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# Value of contrast-enhanced multidetector computed tomography in imaging of symptomatic patients after laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy

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## Abstract

**Background:** To assess the role of contrast-enhanced multidetector computed tomography (MDCT) in the assessment of symptomatic patients following laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy.

**Results:** We reviewed the studies of 129 cases and found complications in 113 patients: 55 early complications and 48 late complications. All of these complications were diagnosed with intravenous contrast-enhanced MDCT. Statistically significant difference was found between UGIS and MDCT in the diagnosis of many cases.

**Conclusion:** The rate of complications in bariatric surgery is high and the associated mortality is not negligible. The interpreting radiologists should know the normal postoperative findings and be aware of possible complications.

**Keywords:** Contrast-enhanced multidetector computed tomography, Laparoscopic Roux-en-Y gastric bypass, Laparoscopic sleeve gastrectomy

## Background

Obesity is a serious, multifactorial, chronic illness that is associated with multiple medical comorbidities and an increase in early mortality [1, 2]. The prevalence of obesity has increased worldwide to epidemic proportions in both developed and developing countries over the past 30 years [3]. Morbid obesity has been defined as body mass index (BMI) greater than 40 kg/m<sup>2</sup> or greater than or equal to 35 kg/m<sup>2</sup> in patients who have some comorbidity [4, 5]. Obesity treatments, such as medications, exercise, and diet modifications, do not usually provide long-standing results; thus, bariatric surgery, either restrictive or mixed restrictive and malabsorptive techniques, became a well-accepted treatment option worldwide [6]. Surgery can provide a sustainable long-term option for weight loss [7], reduce the associated comorbidity, and provide correction of metabolic

disorders, reduction of cardiovascular risk, and improvement of the quality of life [8, 9].

Laparoscopic Roux-en-Y gastric bypass is the most popular bariatric procedure performed in the USA because it is associated with greater sustained weight loss and higher long-term success rates than other forms of bariatric surgery [10, 11]. It was originally introduced in the 1960s and 1970s by Griffen [12] and uses a combination of restriction and malabsorption procedures. Roux-en-Y gastric bypass entails the use of a stapler-cutter device to create a staple line that divides the stomach into a small fundal component around 15 cc (i.e., the *gastric pouch*) and a much larger excluded component (i.e., the *excluded stomach*). After this, one jejunal loop is cut off at 25 to 50 cm distal to the ligament of Treitz, and its distal edge is brought up and anastomosed to the gastric pouch by means of an end-to-end or, more commonly, an end-to-side gastrojejunostomy [13–15]. This is the restrictive part of the RYGB

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**Table 1** The sociodemographic variables and BMI

	Gender	Age	BMI
LSG (N = 84)	Female (66%) Male (34%)	Mean $\pm$ SD = 40.38 $\pm$ 7.11 Range = 25–59	Mean $\pm$ SD = 46.56 $\pm$ 6.27 Range = 35–58
RYGB (N = 45)	Female (78%) Male (22%)	Mean $\pm$ SD = 43.35 $\pm$ 7.63 Range = 27–60	Mean $\pm$ SD = 47.98 $\pm$ 5.76 Range = 39–60
P value	0.479	0.572	0.254

and that limb is called the alimentary/efferent limb and can be placed in an ante or retro-gastric approach. The remnant stomach, duodenum, and proximal jejunum make the biliopancreatic/afferent limb which becomes then attached to the alimentary limb via a jujeno-juenal anastomosis at approximately 75–150 cm distal to the gastrojejunostomy.

Laparoscopic sleeve gastrectomy is a relatively recent surgical technique first introduced in 1999 [16]. It gained popularity among bariatric surgeons due to its simple technique and lower risk profile [17]. It is performed by laparoscopically dividing the stomach along its long axis and resecting the greater curvature of the fundus, body, and proximal antrum, producing a narrow, banana-shaped gastric pouch along the lesser curvature [14]. The remaining stomach has a residual volume of only about 100 ml, promoting weight loss by causing the patient to experience early satiety by means of the restrictive effect of the pouch [10–19]. Although complications due to bariatric surgery are growing thin, all practicing radiologists should be familiar with these complications because by early diagnosis and intervention, patient morbidity and mortality might be reduced [18, 19].

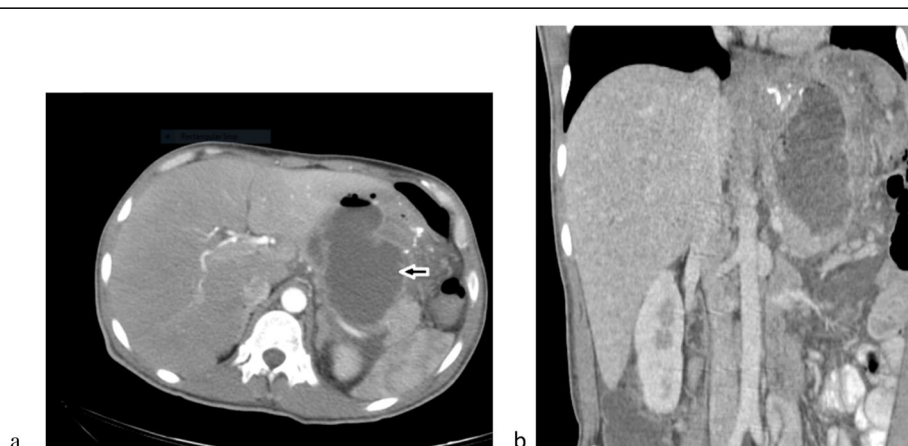
Abdominal pain/discomfort, obstructive symptoms, and hemodynamic instability are the most common complaints following GBP and LSG with highly variable clinical presentation [20, 21]. In the early postoperative period, patients may develop epigastric and postprandial abdominal pain due to maladaptive eating behavior and food intolerance. Constipation is common in the early postoperative period and is usually characterized by diffuse and crampy lower abdominal pain [22]. Esophageal motility disorders may cause pain after bariatric surgery that is typically substernal in location. *Postoperative abdominal pain may also result from biliary causes such as cholelithiasis producing right upper quadrant abdominal pain* after GBP and sleeve gastrectomy. Marginal gastric ulceration has been reported as one of the more common complications, ranging from 1 to 16 % [23–26] in GBP patients generally presenting with burning epigastric pain often immediately postprandial [22]. Anastomotic leak and gastro-gastric fistula which communication between the gastric pouch and the remnant stomach in GBP patients can cause abdominal pain at the time of leakage [27, 28]. Other presenting symptoms can be fever and tachycardia along with nausea, vomiting, fatigue, and diarrhea [29],

**Table 2** Complications of Roux-en-Y gastric bypass

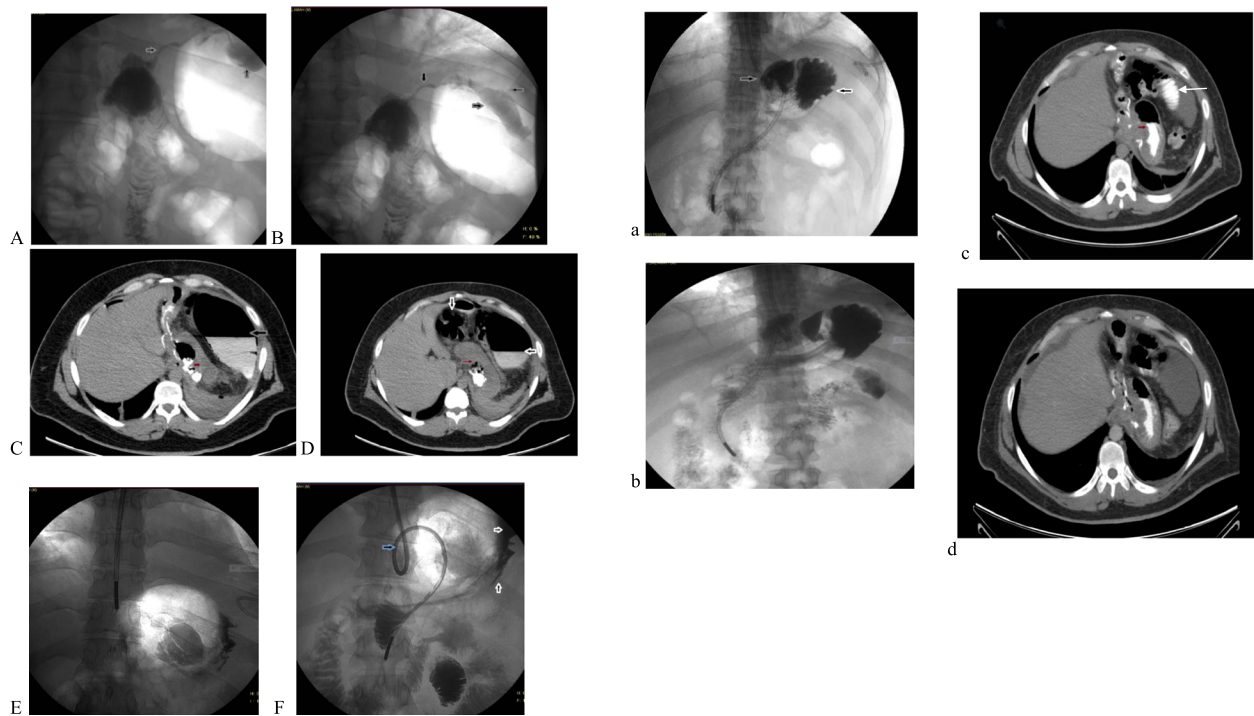
	Complications and radiographic findings	Management
Early postoperative (n = 5)	Leaks (n = 2): (5.7%); within 2–4 days (Figs. 2 and 3) Leakage was at the site of gastrojejunal anastomosis  Perigastric collection and hematoma (n = 3): (8.6%) within 3–7 days (Fig. 1)	Percutaneous drainage by pigtail catheter and insertion of naso-enteric tube.  The small collection was treated conservatively and the large collection was managed by gastro-jejunostomy
Late postoperative (n = 30)	Gastrojejunostomy anastomotic stricture (n = 1)  Internal hernia (n = 14) (40%): 2–4 years (Fig. 4) Altered disposition of loops and anastomosis Twisting of mesenteric vessels (whirl sign) Dilated bowel loops with mushroom appearance of the distended loops in the left hypochondrium Mesenteric fat planes densification  Intestinal obstruction (n = 6) (17%): 2–4 years (Fig. 5)  Intussusception (n = 5) (14.3%): 2–4 years (Fig. 6)  luminal narrowing (n = 1) (2.8%): 1 year  Distended bowel and weight gain (n = 2) (5.7%): after 4 years  Gastroesophageal spasm (n = 1) (2.8%): 9 months	Endoscopic dilation of the stricture  Medical treatment (case 6)  Treated by laparoscopy (case 1)  (cases 20 and 21)

**Table 3** Complications of laparoscopic sleeve gastrectomy

	Complications and radiographic findings	Management
Intraoperative ( <i>n</i> = 3)	Liver contusion ( <i>n</i> = 1) Spleenic tear ( <i>n</i> = 2): a serrated low-density area in the spleen	
Early postoperative ( <i>n</i> = 48)	<ul style="list-style-type: none"> <li>• Leakage (<i>n</i> = 18): (23.1%); within 1–10 days. (Figs. 8 and 9)</li> <li>• The most common site of leak was the proximal 1/3 of the sleeve just below the esophagogastric junction, followed by middle then lower thirds</li> <li>• Pneumoperitoneum</li> <li>• Free fluid</li> </ul> Perigastric collection and hematoma ( <i>n</i> = 26) (33%) within 3–10 days (Fig. 7) <ul style="list-style-type: none"> <li>• Acute hematoma: hyperdense collection</li> <li>• Hemoperitoneum (<i>n</i> = 5)</li> <li>• Extravasation of IV contrast if there is active bleeding from staple lines or suture lines (<i>n</i> = 2)</li> </ul> Gastropancreatic abscess ( <i>n</i> = 1) located in the left subphrenic area (Fig. 11) Gastrobronchial fistula ( <i>n</i> = 1) The site of the fistulous tract was clearly visualized by CT Rectus sheath hematoma: ( <i>n</i> = 2)	Laparoscopic re-exploration and surgical closure  Conservative ( <i>n</i> = 9) laparoscopic—re-exploration and surgical drainage in the presence of hemodynamic instability ( <i>n</i> = 3)  CT-guided percutaneous drainage with appropriate antibiotic coverage  failed to heal after endoscopic insertion of a stent
Late postoperative ( <i>n</i> = 27)	Vascular thrombosis: PV, SMV, and SV ( <i>n</i> = 10) (13%) within 6 months to 2 years postoperatively (Fig. 10) Gastric stricture ( <i>n</i> = 1) (Fig. 12)  Dilatation of the gastric pouch ( <i>n</i> = 8) (10%) and weight gain (Fig. 13) Incisional hernia( <i>n</i> = 1): eventration of bowel loops and mesenteric fat Hiatus hernia ( <i>n</i> = 4) Gastritis( <i>n</i> = 1) S.C. seroma ( <i>n</i> = 1) Port site hernia ( <i>n</i> = 1)	Medical treatment.  Focal strictures respond to endoscopic dilation, but longer segments of narrowing necessitate surgical revision or resection of the pouch  Surgical revision of the pouch



**Fig. 1** A thirty-five-year-old male patient presented 5 days post-Roux-en-Y gastric bypass by abdominal pain and fever. **a** MSCT axial and **b** coronal reconstruction images show thick-walled marginally enhancing fluid collection with increased density of the surrounding mesenteric fat planes. MSCT diagnosis, operative bed-infected hematoma



**Fig. 2** A thirty-five-year-old male patient presented 3 days post Roux en y gastric bypass by severe abdominal pain & vomiting: (A) & (B) UGIS revealed: evidence of leakage track extending upwards, to the left and posterior from the gastric pouch to a large left upper quadrant collection. (C) & (D) MSCT axial images revealed; evidence of contrast leakage at the site of gastrojejunal anastomosis with a thin walled large air and contrast filled collection at the left hypochondrium and pneumoperitoneum. (E, F) shows; successful insertion of naso-enteric tube (blue arrow) under fluoroscopic guidance for drainage of the leak (white arrow). (a) and (b) UGIS and (c) and (d) MSCT follow up 1 week after insertion of a nasoenteric tube for drainage of the gastrogastic fistula for the same case show significant decrease in size of the fluid and air collections seen in the previous images but there is residual contrast at the excluded stomach (white arrow in c) due to fistulous tract formation which developed between the gastric pouch and excluded stomach probably through the jejunal stump.

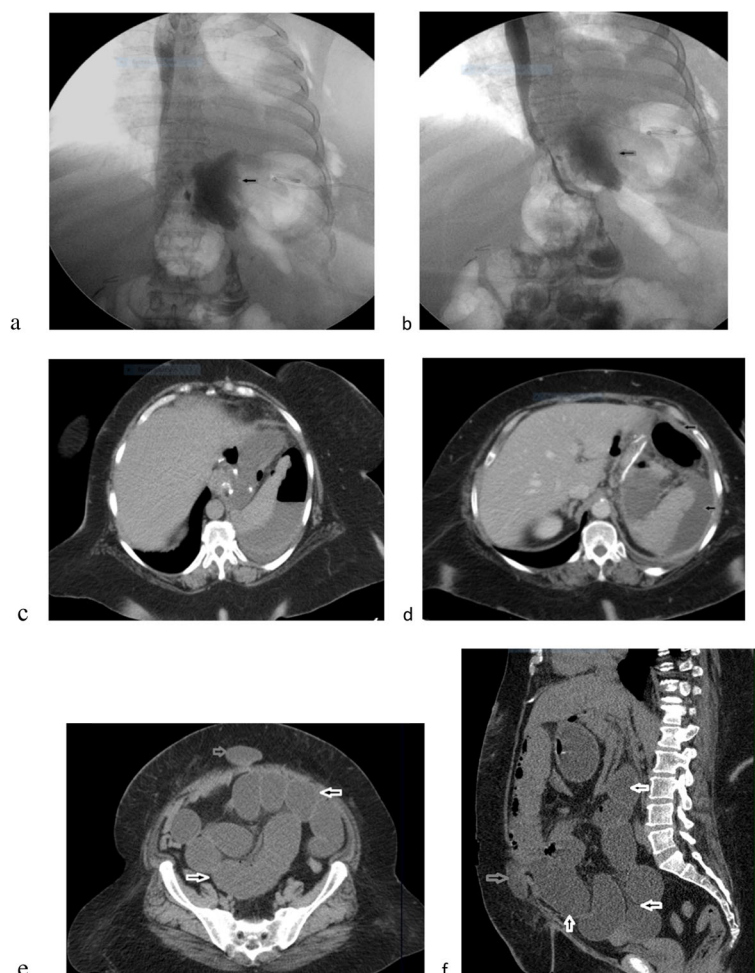
*small-bowel-related causes* of postoperative abdominal pain include internal hernia, adhesive intestinal obstruction, *intussusception*, and blind loop syndrome. *Internal hernia* patients often present with diffuse, episodic, and severe abdominal pain that lasts hours and may or may not be postprandial [22]. Adhesive small-bowel obstruction is thought to occur less in the era of laparoscopy. However, this should always be considered when a patient presents with abdominal pain or vomiting after GBP [30]. Although rare, jejunojejunal intussusception can be a cause of abdominal pain in GBP patients often presenting with upper quadrant abdominal pain. *Blind limb syndrome* is the enlargement or dilation of the blind limb and can also cause postprandial abdominal pain in GBP patients due to distention [31].

Our aim in this prospective study was to investigate the value of intravenous contrast-enhanced multidetector computed tomography (IVCE-MDCT) in identifying postoperative complications of laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy in symptomatic patients.

## Methods

### Patients

This study was conducted at the radiology department of a specialized hospital in the period from December 2014 to March 2018. The study cohort primarily included all patients who underwent laparoscopic gastric bypass and sleeve gastrectomy operated at the bariatric surgery department for treating their morbid obesity ( $\text{BMI} \geq 35 \text{ kg/m}^2$ ) with obesity-related serious comorbidities (ex. DM, HTN) or  $\text{BMI} > 40$  with or without comorbidities. These patients were referred for the diagnostic evaluation of their postoperative complaints in the early and late postoperative periods. Thorough history taking, clinical review, and laboratory investigations were done to rule out nutritional/functional causes of abdominal pain. An upper gastrointestinal imaging (UGI) was performed for all patients. This was followed by CT scans and right upper quadrant ultrasound (when the gallbladder is present). Exclusion criteria included 47 patients who had undergone other surgical techniques or had been operated by a different team, those proved to have functional or



**Fig. 3** A fifty-six-year-old female patient presented 7 days post-Roux-en-Y gastric bypass by abdominal pain, vomiting, and tachycardia. **a, b** UGSI shows evidence of leakage (black arrow). **c, d** Axial MSCT shows evidence of leakage. **e, f** Axial and coronal reformatted MSCT shows abdominal wall hernia containing fluid-filled small bowel (gray arrow) with dilated small bowel proximally (white arrow) and collapsed bowel loops distally (intestinal obstruction)

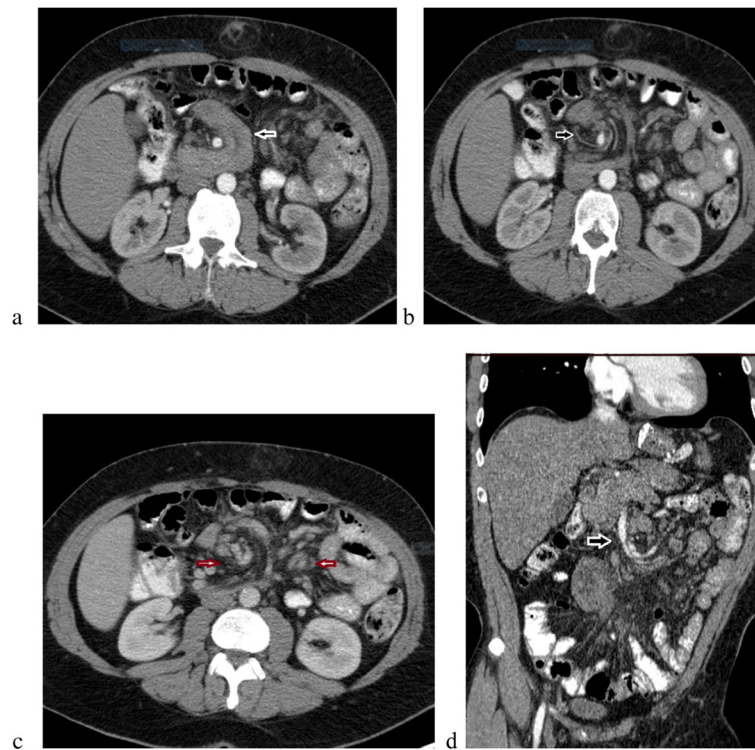
biliary causes of abdominal symptoms as shown by ultrasound, those with contraindications to radiation exposure or iodinated contrast media and those exceeding the weight limit of the examination table (300 kg maximum weight capacity). Included patients (a total 129) were interviewed and a protocol was filled with identification of hospital number, name, age, gender, time of surgery, and history of allergy to the iodinated contrast media or drugs.

#### Technique

An upper gastrointestinal contrast-enhanced study (UGIS) was first performed for all patients. The choice of contrast medium whether gastrografin or barium was determined by the time of presentation of the patient and his complain. For patients presenting in the early postoperative period (first 30 days after surgery) gastrografin meal was done unless there is any suspicion of aspiration or a fistulous communication to tracheobronchial tree due to the

risk of gastrografin-associated pneumonitis. For patients presenting later, barium meal was done unless there is any fear of communication to the mediastinum or to the peritoneal cavity, gastrografin was used instead because of barium's risk of massive peritonitis or mediastinitis. The patients were asked to fast for 6 h prior to the study. Scout images were obtained to detect free or loculated extraluminal gas as well as radiopaque staple lines that otherwise could be mistaken for small leaks during the fluoroscopic examination. Under fluoroscopic screening the patient was asked to swallow the bolus of the contrast and imaging was performed in the supine and supine left posterior oblique position, screening down the esophagus into the gastric pouch. If leakage was demonstrated across the staple line in RYGB or along the resection line in sleeve gastrectomy the examination was stopped. If no leakage was noticed, rotation from left lateral to RAO to supine until opacification of the duodenum then jejunal loops occurs. In RYGB, the CM is followed from the pouch into



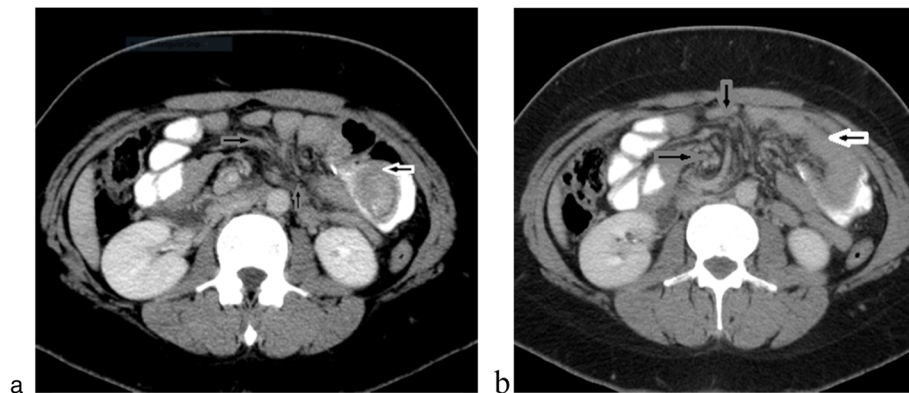


**Fig. 4** A forty-two-year-old male patient presented 2 years post-Roux-en-Y gastric bypass by abdominal pain and vomiting. **a–c** MSCT axial. **d** Coronal reformat images showed the whorly appearance of the nearby mesentery with converging vessels at an orifice and reversal of the mesenteric artery and vein relation (paraduodenal hernia), multiple enlarged mesenteric and para-aortic lymph nodes are seen. UGSI shows no abnormality. MSCT diagnosis, paraduodenal internal hernia

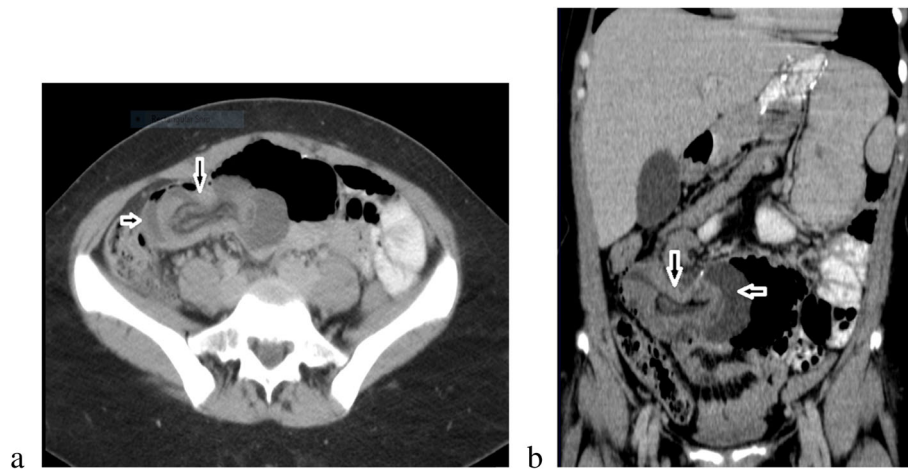
the Roux limb via the gastrojejunal anastomosis. The time taken for complete passage of the contrast through the gastric pouch was calculated (gastric emptying time) and the free passage through the bowel loops was assessed.

For computed tomography, a consent form was delivered to all patients and thoroughly explained. The MDCTs were conducted using 128-MDCT scanner (Toshiba Aquilion)

with detector configuration of  $128 \times 0.5$  mm, rotation time of 0.35 s, 120 kV, and 93 mAs. Axial slices were obtained from the diaphragmatic domes to the lower end of symphysis pubis. Unenhanced scan is performed to detect hemorrhage followed by contrast-enhanced scan after the intravenous injection of Omnipaque at a dose of 150 ml, with mechanical pump injectors at 2–3 ml/s in the arterial,



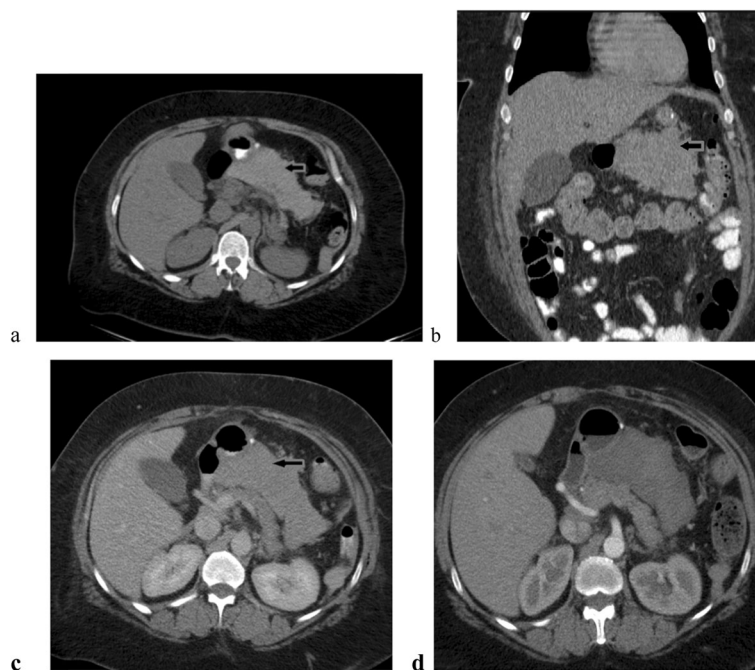
**Fig. 5** A thirty-nine-year-old male patient presented 2 years post-Roux-en-Y gastric bypass by abdominal pain and vomiting. **a, b** Axial MSCT shows dilatation of some of the proximal jejunal loops with a mild thickened wall (white arrow) associated with a right para-central whirling appearance of the mesenteric structures (gray arrow), below the origin of the superior mesenteric artery. Diagnosis: internal hernia with proximal bowel obstruction post-RYGB



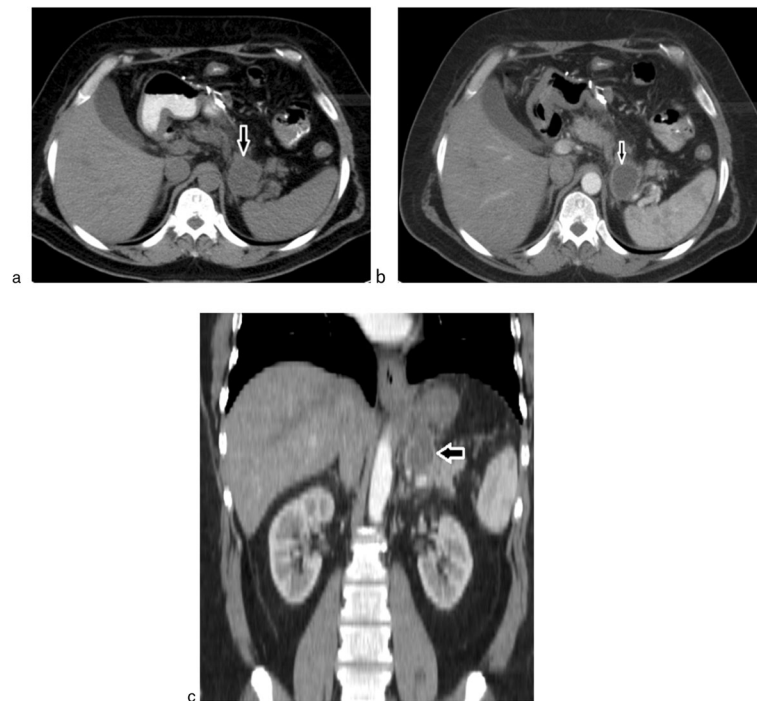
**Fig. 6** A thirty-four-year-old female patient presented 2 years post-Roux-en-Y gastric bypass by abdominal pain and diarrhea. **a, b** MSCT axial and coronal reconstruction images show complex mass seen at right lower abdominal quadrant (white arrow) showing edematous bowel loops wall with bowel-within-bowel configuration (target appearance). Small bowel intussusception post-GRYB

portal, and equilibrium phases. The arterial phase is used mainly to identify active bleeding and the portovenous phase to identify an abscess. On suspicion of dehiscence of sutures or perforation, a sequence is then performed after oral intake of iohexol (Omnipaque 300<sup>®</sup>, Nycomed,

Princeton, NJ, USA, diluted in mineral water for 30 min). The volume of administered oral contrast material will depend on the patient's tolerance. Finally, the reconstructed image data set was networked to the workstation. Coronal and sagittal reconstruction was



**Fig. 7** A thirty-nine-year-old female patient with BMI of 42 kg/m<sup>2</sup> was presented 4 days post-lap. sleeve gastrectomy by abdomen pain and tachycardia. UGS shows no abnormality. **a, b** MSCT axial and coronal reformatted images revealed a large irregular walled extraluminal high-density fluid collection at the operative bed with soft tissue stranding of the surrounding fat. **d** Follow-up CT after 2 weeks shows a stationary course of the previously depicted operative bed collection. Diagnosis: perigastric hematoma post-LSG



**Fig. 8** A forty-three-year-old male patient presented 5 days post-lap. sleeve gastrectomy by severe abdominal pain, fever, and tachycardia. **a, b** MSCT axial and **c** coronal reformatted images show a localized collection on the left of the sleeved stomach, adherent to the tail of the pancreas with no obvious clear cleavage plane between them. This collection is associated with surrounding minimal focal mesenteric fat stranding and mural enhancement post-I.V. contrast administration. UGSI shows no abnormality. MSCT diagnosis: peri-gastro-pancreatic abscess

obtained at 2 mm slice thickness. All studies were reviewed by two radiologists with at least 15 years of experience in abdominal imaging.

#### Image analysis

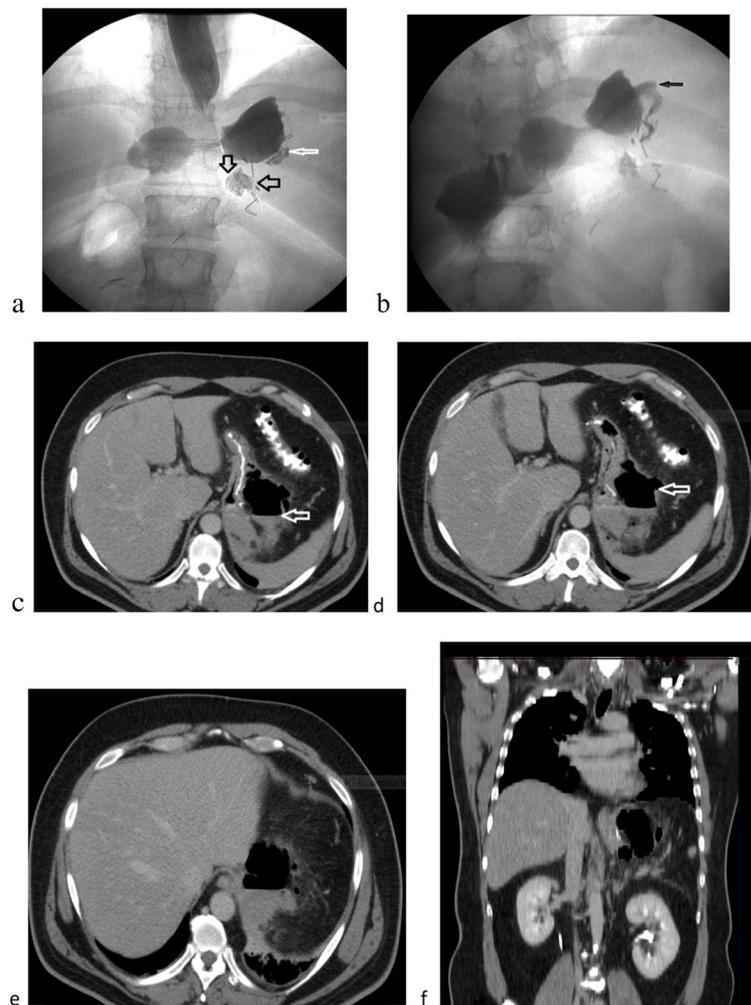
All studies were reviewed by three radiologists with 8, 15, and 20 years of experience in gastrointestinal radiology respectively.

#### In cases of Roux-en-Y gastric bypass

The anatomy of the postoperative gastric bypass was studied by analyzing the volume of the gastric pouch, proximal aspect of the jejunum efferent loop, the jejunal afferent loop (blind loop), the excluded stomach, and the gastric area. The presence of complications was investigated such as (1) anastomotic leaks; most leaks are defined after oral administration of water-soluble contrast as blind-ending tracks or sealed-off collections abutting the anastomotic region or, less frequently, as free leaks into the peritoneal cavity. Most leaks occur at the gastrojejunal anastomosis [24, 25], less common sites of perforation include the gastric pouch, blind-ending jejunal stump, and jejunojejunostomy. Anastomotic leaks may extend as extraluminal collections in the left upper quadrant on upper GI studies or CT scans, sometimes continuing superiorly into the

subphrenic space [15, 23–25, 32]. (2) gastrojejunal anastomotic strictures. They usually appear on UGIS as short segments of smooth narrowing at the gastrojejunal anastomosis [14]. If obstruction is present, the gastric pouch may be dilated, and emptying of barium into the Roux limb may be delayed with no distension of the distal small intestine and colon. (3) Internal hernia, usually results from herniation of small bowel loops through a defect in the transverse mesocolon (for a retrocolic Roux limb), is a defect in the small bowel mesentery (for a jejunojejunal anastomosis), or a defect posterior to the Roux limb (i.e., Petersen defect). It should be suspected on both CT images and barium studies when a cluster of small bowel loops is seen in abnormal locations especially the left mid-abdomen or left upper quadrant above the transverse mesocolon often displacing other bowel and associated with migration of an anastomotic jejunojejunal suture line. This suture line is most often displaced from its typical location in the left mid-abdomen into the left upper quadrant, but it can also be displaced into the right mid-abdomen [33]. One advantage of the barium study over CT is the ability to visualize changes in the configuration of the small bowel entering and exiting the hernia during the course of the examination with retention of barium within these loops [26, 33]. However, CT





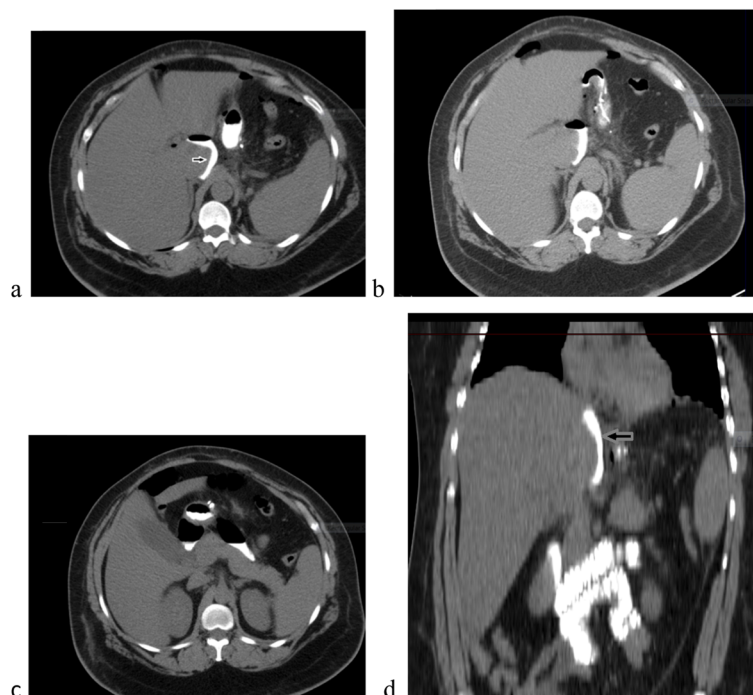
**Fig. 9** A thirty-five-year-old female patient presented 3 days post-lap. sleeve gastrectomy by abdominal pain, fever, and tachycardia. **a, b** Upper gastrograffin meal films revealed: free flow of contrast media through the esophagus with leakage of contrast media across the staple line. **c–f** MSCT; axial and coronal reformatted images showed perigastric serpiginous air-filled tract seen extending from the left anterolateral aspect of the stomach adjacent to the surgical clips to the medial aspect of the left hepatic lobe associated with multiple gas bubbles under the diaphragm (pneumoperitoneum) together with increased perigastric fat density (inflammatory reaction)

enables visualization of changes in the mesentery, such as stretching and rotation of vessels “swirl sign” and or engorgement of mesenteric vessels [33, 34]. (4) Intestinal obstruction may be caused by adhesions, internal hernias, anterior abdominal wall hernias, strictures at the jejunojunal anastomosis, and, rarely, intussusceptions. (5) Intussusception typically occurs at or near the jejunojunal anastomosis, with the staple line at this anastomosis presumably acting as the lead point for the intussusception [35]. (6) Gastroesophageal spasm.

#### *In cases of sleeve gastrectomy*

UGSI and C.T images were assessed for the presence of the following: (1) intraoperative organ injury, e.g., splenic injury. (2) Gastric leaks along the staple line, the leak

may be free or contained. A free leak was diagnosed if spillage of contrast was seen into the peritoneal cavity, whereas a contained leak was diagnosed on the extension of the contrast beyond the expected lumen. (3) Perigastric collection, hematoma, and hemoperitoneum. Acute hematoma has high attenuation values (40–60 HU) Chronic hematoma may be difficult to distinguish from other fluid collections. (4) Presence of vascular affection, e.g., portal, splenic, and mesenteric vascular occlusion. (5) Abscess formation secondary to leak identified as high-density intraperitoneal fluid collection with rim enhancement that contains both gas and fluid. The presence of contrast material within the abscess after oral ingestion of contrast material confirms its origin. (6) Fistula formation: gastrocutaneous and gastrobronchial fistula secondary to subphrenic infection complicating



**Fig. 10** A forty-five-year-old female patient presented 6 days post-lap. sleeve gastrectomy by abdominal pain and fever and tachycardia. **a–c** MSCT axial and **d** coronal reformatted images revealed evidence of leakage of the oral contrast noted; pooling around the caudate lobe with air-fluid level associated with increased fat density noted in the vicinity of the stomach. UGSI shows no abnormality. Diagnosis: gastric leak post-LSG

staple line leak. CT may demonstrate the fistula, sub-phrenic abscesses, associated pleural effusion, and lung infection. (7) Strictures; gastric strictures may occur early, within a few days, secondary to ischemia or edema, or may occur later, usually as a result of fibrosis. Focal strictures or long segments of narrowing may occur when scarring occurs along the greater curvature staple line and barium studies may reveal focal strictures or long segments of narrowing with delayed emptying of barium from the residual stomach. (8) dilatation of gastric pouch. Barium studies may reveal the widening of the gastric sleeve, which no longer has a tubular appearance. (9) Incisional hernia. (10) Hiatus hernia [15, 23, 32].

#### Statistical analysis

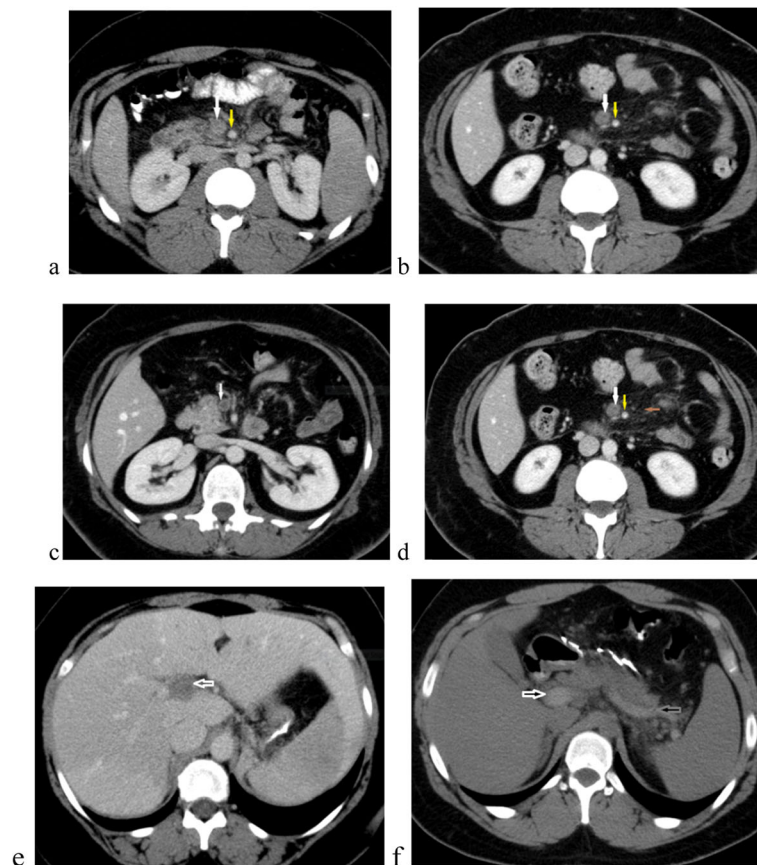
Data were analyzed using Statistical Program for Social Science (SPSS) version 20.0. Quantitative data were expressed as mean  $\pm$  standard deviation (SD). The following tests were done: (1) independent samples *t* test of significance was used when comparing between two means. (2) A one-way analysis of variance (ANOVA) when comparing between more than two means. (3) Chi-square ( $\chi^2$ ) test of significance was used in order to compare proportions between two qualitative parameters. Probability (*P* value) *P* value < 0.05 was considered

significant. *P* value < 0.001 was considered as highly significant. *P* value > 0.05 was considered insignificant.

#### Results

The sociodemographic variables and BMI of the 129 patients finally included in the study are shown in Table 1 and revealed no statistically significant difference regarding the age, gender, and BMI among the patients included in each type of surgery. Postoperative complications were detected in 113 patients as follows: 78 out of the 84 patients (92.8 %) who underwent sleeve gastrectomy (Table 2), 35 out of the 45 patients (77.7 %) who underwent Roux-en-Y gastric bypass (Table 3). Early postoperative complications were defined as complications occurring within 30 days after surgery; late complications were defined as those occurring > 30 days after surgery.

In patients who underwent Roux-en gastric bypass, the most common early postoperative complication was perigastric collection/hematoma (8.6%) (Fig. 1) followed by leakage at the site of gastrojejunal anastomosis (5.7%) (Figs. 2 and 3). The most common late postoperative complication was internal hernia (40%) (Fig. 4), followed by an intestinal obstruction (17%) (Figs. 5 and 6). The CT findings and management of these complications are summarized in Table 2. The most common early postoperative complication of laparoscopic sleeve gastrectomy was



**Fig. 11** A twenty-six-year-old male patient presented 1.5 years post-lap. sleeve gastrectomy by severe abdominal pain. **a–d** MSCT scans shows SMV thrombosis (white arrow). Note the normal SMA (yellow arrow) enhancement and ratio of SMV to SMA diameters  $> 2$  and increased density of the surrounding fat (brown arrow). Portal and splenic veins thrombosis post-LSG. **e** MSCT scan axial cut with IV contrast showing non-enhanced portal vein (arrowed). **f** MSCT scan without intravenous contrast hyperattenuating splenic and portal vein. UGSI shows no abnormality. MSCT diagnosis: thrombosed portal, superior mesenteric and splenic vein

perigastric collection/hematoma (33.3%) (Figs. 7 and 8) followed by leakage 23% (Figs. 9 and 10). The most common late postoperative complication was vascular thrombosis (13%) (Fig. 11), followed by dilatation of gastric pouch (10%) (Fig. 12). The CT findings and management of these complications are summarized in Table 3.

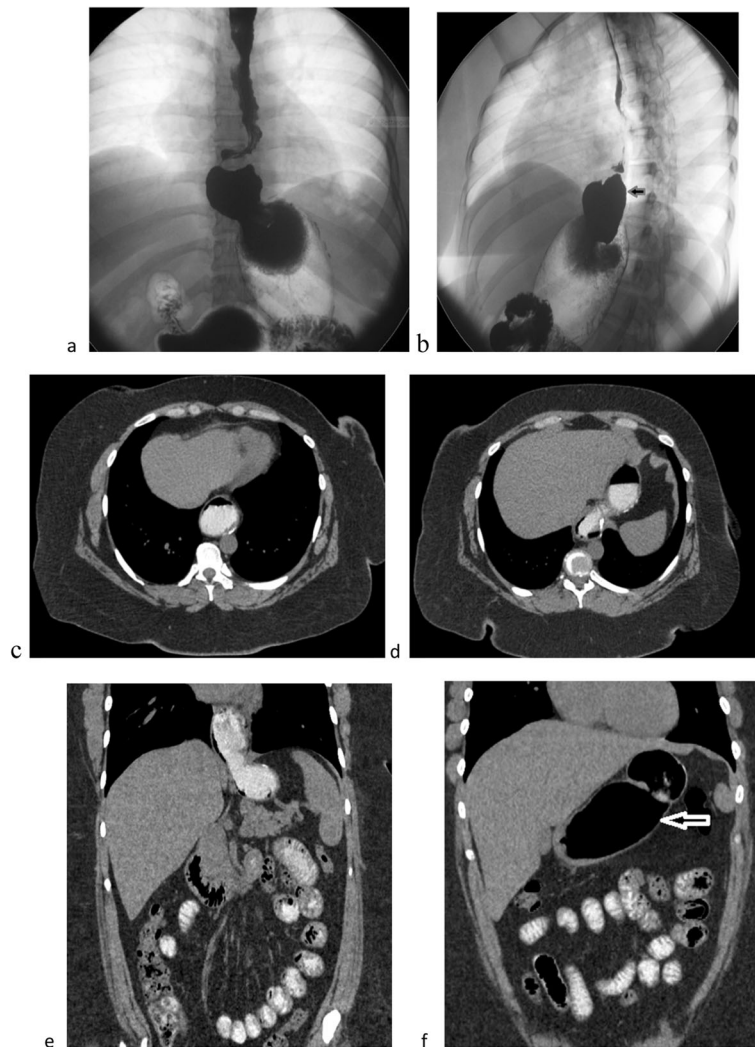
In the 35 symptomatic patients with RYGB complications, 6 complications (17%) were diagnosed by both UGSI and C.T. abdomen and 29 complications (80%) were diagnosed by C.T. only (Table 4). Statistically significant difference was found between UGIS and CT in diagnosis internal hernia, intestinal obstruction, and intussusception.

In the 78 symptomatic patients following post-sleeve gastrectomy, 29 complications (37.1%) were diagnosed by both UGSI and C.T. abdomen (Fig. 13), 49 complications (62.8%) were diagnosed by CT only (Fig. 14) (Table 5). Statistically significant difference was found between UGIS and CT in the detection of perigastric collection and hematoma, gastropancreatic abscess and

portomesenteric thrombosis. UGSI were able to diagnose only 14 cases of leakage from stable line out of 18 cases, the 9 cases of increased size of gastric pouch, the 4 cases of hiatus hernia, 1 case of mid gastric sleeve stricture, 1 case of gastrobronchial fistula, and 1 case of mid gastric sleeve stricture and failed to diagnose the rest of complications which were diagnosed by CT only. Thus, CT was superior to or equivalent to UGSI in the detection of all sleeve gastrectomy and RYGB postoperative complications.

## Discussion

During the past two decades, bariatric surgery has become an increasingly popular form of treatment for morbid obesity. The most common bariatric procedures performed include laparoscopic Roux-en-Y gastric bypass, laparoscopic sleeve gastrectomy, laparoscopic adjustable gastric banding, vertical-banded gastroplasty (VBG), jejunoileal bypass, biliopancreatic diversion, and biliopancreatic diversion with duodenal switch [23]. It is



**Fig. 12** A forty-year-old female patient with BMI of  $56 \text{ kg/m}^2$  weighted 165 kg presented 3 years post-lap. sleeve gastrectomy by weight gain and heartburn. UGIS revealed increased size of the sleeved stomach and a hiatus hernia. **c, d** MSCT axial and **e, f** coronal reformatted images showed the increased size of the sleeved stomach associated with hiatus hernia

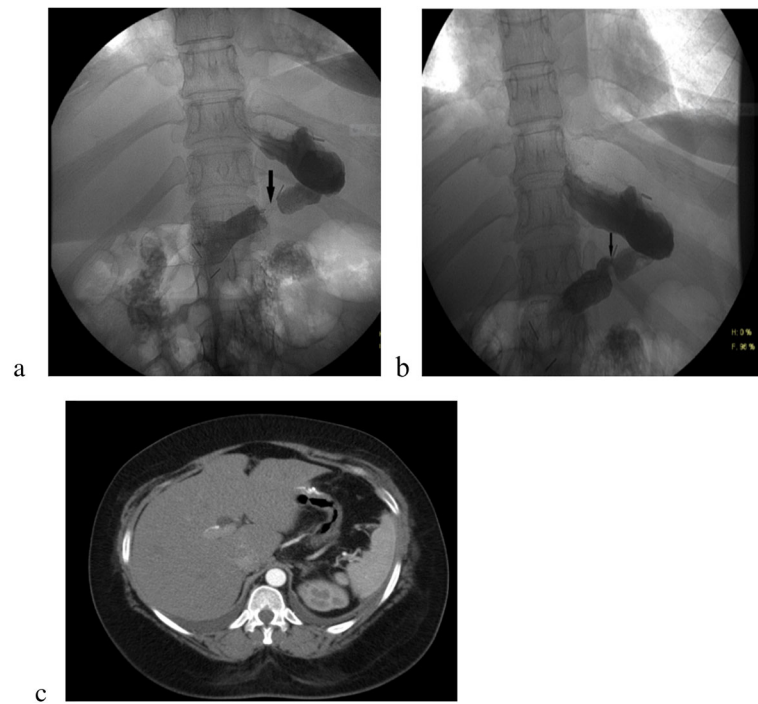
of ultimate importance to know the possible complications to allow prompt management, but unfortunately, physical examination of these patients is frequently impaired by obesity itself particularly in the postoperative period. Little is generally known about the role of imaging studies in the diagnosis of postoperative complications of bariatric surgery [24]. Fluoroscopic upper gastrointestinal examinations and abdominal computed tomography (CT) are the major imaging tests used to evaluate patients after bariatric surgery. In this prospective study, we investigated the value of contrast-enhanced MDCT in identifying postoperative complications of laparoscopic Roux-en-Y gastric bypass and laparoscopic sleeve gastrectomy in symptomatic patients.

According to multiple previous studies contrast-enhanced CT imaging is considered the method of

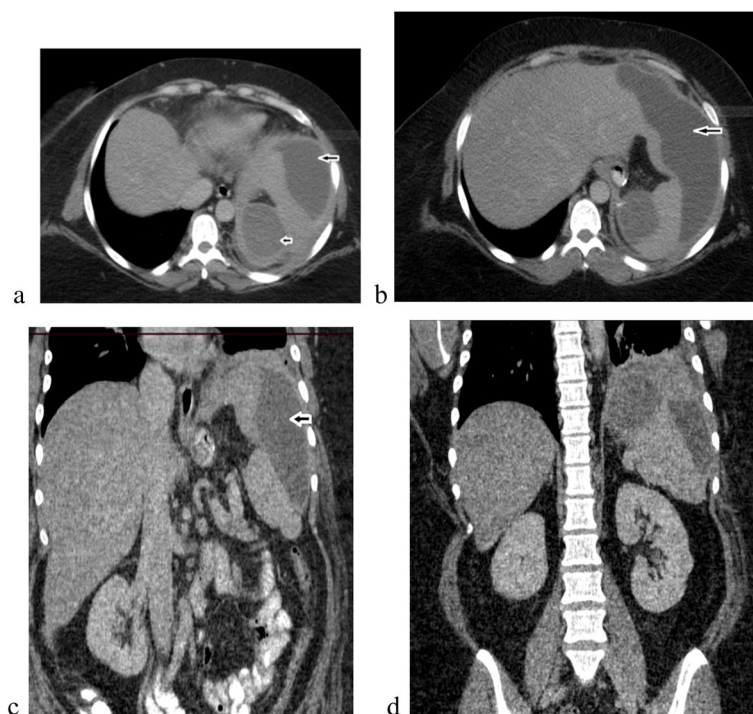
choice for investigation of abdominal symptoms, especially of patients undergoing gastric bypass [36–38]. Merckle et al. [39] reported that CT can provide a detailed view of the anatomy after Roux-en-Y gastric bypass. The positive oral contrast material administered just prior to image acquisition helps differentiate the gastric pouch and Roux limb from the excluded stomach and biliopancreatic limb, which are not opacified. For these authors, the afferent gastric distention occurring after Roux-en-Y gastric bypass can be due to obstruction or swelling of the enteroenterostomy and the imaging modality for this situation is the CT.

Carucci et al. stated that extraluminal leak is the most serious early complication of Roux-en-Y gastric bypass, occurring in up to 5% of patients within 10 days of surgery. Early detection is critical because of the risk of





**Fig. 13** A fifty-two-year-old male patient presented 1 year post-lap. sleeve gastrectomy by abdominal pain and vomiting. **a, b** UGIS films showed stricture at mid-body of the stomach with delayed passage of the contrast at this part. **c** MSCT axial cuts show stricture of mid-sleeved stomach. Diagnosis: stricture of mid-sleeved stomach more evident in UGSI



**Fig. 14** A thirty-nine-year-old female patient with BMI of 48 kg/m<sup>2</sup> weighted 160 kg presented immediate post-lap. sleeve gastrectomy by severe abdominal pain and tachycardia. **a, b** MSCT axial and **c, d** coronal reformatted images showed an upper pole subcapsular hematoma and another encapsulated homogenous fluid adjacent to the lateral and superior aspect of the spleen extending superomedially to the left lobe of the liver anteriorly. UGSI shows no abnormality. MSCT diagnosis: upper pole subcapsular hematoma and another encapsulated subcapsular/perisplenic hematoma

**Table 4** Comparison of UGIS and CT in the detection of Roux-en-Y gastric bypass postoperative complications ( $N = 35$ )

Complication	UGIS		CT		Chi-square	
	No.	%	No.	%	$\chi^2$	$P$
Leakage	2	100.0	2	100.0	0.000	1.000
Perigastric collection and hematoma	0	0.0	3	100.0	2.667	0.103
Internal hernia.	0	0.0	14	100.0	24.143	< 0.001
Intestinal obstruction	0	0.0	6	100.0	8.333	0.004
intussusception	0	0.0	6	100.0	8.333	0.004
luminal narrowing	1	100.0	1	100.0	0.000	1.000
Distended bowel and weight gain	2	100.0	2	100.0	0.000	1.000
Gastroesophageal spasm	1	100.0	1	100.0	0.000	1.000

This table shows a statistically significant difference between UGIS and CT regarding to internal hernia, intestinal obstruction, and intussusception

abscess formation, peritonitis, and sepsis, with a mortality rate of more than 5% [25]. The clinical symptoms of fever, tachycardia, abdominal pain, or an elevated WBC are often non-specific in the immediate postoperative period, and the physical examination may be limited by the large body habitus. The presence of tachycardia with a pulse exceeding 120 beats per minute has been reported to be the most consistent and reliable finding of peritonitis in bariatric patients [20]. Because of clinical difficulties in diagnosing postoperative leaks, some authors advocate routine upper GI examinations with water-soluble contrast agents 1–2 days after surgery as the preferred imaging test for ruling out leaks after gastric bypass surgery [24, 25]. In accordance with these authors, the gastrojejunal anastomosis was the most common site of leak in our study occurring in 5.6%. CT

had greater sensitivity in detecting direct signs of fistula formation, namely, oral contrast extravasation and extraluminal gas, in assessing indirect signs as collections adjacent to the gastric pouch and free fluid in the abdominal cavity and in identifying complications as subphrenic abscess and peritonitis

Strictures at the gastrojejunal anastomosis may be caused by postsurgical scarring at the anastomosis or by chronic ischemia resulting from tension on the gastrojejunostomy [40]. Clinical presentation includes vomiting, bloating, and upper abdominal pain. Obstructive symptoms from strictures at the gastrojejunal anastomosis tend to develop shortly after meals, whereas vomiting associated with a small bowel obstruction may occur 1 h or more later. We identified a single case with gastrojejunal anastomotic strictures which were diagnosed on both

**Table 5** Comparison of UGIS and CT in the detection of sleeve gastrectomy postoperative complications ( $N = 78$ )

Complication	UGIS		CT		Chi-square test	
	No.	%	No.	%	$\chi^2$	$P$ value
1-Liver contusion	0	0.0	1	100.0	0.187	0.665
2-Splenic tear	0	0.0	2	100.0	0.444	0.505
3-Leakage from staple line	14	77.8	18	100.0	2.527	0.112
4-Perigastric collection and hematoma	0	0.0	26	100.0	48.077	< 0.001
5-Gastropancreatic abscess	0	0.0	1	100.0	0.187	< 0.001
6-Gastrobronchial fistula	1	100.0	1	100.0	0.000	1.000
7-Rectus sheath hematoma	0	0.0	2	100.0	0.444	0.505
8-Portomesenteric thrombosis	0	0.0	9	100.0	14.222	< 0.001
9-Mid-gastric sleeve stricture	1	100.0	1	100.0	0.000	1.000
10-Incisional hernia	0	0.0	1	100.0	0.187	0.665
11-Increased size of gastric pouch	9	100.0	9	100.0	0.000	1.000
12-Hiatus hernia	4	100.0	4	100.0	0.000	1.000
13-Gastritis	0	0.0	1	100.0	0.187	0.665
14-S.C. seroma	0	0.0	1	100.0	0.187	0.665
15-Port site hernia	0	0.0	1	100.0	0.187	0.665

This table shows statistically significant difference between UGIS and CT in the detection of perigastric collection and hematoma, gastropancreatic abscess, and portomesenteric thrombosis

upper GIT studies and CT. Intestinal obstruction following RYGB may be the result of internal hernia, adhesions, jejunojejunal anastomotic stricture or rarely intussusception. Blachar et al. [24] believe that the combination of clinical and CT imaging findings may help distinguish the cause of bowel obstruction. Though adhesions are the most common cause of SBO after open Roux-en-Y gastric bypass, internal hernias are the most common cause after the laparoscopic form of surgery [37–39]. Small bowel obstruction resulting from internal hernias tend to appear longer periods after the operation and demonstrate the sign of mushroom aspect of the distended loops, accompanied by rotation of the mesenteric vessels. Internal hernia, intestinal obstruction, and intussusception were only identified on CT.

In patients who underwent LSG, the perigastric and intraperitoneal hematoma were the most common and most life-threatening early complications and required surgical management when the patients were hemodynamically unstable [1, 2]. The second most common early complication was the dehiscence of sutures. Leaks most commonly occurred from the proximal end of the staple line just below the esophagogastric junction, followed by middle then lower thirds. They are usually manifested on UGIS by extravasation of water-soluble contrast material into extraluminal tracks or collections in the left upper quadrant. CT scans demonstrated the site of leakage as well as localized extraluminal collections or abscesses in this region. Two cases of splenic tears and a single case of liver contusion complicated surgery and a single gastro-bronchial fistula and a single rectus sheath hematoma were detected in the early postoperative period. The cases complicated by portomesenteric vascular thrombosis were only diagnosed by CT. Gastric strictures developed when scarring along the greater curvature staple line causes marked narrowing of the pouch. Barium studies revealed focal or long narrowed segments with delayed emptying of barium from the residual stomach.

## Conclusion

In conclusion, CE-MDCT is the imaging modality of choice in the diagnosis of major complications of RYGP and LSG. It can indirectly identify sutures dehiscence or perforation by the presence of pneumoperitoneum or free fluid. Also, the site of leakage can be directly identified by the administration of oral contrast. In patients operated through GBP, the presence of oral contrast in the excluded stomach is usually secondary to reflux and should not be mixed up with collections [2, 8, 11, 32]. In cases of intestinal obstruction and internal hernia, IVCE-MDCT is able to identify the site of obstruction and rules out any associated complications.

## Abbreviations

BMI: Body mass index; GBP: Gastric bypass; LSG: Laparoscopic sleeve gastrectomy; MDCT: Multidetector computed tomography; RYGB: Roux-en-Y gastric bypass; UGIS: Upper gastrointestinal contrast-enhanced study

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## Authors' contributions

RHB provided the main idea and the main design of the work, contributed in the acquisition, analysis, and interpretation of the imaging studies, have drafted the manuscript, revised and approved the submitted version, and agreed to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. NAMC assisted in the collection of the clinical and pathologic data, contributed to the acquisition, analysis, and interpretation of the imaging studies, revised, and approved the submitted version. Both authors have read and approved the final manuscript.

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## Availability of data and materials

All datasets used and/or analyzed during the current study are available in the Radiology Department of El Salam International Hospital (Kuwait).

## Ethics approval and consent to participate

The study was approved by the ethical committee of El Salam International Hospital (Kuwait) in December 2014 (no reference number was given at that time). Written consent for participation in the study was obtained from all patients or relatives of patients.

## Consent for publication

Written informed consent for publication of the study was obtained from the patients themselves.

## Competing interests

Both authors declare that they have no competing interests.

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