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ORIGINAL CONTRIBUTIONS

# Test Characteristics of Abdominal Computed Tomography for the Diagnosis of Gastro-gastric Fistula in Patients with Roux-en-Y Gastric Bypass

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## Abstract

**Introduction** Gastrogastric fistulae (GGF) occur in 1–6% of Roux-en-Y gastric bypass (RYGB) patients. Many patients undergo abdominal computed tomography (CT) as an initial test owing to its wide availability; however, CT diagnostic accuracy for GGF is unclear. Our aim was to evaluate test characteristics of abdominal CT compared to upper gastrointestinal series (UGI) and esophagogastroduodenoscopy (EGD) for diagnosing GGF using surgery as a gold standard.

**Methods** Retrospective review of RYGB patients who underwent abdominal CT with oral contrast within 1 year. Demographics, weight parameters, and symptoms were collected. Surgery within 1 year of the diagnostic tests was included as the gold standard comparison. Primary outcomes included CT sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy (DA) for GGF.

**Results** One hundred thirty-seven patients were included, where 42 (30.1%) had positive CT and 95 (69.3%) had negative CT for GGF. Compared to surgical confirmation, CT abdomen with PO contrast had sensitivity of 73.1% (59–84.4), specificity of 95.2% (88.3–98.7), PPV 90.5% (77.4–97.3), NPV of 85.1% (76.3–91.2), and DA 89.7%. UGI series had sensitivity of 58.5% (42.1–73.7), specificity of 98.8% (93.5–99.9), PPV of 96% (79.7–99.9), NPV of 82.8% (73.9–89.7), and diagnostic accuracy (DA) of 85.4%. EGD had sensitivity of 78.3% (63.6–89.1), specificity of 98.8% (93.5–99.9), PPV 97.3 (85.8–99.9), and DA 91.5%. There were no significant differences in diagnostic test characteristics among modalities.

**Conclusions** Abdominal CT with oral contrast has similar diagnostic test characteristics to UGI and EGD at detecting GGF when using surgical diagnosis as a gold standard.

**Keywords** Gastrogastric fistula · Roux-en-Y gastric bypass · Computed tomography

## Introduction

Roux-en-Y gastric bypass (RYGB) is one of the most common bariatric surgeries performed for obesity in the USA, estimated to be more than 40,000 cases performed in 2018 alone [1]. Despite a proven efficacy of inducing weight loss and resolving obesity-associated comorbidities such as diabetes mellitus [2, 3], complications such as the onset of gastrogastric fistulae (GGF) are common and occur in 1–6% of cases [1, 4–7]. Causative factors include inadequate surgical technique, the presence of foreign bodies, ischemia or marginal ulcer perforation, staple line leaks, and idiopathic or unknown causes [8].

When present, GGF can cause marginal ulceration, contribute to weight recidivism, and may be associated with symptoms including abdominal pain and worsening gastroesophageal reflux disease (GERD) [5, 9, 10] that may prompt diagnostic evaluation. Despite a paucity of data representing their diagnostic accuracy, both esophagogastroduodenoscopy (EGD) and upper gastrointestinal series (UGI) are commonly performed as the gold standard to diagnose GGF [11]. However, these imaging modalities are not often initial diagnostic imaging procedures utilized upon presentation to the emergency department. Contrarily, computed tomography

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(CT) is a commonly performed diagnostic modality in the setting of non-traumatic abdominal pain, occurring in 70 million emergency department visitations annually in the USA alone [12]. The diagnosis of GGF can be suspected on CT scan by the presence of oral contrast in the remnant stomach or relative attenuation differences between the excluded stomach and gastric pouch [13]; however, the diagnostic ability of CT for the diagnosis of GGF, particularly in comparison to UGI and EGD, remains unknown. Furthermore, reference to a surgical diagnosis as the gold standard has not been studied. The aim of this study was to evaluate the test characteristics of abdominal CT with oral contrast for the diagnosis of GGF in patients with RYGB using reference to surgery as the gold standard modality.

## Methods

We performed a retrospective chart review of adult patients with RYGB who underwent surgical revision at our center between April 1, 2006, and March 31, 2020. A large Research Patient Data Registry (RPDR) was used to systematically search for patients using terms "fistula," "gastro-gastric fistula," "bypass," "surgical revision," and "Roux-en-Y" to identify patients with concern for GGF. Patients were included if they had CT abdomen with oral contrast within 1 year preceding surgical revision. Patients were excluded if they did not have a CT of the abdomen with oral contrast performed within 1 year prior to surgery. Details on whether patients also underwent UGI and/or EGD within 1 year prior to surgery were included; however, included patients were not required to have either UGI or EGD during the 1 year prior to surgery. CT scans included a 64-slice scanner with Omnipaque used as the oral contrast agent. Upper GI series was performed using Gastrografin or barium contrast. Upper endoscopy was performed under conscious sedation with fentanyl and midazolam, monitored anesthesia care, or general anesthesia using propofol depending on the patient's age, weight, and associated comorbidities and per the anesthesiologist's discretion. Imaging interpretation was performed by expert abdominal radiologists.

Baseline data were collected for age, sex, pre-RYGB weight, pre-RYGB body mass index (BMI), post-RYGB nadir weight and BMI, weight and BMI at time of CT image, and indications for CT abdomen and surgical revision. GGF were stratified by location, with "high" GGF being identified between the gastric pouch, and excluded stomach and "low" GGF were those identified at the gastrojejunal anastomosis. The primary outcome was the diagnostic test characteristics of CT abdomen with oral contrast at detecting GGF using surgery as a gold standard and included sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy. Secondary outcomes included diagnostic test characteristics for UGI, EGD, and testing combinations within the same population. Mean (standard deviation) and percentages were used to summarize patient characteristics and a Chi-squared test for comparing the test characteristics of the three diagnostic modalities using surgery as the gold standard. Statistical analysis was performed using SAS software, version 9.4 (SAS Institute, NC, USA). The Institutional Review Board approval was obtained for retrospective review of the prospectively collected data used in this study (approval number: 2003P-001597, renewed approval on May 8, 2020).

## Results

A total of 137 patients who met inclusion criteria were identified, of which 8 patients received solely CT abdomen with oral contrast within the 1 year prior to surgery, and the remainder had CT abdomen and an additional test (i.e., UGI or EGD) within 1 year prior to surgery. Among included patients, 42 (30.1%) had the presence of a GGF detected on CT compared to 95 (69.3%) who had a CT negative for GGF (Table 1). Those with a GGF on CT were older (49.7 vs 38.2 years), experienced greater weight regain from their nadir post-RYGB weight (23.5 vs 13.2 kg), and had a higher weight at time of CT scan (100.5 vs 92.6 kg) and higher BMI at CT scan (36.6 vs 34.0 kg/m$^2$). Those with a positive CT abdomen for GGF had a similar pre-bypass weight (139.4 vs 137.4 kg), pre-bypass BMI (50.4 vs 51.8), and post-bypass nadir weight (79.3 vs 79.1 kg) compared to those without GGF on CT. Indications for revisional surgery included abdominal pain (58), weight regain (30), worsening GERD (12), bleeding (2), nausea/vomiting (15), ulcer (16), and others (3).

Indications for CT abdomen included abdominal pain (92), weight regain (7), confirm the presence of a previously detected GGF (2), worsening GERD (3), bleeding (2), and nausea/vomiting (24). Among GGF diagnosed on CT, 30 (71.4%) were high GGF compared to 12 (28.6%) low, and among surgical GGF identified, 38 (71.7%) were high compared to 15 (28.3%) low. There was a total of 14 GGFs identified on surgery that were not detected on CT within 1 year prior, of which 9 (63.2%) were high and 5 (28.6%) were low. In reference to the gold standard diagnostic test for GGF being surgery, CT abdomen and surgery agreed with the presence of GGF in 38 (27.9%) and the absence of GGF in 80 (58.8%) of patients, corresponding to a CT diagnostic sensitivity of 73.1% (59.0 – 84.4%) and specificity of 95.2% (88.3 – 98.7%) for detecting GGF. PPV, NPV, and DA were 90.5% (77.4–97.3%), 85.1% (76.3–91.2%), and 89.7%, respectively. There were a total of 4 cases where CT abdomen was falsely positive and 14 cases where CT was falsely negative for GGF in comparison to surgery, corresponding to false-positive and false-negative rates of 2.9% and 10.3%, respectively. Among

**Table 1** Baseline patient characteristics at time of computed tomography scan

| Characteristics | CT negative for GGF (*n*=95) | CT positive for GGF (*n*=42) |
|---|---|---|
| Sex (female)—*n* (%) | 73 (80.2) | 37 (88.1) |
| Age (years) | 38.2 (26.6) | 49.7 (11.2) |
| Pre-RYGB weight (kg) | 139.4 (30.8) | 137.4 (38.0) |
| Pre-bypass BMI (kg/m$^2$) | 51.8 (11.9) | 50.4 (11.3) |
| History of GGF surgical repair—*n* (%) | 20 (22.7) | 10 (23.8) |
| History of GGF endo repair—*n* (%) | 4 (4.6) | 2 (4.8) |
| Nadir weight (kg) | 79.3 (22.5) | 79.1 (28.7) |
| Nadir BMI (kg/m$^2$) | 29.1 (8.2) | 28.8 (9.5) |
| Weight regain from nadir (kg) | 23.5 (13.7) | 13.2 (22.8) |
| Weight at GGF (kg) | 100.5 (27.1) | 92.6 (38.1) |
| BMI at GGF (kg/m$^2$) | 34.0 (10.5) | 36.6 (12.2) |
| Indication for CT—*n* (%) | | |
| Abdominal pain | 65 (58.4) | 27 (64.3) |
| Weight regain | 0 | 7 (5.1) |
| GERD | 2 (2.1) | 2 (4.8) |
| Gastrointestinal bleeding | 1 (1.1) | 2 (4.8) |
| Nausea/vomiting | 20 (21.1) | 4 (9.5) |
| Ulcer | 2 (2.1) | 0 |
| Other | 5 (5.3) | 0 |
| Indication for surgery—*n* (%) | | |
| Abdominal pain | 43 (45.3) | 15 (35.7) |
| Weight regain | 19 (20) | 11 (26.2) |
| GERD | 7 (7.4) | 5 (11.9) |
| Gastrointestinal bleeding | 2 (2.1) | 0 |
| Nausea/vomiting | 14 (14.7) | 1 (2.4) |
| Ulcer | 8 (8.4) | 9 (21.4) |
| Other | 2 (2.1) | 1 (2.4) |

Baseline demographics stratified by computed tomography scan detection of gastro-gastric fistula. Presented as mean (standard deviation). *CT* computed tomography, *RYGB* Roux-en-Y gastric bypass, *BMI* body mass index, *GGF* gastro-gastric fistula, *GERD* gastroesophageal reflux disease

high GGF, CT indications included abdominal pain (*n*=17; 56.7%), weight regain (*n*=7; 23.3%), confirmation of previously detected GGF (*n*=1; 3.3%), GERD (*n*=2; 6.7%), and nausea/vomiting (*n*=3; 10%). Among low GGF, CT indications included abdominal pain (*n*=10; 83.3%), bleeding (*n*=1; 8.3%), and nausea/vomiting (*n*=1; 8.3%). When stratifying by surgical GGF location, CT abdomen identified 29 (76.3%) of high GGF determined by surgery and 9 (64.3%) of low GGF determined by surgery. There were no false-positive CT diagnoses of high GGF; however, there was 1 false-positive CT diagnosis of low GGF. CT test performance was not significantly different when stratifying by GGF location (*p*=1.0).

When comparing UGI to the gold standard measurement of surgery, there were a total of 124 patients that received an UGI within 1 year of surgery, of which 41 (33.1%) were diagnosed with a GGF at the time of surgery (Table 2). Indications for UGI included abdominal pain (9), weight regain (3), confirm the presence of a previously detected GGF (40), worsening GERD (3), nausea/vomiting (13), ulcer (1), and others (36). UGI and surgery agreed with the presence of GGF in 24 (19.4%) and the absence of GGF in 82 (66.1%) of patients, corresponding to a UGI diagnostic sensitivity of 58.5% (42.1–73.7%), specificity of 98.8% (93.5–99.9%), PPV of 96% (79.7–99.9%), NPV of 82.8% (73.9–89.7%), and DA of 85.4%. There was 1 case where the UGI was falsely positive and 17 cases where the UGI was falsely negative for GGF in comparison to surgery, corresponding to false-positive and false-negative rates of 0.8% and 13.7%, respectively.

When comparing EGD to the gold standard measurement of surgery, there were a total of 129 patients that received an EGD within 1 year of surgery, of which 46 (35.7%) were diagnosed with a GGF at the time of surgery. Indications for EGD included abdominal pain (51), weight regain (16), confirm the presence of a previously detected GGF (15), worsening GERD (2), bleeding (7), nausea/vomiting (8), ulcer (5), and others (24). EGD and surgery agreed with the presence of GGF in 36 (27.9%) and the absence of GGF in 82 (63.6%) of patients, corresponding to an EGD diagnostic sensitivity of

**Table 2** Diagnostic measurements of accuracy for CT abdomen/pelvis with oral contrast in comparison to upper gastrointestinal series and esophagogastroduodenoscopy in those who underwent surgery within 1 year

| Test characteristic | Upper gastrointestinal series ($n$ = 124) | EGD ($n$=129) | Computed tomography abdomen ($n$ = 137) | $p$ value |
|---|---|---|---|---|
| Sensitivity | 58.5 (42.1–73.7) | 78.3 (63.6–89.1) | 73.1 (59–84.4) | 0.72 |
| Specificity | 98.8 (93.5–99.9) | 98.8 (93.5–99.9) | 95.2 (88.3–98.7) | 0.22 |
| Positive predictive value | 96 (79.7–99.9) | 97.3 (85.8–99.9) | 90.5 (77.4–97.3) | 0.39 |
| Negative predictive value | 82.8 (73.9–89.7) | 89.2 (80.1–95.5) | 85.1 (76.3–91.2) | 0.46 |
| Diagnostic accuracy | 85.4 | 91.5 | 89.7 | 0.30 |

*EGD* Esophagogastroduodenoscopy

78.3% (63.6–89.1%), specificity 98.8% (93.5–99.9%), PPV of 97.3% (85.8–99.9%), NPV of 89.2% (80.1–94.5%), and DA 91.5%. There was 1 case where the EGD was falsely positive and 10 cases where the EGD was falsely negative for GGF in comparison to surgery, corresponding to false-positive and false-negative rates of 0.8% and 7.8%, respectively.

When comparing CT abdomen to UGI at detecting GGF, there were a total of 281 patients that received both CT abdomen and UGI, of which 32 (11.4%) had a positive CT abdomen and negative UGI and 19 (6.8%) had a negative CT abdomen/pelvis and positive UGI. This corresponded to an odds ratio (OR) of 1.68 ($p$=0.14), indicating that these patients were 1.68 times more likely to have a positive GGF on CT compared to UGI, although this was not a significant difference. When comparing CT abdomen to EGD at detecting GGF, there were a total of 288 patients that received both a CT abdomen and EGD, of which 30 (10.4%) had a positive CT abdomen and negative EGD and 15 (5.2%) had a negative CT abdomen and positive EGD. This corresponded to an OR of 2.0 ($p$=0.05), indicating that these patients were 2.0 times more likely to have a GGF detected on CT compared to EGD, although this was not a significant difference.

Test performance of combined modalities is demonstrated in Table 3. Testing characteristics were similar between CT+UGI, CT+EGD, UGI+EGD, and CT+UGI+EGD, with the combination of UGI+EGD trending toward the most accurate.

## Discussion

The present study demonstrates that CT of the abdomen with oral contrast administration can serve as a reliable modality to detect GGF in the RYGB population and has similar test characteristics to more traditional diagnostic modalities including UGI series and EGD. Subsequently, if considered early during the presentation of symptoms including abdominal pain or worsening gastroesophageal reflux disease may reveal an earlier diagnosis of GGF and obviate the need for additional imaging studies or procedures. This was supported with note that test characteristics were not improved with additional testing using UGI and/or EGD. Although intuitively additional testing with UGI and EGD should improve the ability to detect a GGF, this was not seen in the present study.

Two types of GGF were identified, including the presence of exclusively gastro-gastric fistula (“high”) and gastro-jejuno-gastric fistula (“low”; at gastrojejunal anastomosis). The most common indication for CT abdomen within both groups was abdominal pain (56.7% and 83.3%, respectively). The higher proportion within the low GGF group is consistent with complications associated with low GGF, including marginal ulceration and GJA stenosis. Contrarily, indications of weight regain and worsening reflux were exclusively seen within the high GGF group, which are known to be associated with pouch dilation [4] and permit reflux of gastric acid produced within the gastric remnant.

**Table 3** Diagnostic measurements of accuracy of abdominal computed tomography stratified by indication

| CT indication | Sensitivity | Specificity | Positive predictive value | Negative predictive value | Accuracy |
|---|---|---|---|---|---|
| CT + UGI | 76.2 (63.3–79.1) | 95.2 (90.1–99.8) | 88.9 (0.79–99.2) | 88.8 (82.2–95.3) | 88.9 |
| CT + EGD | 78.7 (67.0–90.4) | 95.2 (90.6–99.8) | 90.2 (81.1–99.3) | 88.8 (82.2–95.3) | 89.2 |
| UGI + EGD | 75.7 (61.9–89.5) | 98.8 (96.5–100) | 96.5 (89.9–100) | 90.1 (84.0–96.2) | 91.7 |
| CT + UGI + EGD | 75.7 (61.9–89.6) | 95.2 (90.6–99.8) | 87.5 (76.0–99.0) | 89.8 (83.4–96.1) | 89.2 |

Test performance of combined modalities. A positive result in any of the modalities within each row yielded a “positive” diagnosis of gastrogastric fistula, which was compared to surgical diagnosis to measure combined test performance. *CT* computed tomography, *UGI* upper gastrointestinal series, *EGD* esophagogastroduodenoscopy

Notably, the prevalence of GGF in the present study (30.7%) was higher than overall prevalence cited in the literature of 1–6% [1, 4, 6], which is thought to be due to GGF being a primary indication for surgical revision at our two institutions. Given that prevalence impacts the PPV and NPV, the reported PPV is likely higher (and similarly, NPV lower) than the overall population; however, sensitivity and specificity are intrinsic to the test itself and are minimally affected by prevalence, if at all [14]. This should be considered when generalizing to broader populations.

The present study provides novelty in evaluating the test performance for CT abdomen with oral contrast in detecting GGF, which has only been evaluated in a single prior study. Prior evaluation of the CT abdomen's performance at diagnosing GGF has shown it to be a reliable modality when comparing relative attenuation ratios (through measurement of Hounsfield units) between the excluded stomach and gastric pouch. However, this one prior study evaluating the CT abdomen's ability to diagnose GGF was limited in size (13 CT scans on 12 patients) and compared CT to the UGI series as the gold standard [13]. Specifically, when optimizing the relative attenuation ratio (0.8) on CT through receiver operating curve analysis, the sensitivity was shown to be 58.3%, specificity 100%, PPV 85.7%, NPV 100%, and accuracy of 92.3%. Our study demonstrates similar test characteristics for the CT abdomen's ability to diagnose a GGF, aside from a lower negative predictive value. Additionally, our study is the first to reference surgery as a gold standard comparison. When comparing to surgery, we demonstrated that both CT and UGI performed similarly in reference to surgery, for which CT test characteristics may be inflated when compared to UGI as the gold standard (as performed in the prior study), which itself demonstrated a modest NPV of 82.8% in our study.

Furthermore, there remain no studies that have assessed CT test characteristics with reference to surgery as a gold standard, while simultaneously comparing UGI and EGD modalities within the same population. There remains a paucity of data describing either the UGI or EGD's diagnostic accuracy at detecting GGF, despite commonly used as a gold standard [11, 15]. When referencing surgery as the gold standard in our study, the CT is performed similarly at both excluding and detecting the presence of a GGF compared to the historical gold standards of UGI series and EGD. This is an important finding as CT is a common early imaging modality in the setting of symptoms including abdominal pain or GERD, and utilization of oral contrast may obviate the need for additional imaging studies or diagnostic procedures.

There are limitations to the present study that should be noted. First, this is a retrospective analysis at a large multicenter institution, and prospective evaluation should be performed to validate the reported test characteristics. Second, data on fistula size were unavailable, and this could be a consideration for further studies, as the presence of smaller fistulae may induce an increased prevalence of false negatives on CT imaging. Additionally, the indication for CT abdomen in the present study varied and not always obtained for the clinical question of GGF presence; however, this remains consistent with clinical practice when CT abdomen is obtained to evaluate vague, overlapping symptoms with multiple potential etiologies. Despite these limitations, notable strengths of this study include the large patient population and comparison to surgery as a gold standard.

In conclusion, CT of the abdomen with oral contrast is a reliable initial diagnostic modality for detecting and excluding the presence of a gastro-gastric fistula following Roux-en-Y gastric bypass and has similar test characteristics to prior gold standard modalities of upper gastrointestinal series and esophagogastroduodenoscopy. Early utilization of oral contrast during CT imaging may obviate the need for additional diagnostic procedures seeking a diagnosis of GGF.

## Declarations

**Ethics Approval and Consent to Participate** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required. Informed consent does not apply.

**Conflict of Interest** Russell D. Dolan, MD: No conflicts of interest to report.

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