

# Internal Hernia After Gastric Bypass: Sensitivity and Specificity of Seven CT Signs with Surgical Correlation and Controls

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**OBJECTIVE.** The purpose of this study was to evaluate the sensitivity and specificity of seven CT signs in the diagnosis of internal hernia after laparoscopic Roux-en-Y gastric bypass.

**MATERIALS AND METHODS.** With institutional review board approval, the CT scans of 18 patients (17 women, one man) with surgically proven internal hernia after laparoscopic Roux-en-Y gastric bypass were retrieved, as were CT studies of a control group of 18 women who had undergone gastric bypass but did not have internal hernia at reoperation. The scans were reviewed by three radiologists for the presence of seven CT signs of internal hernia: swirled appearance of mesenteric fat or vessels, mushroom shape of hernia, tubular distal mesenteric fat surrounded by bowel loops, small-bowel obstruction, clustered loops of small bowel, small bowel other than duodenum posterior to the superior mesenteric artery, and right-sided location of the distal jejunal anastomosis. Sensitivity and specificity were calculated for each sign. Stepwise logistic regression was performed to ascertain an independent set of variables predictive of the presence of internal hernia.

**RESULTS.** Mesenteric swirl was the best single predictor of hernia; sensitivity was 61%, 78%, and 83%, and specificity was 94%, 89%, and 67% for the three reviewers. The combination of swirled mesentery and mushroom shape of the mesentery was better than swirled mesentery alone, sensitivity being 78%, 83%, and 83%, and specificity being 83%, 89%, and 67%, but the difference was not statistically significant.

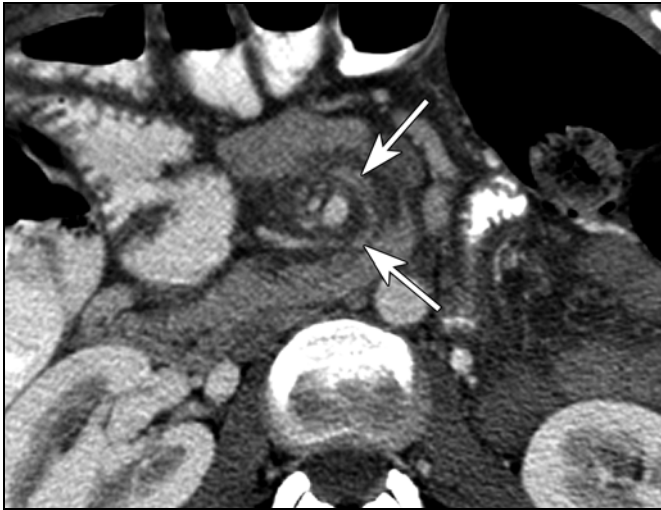
**CONCLUSION.** Mesenteric swirl is the best indicator of internal hernia after laparoscopic Roux-en-Y gastric bypass, and even minor degrees of swirl should be considered suspicious.



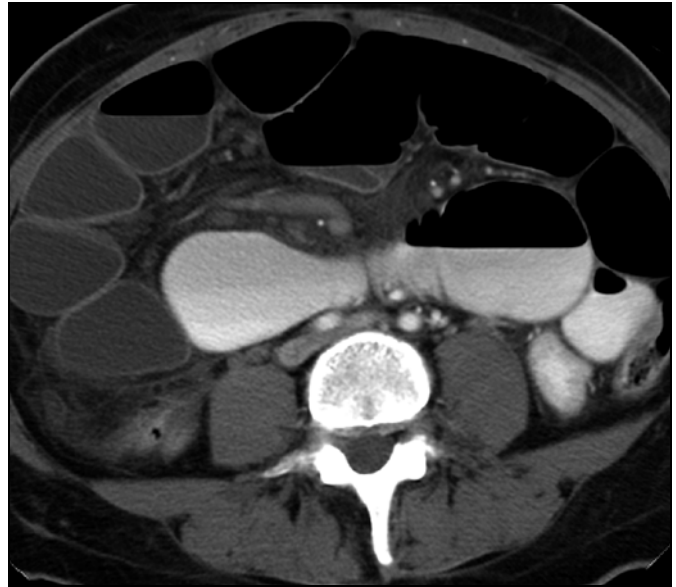
obesity, which is associated with type 2 diabetes, hypertension, and other serious disorders, is widely recognized as one of the most important public health problems in the United States [1]. A variety of nonsurgical treatments have been attempted in patients with morbid obesity, which is defined as a body mass index (BMI) greater than 40 (35 with comorbidity), but results have been disappointing [2]. Surgical approaches to therapy, collectively known as bariatric procedures, have been far more promising and are now routinely used to treat patients with morbid obesity [3]. In many centers, laparoscopic Roux-en-Y gastric bypass has become the most common bariatric procedure. In this operation, the stomach is stapled or divided to form a small pouch (typically < 30 mL in volume), which empties into a Roux-en-Y limb of jejunum of varying length (typically 75–150 cm). The Roux limb may be brought up to the gastric pouch anterior (antecolic) or posterior (retro-

colic) to the transverse colon [4]. Any visible defects that might allow potential bowel herniation are routinely closed at surgery.

Recognized gastrointestinal complications of gastric bypass surgery include anastomotic leak, stenosis, and small-bowel obstruction [5–9]. Internal hernia, the movement of bowel into abnormal spaces, is more common after laparoscopic gastric bypass than after the open procedure. It is a particularly sinister complication with a variable, nonspecific clinical presentation [10, 11]. Although several CT findings have been described, including clustering of bowel loops against the anterior abdominal wall and swirled appearance of the mesentery, studies have been limited by small numbers (the largest series to our knowledge included only five patients who had undergone laparoscopic Roux-en-Y gastric bypass, and individual CT signs were not evaluated), by the inclusion of patients who did not undergo gastric bypass, and by the lack of a control group of bypass patients



**Fig. 1**—39-year-old woman with internal hernia. CT sign, mesenteric swirl. Enhanced transverse CT scan through mesentery shows swirled appearance of mesenteric vessels (*arrows*) in superior mesenteric artery region. Associated mild mesenteric edema appears as increased attenuation of mesenteric fat.



**Fig. 2**—35-year-old woman with internal hernia. CT sign, small-bowel obstruction. Enhanced transverse CT scan shows numerous dilated loops of small bowel, which contain oral contrast medium. Colon is relatively collapsed.

without internal hernia [12–15]. We undertook this study to evaluate the ability of radiologists using seven CT signs to diagnose internal hernia after laparoscopic Roux-en-Y gastric bypass.

## Materials and Methods

### Subjects and Image Acquisition

With approval from our institutional review board and using procedures compliant with the Health Insurance Portability and Accountability Act, we reviewed the records of 501 patients who underwent bariatric laparoscopic Roux-en-Y gastric bypass performed by a single surgeon between January 2002 and January 2005. In this population, we found the records of 19 patients who underwent subsequent CT and surgery at which internal hernia was proved. One patient with known severe congenital bowel malrotation was excluded, leaving 18 patients in the study group. In all cases, the type of hernia was defined by the surgeon during the operation.

We also found the records of 18 patients who underwent consecutive laparoscopic Roux-en-Y gastric bypass procedures and underwent subsequent CT and surgery but were not found to have internal hernia, and these patients served as controls. The control group underwent surgery for a variety of indications, including cholelithiasis, sigmoid diverticulitis, appendicitis, flank pain, bowel anastomotic stricture, and biliary colic. All CT studies were performed with LightSpeed or HiSpeed scanners (GE Healthcare).

The preoperative CT examinations were performed on a variety of scanners at a slice thickness of 5 mm after IV injection of 125–150 mL of iodinated contrast medium with a scan delay of 60–80 seconds. Oral contrast medium was given to all patients who were able to tolerate it. The CT images for the study and control groups were retrieved from our digital archives and collected and stored for review.

### Image Analysis

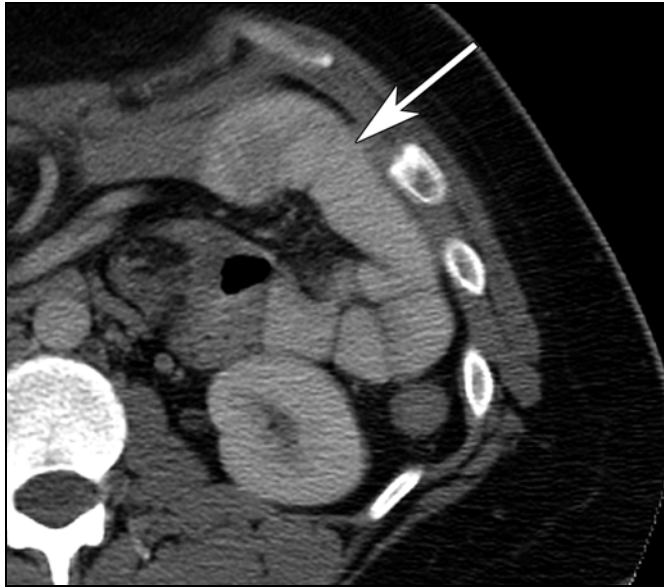
Seven signs of internal hernia were chosen for study. The first four signs, all previously described in the literature [12, 16], were as follows: swirled appearance of mesenteric fat or vessels at the root of the mesentery (Fig. 1), small-bowel obstruction (Fig. 2), clustered loops of small bowel (Fig. 3), and mushroom shape of the herniated mesenteric root with crowding and stretching of the mesenteric vessels (Fig. 4). The following three signs, which were based on our own experience, had not been described previously, to our knowledge: tubular or round shape of distal mesenteric fat closely surrounded by bowel loops (Fig. 5), small bowel other than duodenum passing posterior to the superior mesenteric artery (SMA) (Fig. 6), and right-sided location of distal jejunal anastomosis (Fig. 7).

The mushroom shape of the mesenteric root refers to the shape of the hernia as it passes through a narrow opening between vessels at the base of the mesentery. Distal tubular mesenteric fat with closely surrounding bowel loops is similar to mesenteric

swirl but includes small-bowel loops closely surrounding round or tubular mesenteric fat. The presence of a small-bowel loop other than duodenum behind the SMA suggests the presence of an internal hernia because no small bowel should pass through this region. In patients with internal hernia, the distal ileum may be stretched behind the SMA as it courses from the fixed cecum toward a hernia sac. The last sign is related to the surgical technique used at our institution. Because the distal bowel anastomosis is always placed to the left of the midline, its displacement to the right side suggests herniation.

The CT studies were randomly presented to two experienced abdominal radiologists and a third-year radiology resident. These observers were asked to evaluate the images for presence or absence of the seven signs of internal hernia. The three reviewers were not the clinical reviewers of the images obtained before the study. To ensure consistency, the reviewers were first shown line drawings depicting the signs. For patients judged to have mesenteric swirl, the amount of swirl was estimated as  $<45^\circ$ ,  $45^\circ$ – $90^\circ$ ,  $91^\circ$ – $180^\circ$ ,  $181^\circ$ – $270^\circ$ ,  $271^\circ$ – $360^\circ$ , or  $>360^\circ$  relative to the origin of the SMA. The entire transverse CT series for each patient was available for review on a PACS workstation. The reviewers scrolled through the data set and adjusted window level and width as needed. Images were interpreted in a double-blind manner, and an observer monitored interpretation of the images. The CT findings were correlated with clinical data and surgical outcome.

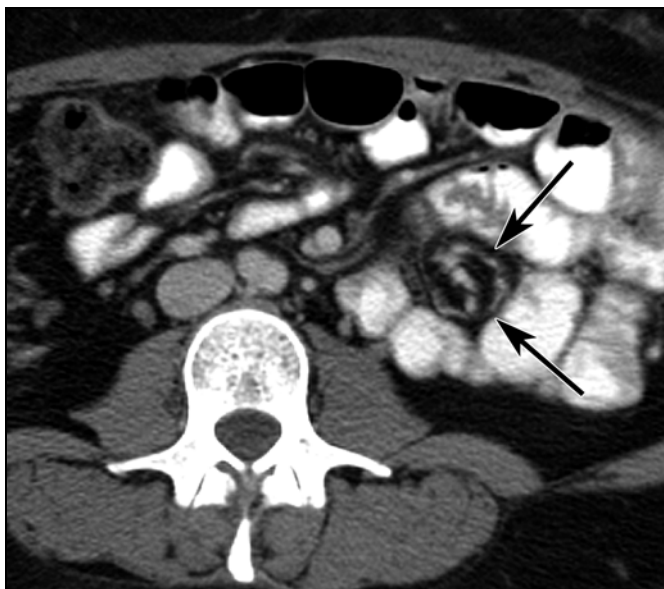
## CT of Hernia After Gastric Bypass



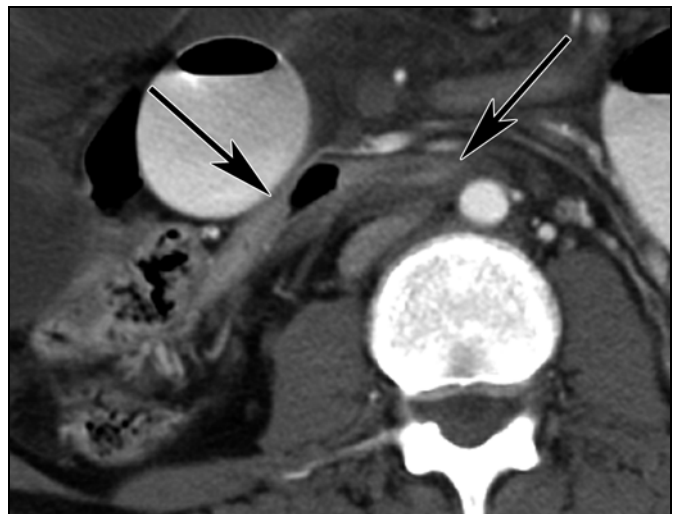
**Fig. 3**—36-year-old woman with internal hernia. CT sign, clustered loops of small bowel. Magnified enhanced transverse CT scan of bowel loops shows grouping of nondilated small-bowel loops (*arrow*) near anterior abdominal wall.



**Fig. 4**—35-year-old woman with internal hernia. CT sign, mushroom-shaped mesenteric root. Enhanced transverse CT scan through mesenteric root shows narrowed mesenteric root with fat and vessels passing between superior mesenteric artery (*arrow*) and distal mesenteric arterial branch (*arrowhead*). Contrast agent-filled loops of small bowel are narrowed as they pass through this region. Stretching of mesenteric vessels in this area is evident.



**Fig. 5**—34-year-old woman with internal hernia. CT sign, distal tubular mesentery with surrounding loops of small bowel. Enhanced transverse CT scan at level of loops of small bowel shows round appearance of distal mesenteric fat (*arrows*) with small-bowel loops completely surrounding this region. Similar appearance was present on adjacent images (not shown) and was consistent with tubular twisted shape of distal mesenteric fat.



**Fig. 6**—35-year-old woman with internal hernia. CT sign, small-bowel loop behind superior mesenteric artery. Enhanced transverse CT scan shows distal small-bowel loop (*arrows*) posterior to superior mesenteric artery. No bowel loop should lie in this position after laparoscopic Roux-en-Y gastric bypass. This loop usually is stretched distal ileum coursing from its insertion into cecum to internal hernia.

### Statistical Analysis

A biostatistician performed the statistical analysis using SPSS 12.0 software (issued September 2003,

SPSS). The demographics of the two patient cohorts were compared with use of Student's *t* test for continuous variables and Fisher's exact test for discrete

variables. Sensitivity for each sign was calculated as the percentage of patients with hernia who had the sign, and specificity was the percentage without her-

**Fig. 7**—34-year-old woman with internal hernia. CT sign, right-sided anastomosis. Enhanced transverse CT scan at level of small bowel shows suture line of distal jejunojunctional anastomosis (arrows) to right of midline. At our institution, anastomosis is always positioned on left side of abdomen, and right-sided location is suggestive of internal hernia.



**TABLE 1: Demographic Characteristics of 36 Patients Who Underwent Laparoscopic Roux-en-Y Gastric Bypass**

Variable	No Hernia	Hernia	<i>p</i>
Sex	18 F	17 F/1 M	0.999
Race	16 white/2 black	14 white/4 black	0.329
Age (y)	39.3 ± 9.8	36.9 ± 6.9	0.405
Body mass index			
Initial	48.7 ± 5.5	48.3 ± 4.7	0.820
Final	36.9 ± 8.0	28.0 ± 6.2	0.001
Difference	11.8 ± 8.1	20.3 ± 6.2	0.001
Weight (lb)			
Initial	303 ± 37	296 ± 49	0.658
Final	227 ± 36	170 ± 36	0.001
Difference	76 ± 57	126 ± 44	0.005
Time from surgery to CT (d)	280 ± 327	513 ± 228	0.018

Note—Values are mean ± SD unless otherwise indicated.

nia who did not have the sign. Stepwise logistic regression was performed on the data to determine an independent set of variables predictive of the presence of internal hernia. Computations were performed separately for the three reviewers. Statistical significance was considered  $p < 0.05$ .

## Results

### Patient Demographics

Eighteen patients (17 women, one man) with surgically proven internal hernia had a mean age of 36.9 years (range, 31–55 years). The most common presenting symptoms were intermittent postprandial abdominal pain and nausea with or without vomiting. Internal hernia was detected an average of 513 days after bypass surgery. Most patients had a retrocolic (6/18 [33%]) or antecolic (7/18

[39%]) Petersen hernia, and a minority had a transmesenteric (3/18 [17%]) or mesocolic (2/18 [11%]) hernia. The control group of 18 women who had undergone gastric bypass but did not have symptoms, signs, or operative findings of internal hernia was similar to the other group in age, race, sex, initial weight, and initial BMI (Table 1). The two cohorts differed significantly in time from surgery, weight loss, final weight, change in BMI, and final BMI, the hernia patients undergoing imaging longer after surgery and having more weight loss (Table 1). During the time period analyzed, the mean age of all 501 patients who had undergone bariatric laparoscopic Roux-en-Y gastric bypass (341 antecolic and 160 retrocolic) was 40.5 years, and the mean BMI was 48.2.

### Accuracy of Individual CT Signs

The sensitivity and specificity of the seven individual signs of hernia and the interpreters' overall impressions are shown in Table 2. Mesenteric swirl was the best single predictor of hernia with a sensitivity of 61%, 78%, and 83% and a specificity of 94%, 89%, and 67% for the two experienced abdominal imagers and one resident reviewer. The combination of swirled mesentery and mushroom shape of the mesentery had higher sensitivity than swirled mesentery alone with a sensitivity of 78%, 83%, and 83%, but specificity was not better (83%, 89%, and 67%). The difference was not statistically significant. In patients found to have mesenteric swirl but no hernia, the median amount of swirl was less than 90°. The median amount of swirl in patients with hernia was 180–270°. In all cases of at least 270° swirl, hernia was found at surgery.

Distal tubular mesenteric fat surrounded by bowel loops, a small-bowel loop behind the SMA, and distal anastomosis to the right of midline were highly specific (89–100%) but had low sensitivity (0–44%). Clustered loops of bowel was the only CT finding in two patients with hernia, and one hernia patient had none of the seven signs.

### Logistical Regression

Stepwise logistical regression showed the best indicator of internal hernia after bypass was the presence of any degree of mesenteric swirl. Addition of mushroom shape of the mesentery or the interpreter's overall impression did not significantly improve the predictive value. One of the abdominal radiologists successfully identified a single case in which a hernia had less than 90° of swirl without other positive signs; the resident identified two cases. Exclusion of swirl less than 180° would have caused one abdominal radiologist to miss an additional hernia, the other abdominal radiologist to miss two hernias, and the resident to miss two hernias.

## Discussion

The use of bariatric surgery has grown steadily in response to the rising prevalence of obesity in the United States. Between 1996 and 2001, the number of bariatric operations increased sevenfold, mostly attributed to laparoscopic Roux-en-Y gastric bypass [7]. Lengths of hospital stay and acute complication rates have decreased, approximately 10% of patients having significant in-hospital complications in one study [7]. Laparoscopic Roux-en-Y gastric bypass has gained popu-

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**TABLE 2: Sensitivity and Specificity of Seven CT Signs of Internal Hernia**

Sign	Sensitivity (%)			Specificity (%)		
	Reviewer 1	Reviewer 2	Reviewer 3 (Resident)	Reviewer 1	Reviewer 2	Reviewer 3 (Resident)
Swirled mesentery	61	78	83	94	89	67
Mushroom	33	72	33	89	89	100
Hurricane eye	17	11	6	100	100	100
Small-bowel obstruction	11	28	39	94	89	83
Clustered loops	17	6	6	72	78	83
Small-bowel behind superior mesenteric artery	0	22	44	100	89	94
Right-sided anastomosis	11	6	6	100	100	100
Overall impression	56	78	72	89	78	78

larity over the open approach because of a lower rate of perioperative complications [17]. Despite advances in surgical technique, long-term complications, notably internal hernia, remain troublesome.

Laparoscopic Roux-en-Y gastric bypass surgery produces three potential sites for internal hernia formation: at the defect in the transverse mesocolon through which the Roux loop passes (if it is placed in the retrocolic position), at the mesenteric defect at the enteroenterostomy, and behind the Roux limb mesentery placed in a retrocolic or antecolic position (retrocolic Petersen and antecolic Petersen type). Petersen hernia is a specific type in which intestine moves into the potential space between the caudal surface of the transverse mesocolon and the edge of the Roux limb. It has been suggested [6] that patients are more prone to internal hernia after laparoscopic Roux-en-Y gastric bypass than after an open operation because there are fewer adhesions to tether small-bowel loops and prevent them from herniating. In addition, patients who have greater degrees of weight loss after laparoscopic Roux-en-Y gastric bypass may be more prone to internal hernia because of loss of the protective, space-occupying effect of mesenteric fat [5]. In a review of 1,000 laparoscopic Roux-en-Y gastric bypass procedures, Garza and coworkers [18] identified 45 internal hernias, almost all of which were transmesocolic, in 43 patients. Another review [11] revealed 66 internal hernias in 63 of 2,000 patients who underwent laparoscopic Roux-en-Y gastric bypass. Forty-four of the hernias were transmesocolic, 14 were through the small-bowel mesentery, and five were of the Petersen type.

The symptoms of internal hernia are non-specific, making the diagnosis challenging. Most patients report a combination of post-

prandial abdominal pain, nausea, and emesis [18]. We have found that patients typically do not have clinical signs of abdominal inflammation (elevated white blood cell count, peritoneal irritation, lactic acidosis) until there is infarction or perforation of the intestine, which increases the morbidity and mortality of remedial operations.

CT has been shown valuable in the detection of leaks, abscesses, and other perioperative complications of laparoscopic Roux-en-Y gastric bypass, but CT has been found less useful in detection of internal hernia. Blachar et al. [12] prospectively evaluated the ability of radiologists to detect paraduodenal and transmesenteric internal hernias on CT, but only one patient had undergone laparoscopic Roux-en-Y gastric bypass. Those investigators concluded that no sign was pathognomonic and suggested that the diagnosis could be made by applying a combination of signs with variable sensitivity and specificity.

In our clinical practice, we had been frustrated by our inability to confidently diagnose internal hernia in patients who had undergone laparoscopic Roux-en-Y gastric bypass. We had observed anecdotally that certain signs, notably mesenteric swirl, seemed to be helpful in diagnosis. Moreover, published reports of studies of the utility of CT in detection of internal hernia in patients who had undergone laparoscopic Roux-en-Y gastric bypass were limited by various factors, including small populations, inclusion of patients without gastric bypass, and lack of a control group. We therefore designed a study for retrospective evaluation of the sensitivity and specificity of seven CT signs.

Swirling of the mesentery was the best-performing single sign in our series with sensitivity and specificity of 61% and 94%, 78% and 89%, and 83% and 67% for the three review-

ers. The value of the mesenteric swirl sign probably reflects its increased conspicuity compared with the other findings, which may not be as obvious on CT. The CT anatomy in patients who have undergone laparoscopic Roux-en-Y gastric bypass is not straightforward. The undulating leaves of mesentery through which hernias occur are very thin and rarely conform to any imaging plane. Therefore, the CT signs of herniation are largely based on identification of the effects of the hernia on the herniating structures, such as mesenteric vessels, rather than on delineation of the defect itself. The amount of swirl sufficient to make the diagnosis is open to debate because mesenteric swirling occurs in healthy persons and patients who have undergone laparoscopic Roux-en-Y gastric bypass but do not have an internal hernia. We believe, however, that any amount of mesenteric swirl should be viewed with suspicion in a patient with a history of laparoscopic Roux-en-Y gastric bypass who presents with abdominal pain.

Four other CT signs (distal tubular mesenteric fat surrounded by bowel loops, mushroom-shaped mesentery, small bowel behind the SMA, and right-sided anastomosis) were more specific but far less sensitive than mesenteric swirling. Distal tubular fat surrounded by bowel loops, resembling the eye of a hurricane, is similar to mesenteric swirl but occurs in the distal mesentery with bowel loops closely surrounding the round mesenteric fat rather than at the mesenteric root. Three of these signs, which have not been described previously, to our knowledge, were prospectively identified before this study on the basis of our anecdotal experience and discussions with our bariatric surgeon. Although they overlap some of the previously described signs to some extent, their higher specificity may be valuable in some cases.

We found good interobserver agreement for all three reviewers. A third-year radiology resident, who received the same pretest training as the two abdominal radiologists, was included to help us determine whether the findings were useful to imagers with less experience. The abdominal imaging specialists and the radiology resident performed similarly. This finding suggests that the CT signs chosen for the study were robust.

We believe the results of this study emphasize the need for radiologists who interpret CT scans of patients who have undergone laparoscopic Roux-en-Y gastric bypass to make special effort to review and understand the signs of herniation. To some extent, this finding parallels the results of others [14], who have commented on the value of review of CT images by bariatric surgeons, who are intimately familiar with the complex anatomy and the expected CT findings in their own patients. However, patients with symptoms after laparoscopic Roux-en-Y gastric bypass often present to an emergency department or clinic, and the initial imaging assessment is usually performed by a radiologist. Because a history of laparoscopic Roux-en-Y gastric bypass may not be available at interpretation, it is critical for radiologists to familiarize themselves with the CT appearance after laparoscopic Roux-en-Y gastric bypass and the signs of internal hernia.

As always, however, clinical correlation of CT findings with clinical presentation is critical. If the presentation suggests that an internal hernia is present (intermittent postprandial abdominal pain, nausea with or without vomiting) the surgeon should consider laparoscopic exploration to definitively make the diagnosis. This point is extremely important because the consequences of missed internal hernia with strangulation of the bowel are dire.

One limitation of our study was the high proportion of women relative to men, but the numbers represent the referral pattern for bariatric surgery at our institution. Another limitation was the difficulty in selecting a control group. Although we could have easily identified a matched group of controls with normal CT findings, the lack of laparoscopic Roux-en-Y gastric bypass in these patients would have been obvious to the reviewers. Therefore, because there were ethical concerns about imag-

ing of patients who had undergone laparoscopic Roux-en-Y gastric bypass and did not have symptoms, we identified a group of laparoscopic Roux-en-Y gastric bypass patients who underwent CT and reoperations for other reasons and in which internal hernia was not found. This control probably accounts for the difference in time between surgery and CT in the clinical and control groups, which may account for the greater weight loss in the group with hernia. Prospective confirmation of our findings would be valuable.

The CT finding of swirled mesentery is the best single predictor of internal hernia after laparoscopic Roux-en-Y gastric bypass. Radiologists should become familiar with this sign and the other CT signs of internal hernia in laparoscopic Roux-en-Y gastric bypass patients. Even minor degrees of swirl should be considered suspicious for internal hernia in this population. We emphasize that CT findings are helpful in the overall management of complications after laparoscopic Roux-en-Y gastric bypass, but careful clinical correlation is paramount to avoid missed diagnoses that may be detrimental to the patient. This point also emphasizes the importance of a close, collaborative relationship between the bariatric surgeon and the radiologist, who should be committed to the long-term care of the bariatric patient.

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