (*straight arrows*) are displacing transverse colon inferiorly (*curved arrow*).

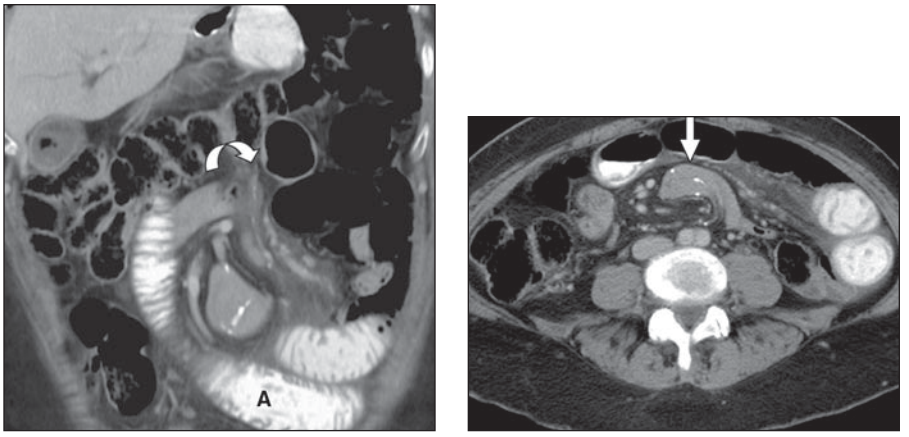


Fig. 7—Transmesenteric hernia in 52-year-old man after Roux-en-Y gastric bypass.
A, Coronal reformatted contrast-enhanced CT image shows obstructed and dilated alimentary limb (A) proximal to transmesenteric hernia (*arrow*).
B, Axial contrast-enhanced CT image illustrates obstructed small-bowel loops due to transmesenteric hernia (*arrow*).

ity and specificity [21] (Fig. 5A). Even smaller degrees of swirl should be viewed with suspicion for internal hernia in patients who have undergone Roux-en-Y gastric bypass and who present with abdominal pain [21]. However, mesenteric swirl may occur in patients without internal hernia, and the degree of swirl necessary to diagnose internal hernia is still debatable. Mushroom-shaped mesentery and dilated small bowel loops are other important findings. MDCT signs, such as right-sided jejunojejunostomy (if routinely placed surgically on the left) and distal small bowel loops drawn behind the superior mesenteric artery, are highly specific signs of internal hernias [21] (Fig. 5B). Multiplanar reformats are very helpful in determining the site of internal hernias and the complications of closed loop obstruction [22–24].

Herniation of the Roux limb through the mesocolic window is the most common type of internal hernia. With mesocolic window herniation, there is dilatation of multiple small bowel loops, including the Roux limb [25]. There may be variable mass effects on the transverse colon depending on the degree of herniation (Fig. 6). Dilatation of the Roux limb near the jejunojejunal anastomosis, with a normal-caliber afferent limb, is a characteristic feature. Occasionally, the jejunojejunal anastomosis may get pulled through the mesocolic window, resulting in obstruction of the afferent limb as well. Typically, the distended bowel loops displace the transverse colon inferiorly and lie in front of the gastric pouch. Internal hernia through the transverse mesocolon may be avoided by placing the Roux-en-Y loop in the antecolic position.

Transmesenteric herniation has been reported in approximately 2.2% of patients undergoing Roux-en-Y gastric bypass [15]. Herniation occurs when variable lengths of the small bowel and its associated mesentery are pulled through the mesenteric defect. CT may show clustered and dilated small bowel loops, superiorly displaced transverse colon with absent overlying omental fat, displacement of the mesenteric trunk, and stretched and engorged mesenteric vessels [26] (Fig. 7).

Petersen hernia occurs when there is herniation of small bowel behind the alimentary limb before it passes through the defect in the transverse mesocolon. The hernia site (Petersen space) lies between the transverse mesocolon and the jejunal mesentery (Fig. 8). The characteristic distribution of clustered bowel loops posterior to the transverse colon, above the small bowel mesentery, and anterior to the pancreas occurs in this type of internal hernia. Typically, dilated midjejunal loops are

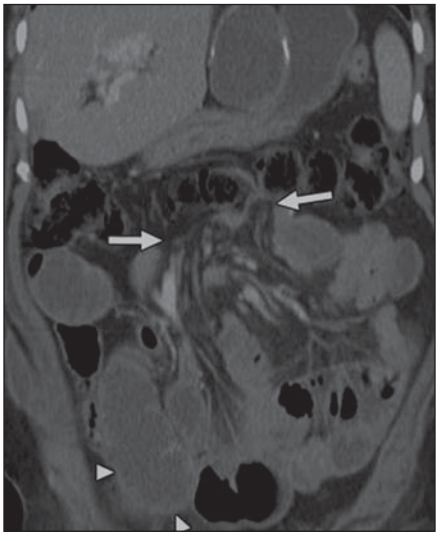


Fig. 8—Coronal reformatted CT image in 47-year-old woman after Roux-en-Y gastric bypass surgery who presented with laparoscopically diagnosed Petersen hernia. Herniation of bowel and its mesentery through Petersen space (*arrows*) is seen with dilated small-bowel loops in right lower quadrant (*arrowheads*).

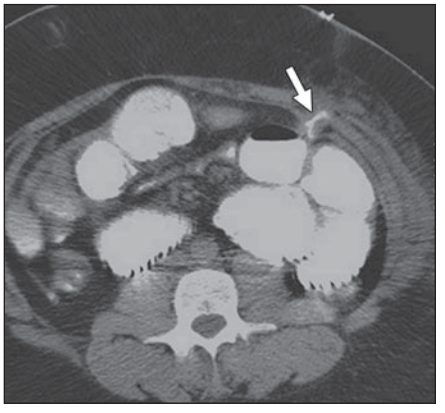


Fig. 9—Axial contrast-enhanced CT image in 52-year-old woman with trocar-site Richter hernia after Roux-en-Y gastric bypass surgery. Contrast opacification of small segment of herniated bowel loop (*arrow*) helps in making accurate diagnosis.

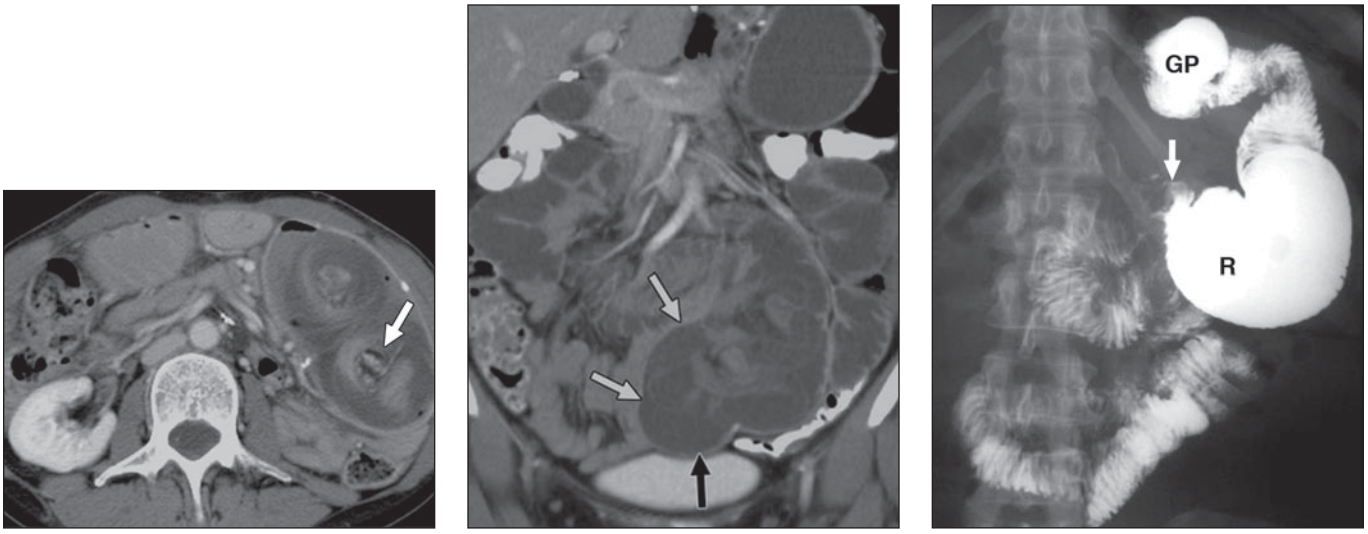


Fig. 10—Small-bowel obstruction (SBO) caused by retrograde intussusception at jejunojejunostomy site in 62-year-old woman after Roux-en-Y gastric bypass.
A, Axial contrast-enhanced CT image shows retrograde intussusception at jejunojejunostomy site. Classic target sign with presence of mesenteric fat (*arrow*) within bowel lumen is characteristic.
B, Coronal reformatted CT image shows SBO (*arrows*) due to intussusception at jejunojejunostomy site.

Fig. 11—44-year-old woman after Roux-en-Y gastric bypass. Contrast-enhanced (diatrizoate meglumine and diatrizoate sodium solution [Gastrografin, Bracco]) gastrointestinal study shows distended gastric pouch (GP) and Roux limb (R) due to mesocolic window stenosis (*arrow*).

seen in the left upper quadrant. This hernia is best appreciated on multiplanar reformatted images [18].

In many patients, exploration and hernia repair may be electively performed through the original trocar site. Lack of postoperative adhesions also facilitates laparoscopic evaluation and repair of hernias [15].

External Hernia

External hernias constitute an important cause of SBO after Roux-en-Y gastric bypass procedures and include different types of hernias, such as ventral hernia, trocar hernia, and Richter hernia. Although external hernias occur commonly after open Roux-en-Y gastric bypass, the trocar site hernia is seen exclusively in patients after laparoscopic Roux-en-Y gastric bypass. Ventral hernias after open Roux-en-Y gastric bypass occur in approximately 5% of patients and are due to several patient-related contributory factors, including elevated intraabdominal pressure and reduced abdominal wall resistance. In morbidly obese patients, a thick preperitoneum predisposes to the development of Richter hernia, which is a type of hernia involving a part of the circumference of the bowel with attendant high risk of strangulation. Richter hernia may occur despite adequate fascial closure. Richter hernia usually presents early during the postoperative period and is uncommon, with a reported incidence of 0.02% in one series [27]. SBO resulting from Richter hernia may be confused for adhesions because the herniated bowel loop is very small and may easily be overlooked (Fig. 9). Differentiation is very important because Richter hernia has a high risk of strangulation. The importance of optimal opacification of bowel loops with oral contrast material cannot be overemphasized.

Intussusception

Intussusception is a rare complication and is more common after open surgery than after laparoscopic surgery. Both jejunojejunal (more common) and gastrojejunal intussusceptions have been described in the literature, typically after significant and rapid weight loss. Although the exact cause is unknown, various theories propose the possibility of lead points (from suture lines, adhesions, and lymphoid hyperplasia) or bowel dysmotility [28]. Thin and redundant small bowel mesentery found in these patients may also predispose to intussusceptions. Regardless of the cause, although antegrade intussusceptions have been described, most intussusceptions after Roux-en-Y gastric bypass are retrograde (against the direction of peristalsis) and are located at or distal to the jejunojejunostomy site. The reported incidence of retrograde intussusceptions after Roux-en-Y gastric bypass is 0.1% [29]. Prompt diagnosis is crucial because serious complications, such as ischemia and infarction of the intussuscepting segment, may occur.

MDCT typically shows the classic target sign, consisting of the invaginating bowel segment (intussusceptum) and its mesentery telescoping into the lumen of the receiving bowel segment (intussuscipiens) [28] (Figs. 10A and 10B). Associated SBO is also seen. Prompt management is crucial to prevent complications.

Mesocolic Window Stenosis

Mesocolic window stenosis occurs in 1–2% of patients with retrocolic placement of the Roux limb and may be seen in either the early or late postoperative setting [6]. Imaging findings include significant dilation of the Roux limb proximal to the expected location of mesocolic window (Fig. 11). Gastric pouch dilatation and gastroesophageal reflux may also be seen [25]. Sagittal or coronal reconstructed CT images are helpful in the diagnosis by showing the exact location of the stricture in relation to the transverse colon [30]. Two important imaging findings differentiate between mesocolic window stenosis and transmesenteric herniation: first, the afferent loop is not dilated in mesocolic window stenosis; and, second, the Roux limb is dilated to a transition point proximal to the jejunojejunostomy site in mesocolic window stenosis [30]. Antecolic placement of the Roux limb may avoid this complication [29]. In many pa-

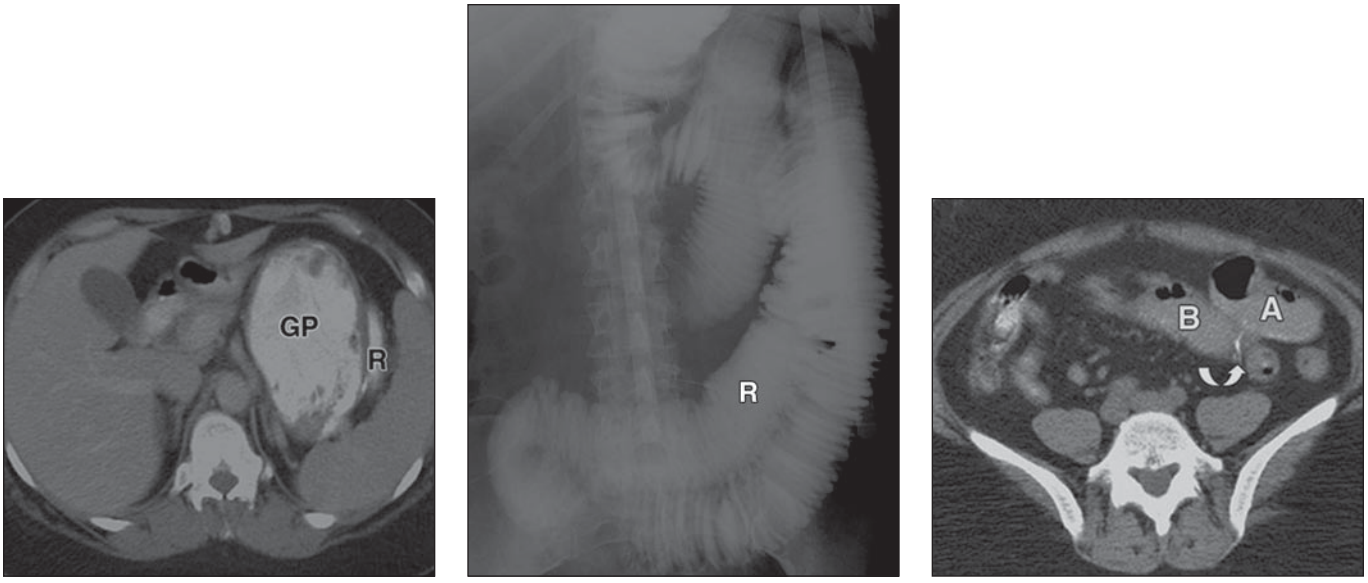


Fig. 12—Stricture at jejunojejunostomy site after Roux-en-Y gastric bypass (GBP).
A, 52-year-old woman who presented with persistent vomiting due to gastrojejunostomy stricture. Axial contrast-enhanced CT image shows distended gastric pouch (GP) and decompressed gastric remnant (R).
B, 44-year-old man who presented 3 days after Roux-en-Y GBP with obstruction at jejunojejunostomy site secondary to edema that resolved 5 days later. Roux limb (R) is dilated on contrast-enhanced (diatrizoate meglumine and diatrizoate sodium solution [Gastrografin, Bracco]) gastrointestinal study.
C, 52-year-old man who presented 3 years after Roux-en-Y GBP with stricture at jejunojejunostomy site. Axial CT image shows dilated alimentary limb (A) and biliopancreatic limb (B); sutures show site of anastomosis (*arrow*).

tients, during the first few days after surgery, edema at the mesocolic window causes transient partial SBO that resolves in a few days. Persistent or worsening narrowing suggests mechanical obstruction and requires surgery.

Anastomotic Strictures

Stricture commonly occurs at the gastrojejunostomy site and rarely at the jejunojejunostomy anastomosis. In one series, the reported incidence of gastrojejunostomy stricture was > 6%, and its incidence appears to be related to technical factors that lead to tissue damage and ischemia at the site of anastomosis [31]. Patients may present with progressive vomiting, initially with solids and eventually with liquids. Fluoroscopy is the preferred technique for diagnosing suspected gastrojejunostomy stricture; it shows narrowing at the gastrojejunal anastomosis, distended gastric pouch, and delayed emptying of the gastric pouch [25]. CT shows distended gastric pouch with normal or collapsed Roux limb (Fig. 12A). Theoretically, there may be a higher stricture rate with antecolic Roux limbs than with retrocolic, probably because of tension or reduced perfusion.

The reported incidence for stricture at the jejunojejunal anastomosis is 0.8% [32]. Luminal narrowing may occur secondary to edema or ischemia during the early postoperative stages, or it may present late, after a few months or years, in association with fibrosis (Figs. 12B and 12C). Imaging findings show a distended Roux limb. Fluoroscopy may show retrograde flow of contrast medium into the afferent limb and remnant stomach [25].

Intraluminal Factors and Extrinsic Compression

Intraluminal factors that may cause SBO include phytobezoars, large food boluses (e.g., meat), and hematoma. Phytobezoars are commonly seen after any gastric surgery, secondary to gastric dysmotility and reduced

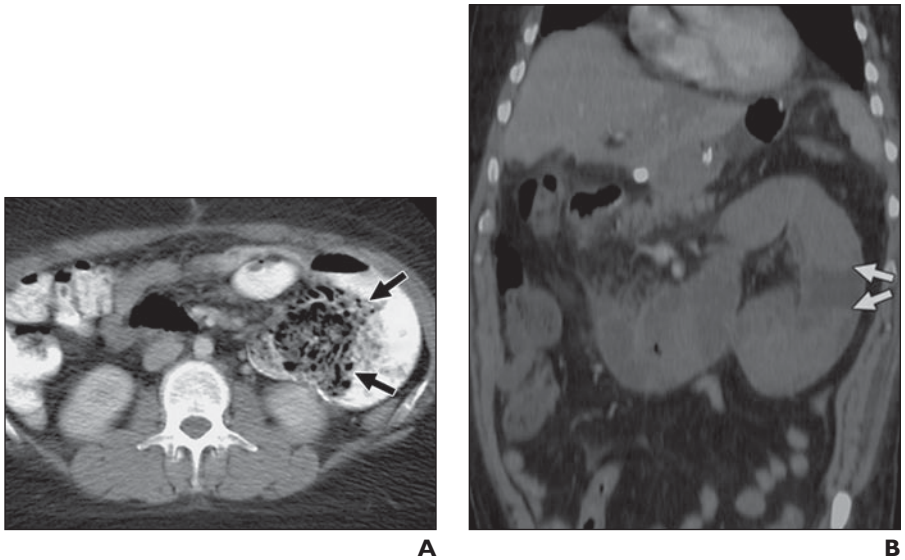


Fig. 13—Small-bowel obstruction (SBO) after Roux-en-Y gastric bypass surgery.
A, Axial contrast-enhanced CT image in 52-year-old woman shows SBO due to impacted phytobezoar (*arrows*) in alimentary limb.
B, Coronal reformatted contrast-enhanced CT image in 57-year-old man shows SBO caused by intraluminal hematomas within alimentary limb (*arrows*).

levels of gastric acid, which lead to incomplete digestion of the cellulose covering of ingested plant material [33]. This complication occurs when patients fail to comply with dietary instructions. Differentiation of phytobezoar from feces in the small bowel seen in chronic SBO is important. Ovoid or round, encapsulated intraluminal mass with mottled gas suggests a phytobezoar [34] (Fig. 13A). Obstruction is usually at one of the anastomotic sites.

The reported incidence of postoperative hematoma in one series was 3.2%, with a higher incidence noted after laparoscopic Roux-en-Y gastric bypass (5.1% vs 2.4%) [35]. The hematoma may be intraluminal, intramural, or extrinsic to the bowel. Tachycardia and a sense of "impending doom" is one of the common presentations of intraluminal hematoma, which causes obstruction at the jejunojejunostomy site [36]. A mesocolic hematoma may cause acute obstruction of the alimentary limb and results when the surgeon fails to identify a small bleeding vessel. The staple lines are the source of hemorrhage in most cases [35]. MDCT is definitive in most cases and shows high-density hematoma, either intrinsic or extrinsic, causing bowel obstruction (Fig. 13B).

Conclusion

There has been an exponential increase in gastric bypass surgeries performed to achieve sustainable weight loss in obese patients. Along with increasing numbers of bariatric surgeries, SBO is being increasingly diagnosed. Many patients with SBO after bariatric surgery manifest nonspecific symptoms, making clinical diagnosis difficult. Imaging studies, particularly MDCT, play an important role in prompt and accurate diagnosis. Classification systems based on either the underlying cause or the anatomic location (i.e., simplified ABC classification) have been proposed to facilitate better categorization of bowel obstructions after bariatric surgery. Accurate diagnosis facilitates optimal management of patients while decreasing postoperative morbidity and mortality.

References

1. Cremieux PY, Buchwald H, Shikora SA, Ghosh A, Yang HE, Buessing M. A study on the economic impact of bariatric surgery. *Am J Manag Care* 2008; 14:589–596
2. Sturm R. Increases in morbid obesity in the USA: 2000–2005. *Public Health* 2007; 121:492–496
3. Merkle EM, Hallowell PT, Crouse C, Nakamoto DA, Stellato TA. Roux-en-Y gastric bypass for clinically severe obesity: normal appearance and spectrum of complications at imaging. *Radiology* 2005; 234:674–683
4. Maggard MA, Shugarman LR, Suttorp M, et al. Meta-analysis: surgical treatment of obesity. *Ann Intern Med* 2005; 142:547–559
5. Peluso L, Vanek VW. Efficacy of gastric bypass in the treatment of obesity-related comorbidities. *Nutr Clin Pract* 2007; 22:22–28
6. Felsher J, Brodsky J, Brody F. Small bowel obstruction after laparoscopic Roux-en-Y gastric bypass. *Surgery* 2003; 134:501–505
7. Fisher BL, Schauer P. Medical and surgical options in the treatment of severe obesity. *Am J Surg* 2002; 184:S9–S16
8. Brolin RE, Kenler HA, Gorman JH, Cody RP. Long-limb gastric bypass in the superobese: a prospective randomized study. *Ann Surg* 1992; 215:387–395
9. Jones KB Jr, Afram JD, Benotti PN, et al. Open versus laparoscopic Roux-en-Y gastric bypass: a comparative study of over 25,000 open cases and the major laparoscopic bariatric reported series. *Obes Surg* 2006; 16:721–727
10. Podnos YD, Jimenez JC, Wilson SE, Stevens CM, Nguyen NT. Complications after laparoscopic gastric bypass: a review of 3464 cases. *Arch Surg* 2003; 138:957–961
11. Brolin RE. Laparoscopic versus open gastric bypass to treat morbid obesity. *Ann Surg* 2004; 239: 438–440
12. Husain S, Ahmed AR, Johnson J, Boss T, O'Malley W. Small-bowel obstruction after laparoscopic Roux-en-Y gastric bypass: etiology, diagnosis, and management. *Arch Surg* 2007; 142:988–993
13. Tucker ON, Escalante-Tattersfield T, Szomstein S, Rosenthal RJ. The ABC system: a simplified classification system for small bowel obstruction after laparoscopic Roux-en-Y gastric bypass. *Obes Surg* 2007; 17:1549–1554
14. Quebbemann BB, Dallal RM. The orientation of the antecolic Roux limb markedly affects the incidence of internal hernias after laparoscopic gastric bypass. *Obes Surg* 2005; 15:766–770, discussion 770
15. Higa KD, Ho T, Boone KB. Internal hernias after laparoscopic Roux-en-Y gastric bypass: incidence, treatment and prevention. *Obes Surg* 2003; 13:350–354
16. ASMBS Clinical Issues Committee. ASMBS guideline on the prevention and detection of gastrointestinal leak after gastric bypass including the role of imaging and surgical exploration. *Surg Obes Relat Dis* 2009; 5:293–296
17. Uppot RN. Impact of obesity on radiology. *Radiol Clin North Am* 2007; 45:231–246
18. Gunabushanam G, Shankar S, Czerniach DR, Kelly JJ, Perugini RA. Small-bowel obstruction after laparoscopic Roux-en-Y gastric bypass surgery. *J Comput Assist Tomogr* 2009; 33:369–375
19. Reddy RM, Riker A, Marra D, Thomas R, Brems JJ. Open Roux-en-Y gastric bypass for the morbidly obese in the era of laparoscopy. *Am J Surg* 2002; 184:611–615, discussion 615–616
20. Iannelli A, Buratti MS, Novellas S, et al. Internal hernia as a complication of laparoscopic Roux-en-Y gastric bypass. *Obes Surg* 2007; 17:1283–1286
21. Lockhart ME, Tessler FN, Canon CL, et al. Internal hernia after gastric bypass: sensitivity and specificity of seven CT signs with surgical correlation and controls. *AJR* 2007; 188:745–750
22. Hodel J, Zins M, Desmottes L, et al. Location of the transition zone in CT of small-bowel obstruction: added value of multiplanar reformations. *Abdom Imaging* 2009; 34:35–41
23. Sinha R, Verma R. Multidetector row computed tomography in bowel obstruction. Part 1. Small bowel obstruction. *Clin Radiol* 2005; 60:1058–1067
24. Yaghmai V, Nikolaidis P, Hammond NA, Petrovic B, Gore RM, Miller FH. Multidetector-row computed tomography diagnosis of small bowel obstruction: can coronal reformations replace axial images? *Emerg Radiol* 2006; 13:69–72
25. Chandler RC, Srinivas G, Chintapalli KN, Schwesinger WH, Prasad SR. Imaging in bariatric surgery: a guide to postsurgical anatomy and common complications. *AJR* 2008; 190:122–135
26. Blachar A, Federle MP, Dodson SF. Internal hernia: clinical and imaging findings in 17 patients with emphasis on CT criteria. *Radiology* 2001; 218:68–74
27. Hwang RF, Swartz DE, Felix EL. Causes of small bowel obstruction after laparoscopic gastric bypass. *Surg Endosc* 2004; 18:1631–1635
28. Ver Steeg K. Retrograde intussusception following Roux-en-Y gastric bypass. *Obes Surg* 2006; 16:1101–1103
29. Sandrasegaran K, Maglinte DD, Lappas JC, Howard TJ. Small-bowel complications of major gastrointestinal tract surgery. *AJR* 2005; 185:671–681
30. Sandrasegaran K, Rajesh A, Lall C, Gomez GA, Lappas JC, Maglinte DD. Gastrointestinal complications of bariatric Roux-en-Y gastric bypass surgery. *Eur Radiol* 2005; 15:254–262
31. Escalona A, Devaud N, Boza C, et al. Gastrojejunal anastomotic stricture after Roux-en-Y gastric bypass: ambulatory management with the Savary-Gilliard dilator. *Surg Endosc* 2007; 21:765–768
32. Cho M, Carrodeguas L, Pinto D, et al. Diagnosis and management of partial small bowel obstruction after laparoscopic antecolic antegastric Roux-en-Y gastric bypass for morbid obesity. *J Am Coll Surg* 2006; 202:262–268
33. White NB, Gibbs KE, Goodwin A, Teixeira J. Gastric bezoar complicating laparoscopic adjust-

able gastric banding, and review of literature. *Obes Surg* 2003; 13:948–950

34. Zissin R, Osadchy A, Gutman V, Rathaus V, Shapiro-Feinberg M, Gayer G. CT findings in patients with small bowel obstruction due to phytobezoar. *Emerg Radiol* 2004; 10:197–200
35. Bakhos C, Alkhoury F, Kyriakides T, Reinhold R, Nadzam G. Early postoperative hemorrhage after open and laparoscopic Roux-en-Y gastric bypass. *Obes Surg* 2009; 19:153–157
36. Awais O, Raftopoulos I, Luketich JD, Courcoulas A. Acute, complete proximal small bowel obstruction after laparoscopic gastric bypass due to intraluminal blood clot formation. *Surg Obes Relat Dis* 2005; 1:418–422

APPENDIX 1: Etiologic Classification of Small Bowel Obstruction After Roux-en-Y Gastric Bypass Surgery

1. Internal hernias
   a. Mesocolic window herniation
   b. Transmesenteric herniation
   c. Petersen hernia
2. External hernias
   a. Trocar site hernia
3. Intussusception
   a. Retrograde (more common)
   b. Antegrade
4. Mesocolic window stenosis
5. Anastomotic strictures
   a. Gastrojejunostomy (more common)
   b. Jejunojejunostomy
6. Intraluminal factors and extrinsic compression
   a. Phytobezoars
   b. Hematomas