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CT of Gastric Volvulus: Interobserver Reliability, Radiologists' Accuracy, and Imaging Findings

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Abstract

OBJECTIVE.—The objective of this study was to identify CT findings and determine interobserver reliability of surgically proven gastric volvulus.

MATERIALS AND METHODS.—This single-center retrospective study included 30 patients (21 women, nine men; mean age, 73 years old) with surgically proven gastric volvulus who underwent preoperative CT and 31 age- and sex-matched control subjects (21 women, nine men; mean age, 74 years old) with large hiatal hernias who were imaged for reasons other than abdominal pain. Two blinded radiologists reviewed the CT images and recorded findings of organoaxial and mesenteroaxial gastric volvulus and ischemia. Interobserver reliability, reader accuracy, sensitivity, specificity, and likelihood ratios of each CT finding were calculated.

RESULTS.—The radiologists were overall 90% accurate (55/61; six false-negatives per reader) in identifying gastric volvulus. Interobserver agreement was substantial ($\kappa = 0.71$) for identifying the presence or absence of gastric volvulus. Agreement for most CT findings of gastric volvulus (11/14, 79%) was excellent (5/14, 36%) or substantial (6/14, 43%); the remaining findings showed moderate agreement (3/14, 21%). The most frequent and sensitive CT findings of volvulus with high positive likelihood ratios were stenosis at the hernia neck (reader 1, sensitivity = 80%, positive likelihood ratio = 26.66; reader 2, sensitivity = 77%, positive likelihood ratio = 12.83) and transition point at the pylorus (reader 1, sensitivity = 80%, positive likelihood ratio = 17; reader 2, sensitivity = 70%, positive likelihood ratio = 15). The presence of perigastric fluid or a pleural effusion were significantly more frequent in patients with ischemia at surgical pathology ($p < 0.05$ in all comparisons, both radiologists).

CONCLUSION.—In our series, CT showed substantial interobserver agreement and fair accuracy in identifying the presence of gastric volvulus.

Keywords

CT; hiatal hernia; stomach; volvulus

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Gastric volvulus refers to at least 180° rotation of the stomach and leads to gastric outlet obstruction, impairment of vascularity, and eventually ischemia [1]. It is a rare condition with unknown exact incidence or prevalence. Although 70% of patients present with the Borchardt triad, a combination of severe epigastric pain, retching, and inability to pass a nasogastric tube, the clinical presentation may not be classic [2]. Alternatively, patients with chronic or intermittent gastric volvulus may present with intermittent abdominal or chest pain, dysphagia, bloating, and heartburn. Diagnosis based on physical examination findings and symptoms alone is difficult, and the nonspecific clinical presentation typically prompts further evaluation with imaging. A delay in diagnosis can lead to life-threatening complications such as bowel ischemia and infarction and in some cases may be fatal.

An upper gastrointestinal series can be helpful in assessing the rotation of the stomach and passage of ingested oral contrast material into the duodenum [3, 4]. However, the procedure is not usually performed as an initial imaging examination in patients with gastric volvulus because symptoms may be vague and because the rarity of the diagnosis means it is often not clinically suspected [3, 5]. Instead, many patients, particularly those with acute abdominal pain, will undergo CT on which findings of gastric volvulus may be identified. Because of its rarity and the overlap in appearance with large hiatal hernias, gastric volvulus remains a challenging condition to diagnose with CT. Acute gastric volvulus may lead to gangrene in 5–28% of patients, so missing or delaying an appropriate diagnosis can have grave consequences [5]. Described CT findings of gastric volvulus stem from case reports and small case series [4, 6–9]. The largest study to date to evaluate the sensitivity and specificity of several CT findings of gastric volvulus was performed by Millet et al. [10] and included 10 patients with surgically confirmed gastric volvulus and 20 control subjects with gastric distention. To our knowledge, no study has evaluated the CT findings of gastric volvulus and compared them with a population of patients with asymptomatic large hiatal hernias. In our experience, this distinction can be difficult; radiologists can both over- and underdiagnose gastric volvulus on CT.

Therefore, the purpose of our study was to examine the frequency, diagnostic sensitivity, and specificity of CT findings of gastric volvulus and to determine interobserver reliability of each CT finding in patients with surgically proven gastric volvulus as a measure of their applicability in common practice.

Materials and Methods

Study Population and Image Acquisition

Our institutional review board approved this retrospective study, which was conducted in accordance with HIPAA. A waiver was granted for the need to obtain informed consent. This single-center retrospective study queried patients from 2008 through 2016 diagnosed with gastric volvulus who underwent CT and had surgical confirmation of the diagnosis. Control subjects were selected from patients with large hiatal hernias who were imaged over the same time period for reasons other than abdominal pain.

The search terms “gastric volvulus” and “large hiatal hernia” were queried in our radiology information search system to identify the patient cohort. From this initial query, patient

records were reviewed to identify patients with gastric volvulus, which, in accordance to previous classifications, we defined as at least 180° rotation of the stomach leading to gastric outlet obstruction [11]. All included patients were confirmed at surgery to have volvulus and obstruction. Although endoscopic decompression may be performed to manage gastric volvulus without surgery, we considered having the reference standard of surgery to be more important than adding what is likely a small number of cases to our dataset. Therefore, patients with only endoscopic treatment were not included in our study. Medical charts were reviewed for demographic data; presenting symptoms; endoscopic, surgical, and pathologic results; final diagnosis; and clinical outcome. The operative and surgical pathology reports were catalogued and categorized as having presence or absence of volvulus (those without volvulus were excluded) and presence of gangrene or necrosis.

For control subjects, images were reviewed by a second-year radiology resident with confirmation by an attending abdominal radiologist of the presence of a large hiatal hernia, defined as 50% or more of the stomach herniated above the diaphragm. The records of control subjects were reviewed to ensure that no admission or intervention for gastric volvulus had occurred within 30 days of the reviewed CT.

Image Analysis

After the eligible study population was identified, all CT examinations for patients and control subjects were electronically placed in a designated study folder within the PACS and listed in random order for image interpretation. CT was performed on 16- to 128-MDCT scanners with axial slice thickness of either 3 or 5 mm. Because of the long study period over which cases were collected, the timing of contrast material administration and protocol varied, but the most commonly used protocol was a routine portal venous phase protocol. Reviewers could view images in the coronal and sagittal planes. Two board-certified, fellowship-trained radiologists who subspecialized in body CT (with 4 years and 1 year of postfellowship experience), who were blinded to all clinical data and diagnosis, independently reviewed the images. Readers knew that the study population was a mix of patients with surgically proven gastric volvulus and control subjects with large hiatal hernias without gastric volvulus, but they were unaware of all other data including the proportion of patients with gastric volvulus compared with control subjects. Readers were asked to identify if gastric volvulus was present or absent and classify it as either organoaxial (Fig. 1), mesenteroaxial (Fig. 2), or mixed type gastric volvulus. Table 1 provides definitions of each type of gastric volvulus and their imaging features.

Each radiologist assessed seven CT features related to the morphology of organoaxial and mesenteroaxial gastric volvulus: unsuccessful passage of the nasogastric tube, severe gastric distention, transition point at the pylorus, antrum seen in the left hemithorax, antropyloric junction above the gastrointestinal junction, greater curvature superior and to the right of the lesser curvature, and stenosis at the hernia neck. In addition, each assessed seven CT findings related to ischemia as a result of volvulus: perigastric fluid, gastric wall hypoenhancement, pneumatosis, gastric wall edema, celiac occlusion, pneumoperitoneum, and pleural effusion. Features and findings were recorded independently by each radiologist (Table 2).

Before conducting the image analysis, each reader completed a self-guided tutorial prepared by one of the authors that contained CT images and descriptions of each of the findings selected for analysis in this study. Images in the tutorial were compiled directly from the literature and did not include images from the study cases. The investigators were then asked to review each of the CT examinations in a blinded fashion to assess the presence or absence of each CT finding. Investigators manually recorded the findings on separate data sheets that were compiled for analysis.

Statistical Analysis

The sensitivity and specificity for each CT finding were calculated using two-way contingency tables. Statistical analysis was performed independently on data from each investigator, and overall sensitivity and specificity for each finding was reported as a range from lowest to highest computed values across both investigators. Interobserver agreement regarding the presence or absence of each of the 14 analyzed CT features and findings in this study was calculated as a series of Cohen kappa values. The strength of agreement between observers was interpreted from these values according to guidelines established by Landis and Koch [12]. CT findings of ischemia along with time from CT examination to start of surgery were compared in patients with ($n = 8$) and without ($n = 22$) ischemia at surgical pathology. Descriptive statistics were used to summarize the data and a D'Agostino-Pearson test was used to determine normality. Characteristics between patients and CT findings were compared using two-tailed chi-square, Fisher test, or Mann-Whitney U test as appropriate. Fisher test and mean were used for data that followed a normal distribution and Mann-Whitney U test and median were used for data that did not have a gaussian distribution.

The recorded CT findings in the independent review were used to determine interobserver variability. Interobserver reliability, reader accuracy, sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio of each CT finding were calculated. Cohen kappa values were calculated for the interobserver portion with values of 0.4–0.6, 0.61–0.8, and > 0.8 considered moderate, substantial, and excellent, respectively.

Results

Study Population

The 30 patients with surgically proven gastric volvulus (21 women, nine men; mean age, 73 years old; age range, 57–90 years old) were age- and sex-matched ($p = 0.90$ and $p = 1.00$, respectively) with 31 control subjects with large hiatal hernias but no symptoms of gastric volvulus (21 women, nine men; mean age, 74 years old; age range, 50–90 years old). Findings on the clinical surgical pathology report included confirmation of volvulus for all 30 patients (100%; basis of inclusion criteria) and eight patients with gangrene, necrosis, or both.

CT Findings of Volvulus

Table 2 summarizes the frequency of CT findings and interobserver agreement. The radiologists were 90% accurate (55/61 with six misclassifications of gastric volvulus as a hiatal hernia for each reader) overall and 80% (24/30) accurate in identifying gastric

volvulus; for the six misses for each reader, only one patient was in common. No control subject was incorrectly identified as having volvulus. Interobserver agreement was substantial ($\kappa = 0.71$) for identifying the presence or absence of gastric volvulus and moderate ($\kappa = 0.51$) when distinguishing the type of gastric volvulus. Most CT features of gastric volvulus studied (11/14, 79%) showed excellent (5/14, 36%) or substantial (6/14, 43%) agreement, whereas the remaining three showed moderate agreement (3/14, 21%). The most frequent and sensitive direct CT findings of volvulus were stenosis at the hernia neck (reader 1, sensitivity = 80% [24/30], specificity = 97% [30/31]; reader 2, sensitivity = 77% [23/30], specificity = 94% [29/31]) and transition point at the pylorus (reader 1, sensitivity = 80% [24/30], specificity = 100% [31/31]; reader 2, sensitivity = 70% [21/30], specificity = 100% [31/31]).

The calculated positive likelihood ratios for several CT findings, including stenosis at the hernia neck and transition point at the pylorus were high (12.8–26.6), which is reflective of the high specificities. Stenosis at the hernia neck and transition point at the pylorus also had low negative likelihood ratios (0.21–0.24).

CT Findings of Ischemia

CT findings of gastric ischemia were uncommon in our series (seen in 1–14 patients for all CT findings) and insensitive but highly specific with near complete agreement. The most frequent CT finding of ischemia was perigastric fluid (reader 1 = 9/30; reader 2 = 14/30). Gastric ischemia was seen in eight cases at surgery. CT findings that were significantly more frequent in the eight patients with ischemia at surgical pathology included gastric wall edema (reader 2 only) and perigastric fluid with a pleural effusion (both reader 1 and reader 2) (Table 3). We found no significant difference in median time from CT examination to surgery for patients without ischemia (14.8 h) compared with patients with ischemia (11.3 h) (Mann-Whitney *U* test, $p = 0.22$).

Discussion

Acute gastric volvulus is a surgical emergency with high morbidity and mortality. The diagnosis of gastric volvulus is difficult to make clinically because symptoms are nonspecific, so imaging is performed to aid in diagnosis. For this reason, radiologists must be familiar with diagnostically useful CT findings of gastric volvulus to enable early detection and reduce morbidity and mortality in this patient population. Few CT findings of gastric volvulus have been described [7–10]. To our knowledge, no large cohort analysis of interobserver agreement in establishing the presence or absence of these CT findings has been conducted, thus calling into question their applicability in common practice. The only other interobserver analysis of CT findings of gastric volvulus was performed with 10 cases of gastric volvulus compared with control cases of gastric distention from other causes, limiting the conclusions drawn from the data [10]. Gastric volvulus most commonly occurs in the setting of a hiatal or diaphragmatic hernia. In our clinical experience, radiologists have difficulty distinguishing between asymptomatic, large hiatal hernias and gastric volvulus on CT, in some cases using these terms synonymously. Distinguishing between these two

similar-appearing but clinically disparate entities is both critically important and poorly understood.

The largest study in the literature that used CT for the diagnosis of gastric volvulus was a retrospective study with a cohort of 26 patients by Light et al. [13]. They did not report individual CT findings or imaging criteria for diagnosis. In that study, 26 of 36 patients underwent CT and Light et al. reported that CT was diagnostic in all 26 patients, although it is unclear how many patients who underwent CT had surgical confirmation. Twenty-eight of 36 total patients underwent surgical repair, and the remaining eight were managed conservatively. The study was primarily a surgical and clinical cohort; the authors did not report individual CT findings or the CT criteria used to diagnose gastric volvulus. Nevertheless, they advocate the use of CT in the diagnosis of gastric volvulus. In their series, CT had better sensitivity (diagnostic in 100% [26/26 patients]) than both direct endoscopic visualization (diagnostic in 45% [9/20 patients]) or fluoroscopic studies with oral contrast medium (performed in four patients; diagnostic in 50% [2/4]).

Millet et al. [10] evaluated CT findings of gastric volvulus by comparing a group of 10 surgically proven gastric volvulus patients with 20 control subjects who were found to have gastric distention on CT without intestinal distention and who received diagnoses other than gastric volvulus. They found the combination of the antrum at the same level or cranial to the fundus and transition point at the pylorus to have 100% sensitivity and specificity for the diagnosis of gastric volvulus. Interobserver agreement on reversal of position of the greater and lesser curvatures was low. However, the study size was small, and control cases were heterogeneous with very few hiatal hernias. These characteristics are relevant because we have observed that most errors interpreting CT in this setting occur because of a failure to distinguish gastric volvulus from large, asymptomatic hiatal hernias, including both falsepositive and false-negative diagnoses.

In our study, we determined the sensitivity, specificity, interobserver reliability, and positive and negative likelihood ratios of 14 different CT findings seen in patients with gastric volvulus. We have found CT to be highly sensitive and specific for the diagnosis of gastric volvulus with an overall accuracy of 90%. All studied CT findings showed high specificity (90–100%) with a wide range of sensitivities (0–80%). The results of the current study indicate that the transition point at the pylorus is the most sensitive (70–80%) and specific (100%) overall CT finding for the diagnosis of gastric volvulus with substantial interobserver agreement, and this result is concordant with published work [10]. In addition, this CT finding had the highest interobserver agreement among the direct CT findings of gastric volvulus in the current study. These observations indicate that the transition point at the pylorus is relatively easy to identify and, therefore, is diagnostically useful if applied in common practice. Stenosis at the hernia neck is the CT finding with the second highest sensitivity (77–80%) and specificity (94–97%). This finding was particularly valuable in our study because our control subjects all had large hiatal hernias. Transition point at the pylorus and stenosis at the hernia neck both had high positive and low negative likelihood ratios. Thus, the presence of these findings in CT images highly increases and their absence substantially decreases the posttest probability of having gastric volvulus.

CT findings related to the organoaxial or mesenteroaxial positioning of the stomach, such as greater curvature superior and to the right of the lesser curvature (seen in organoaxial volvulus) or antropylic junction above the gastroesophageal junction (seen in mesenteroaxial volvulus) were found to have low sensitivities (33–47%) and moderate and substantial interobserver reliability, respectively. This outcome highlights the observation that organoaxial and mesenteroaxial positioning of the stomach can be difficult to ascertain, with many cases having a mixed presentation. Also, patients with no symptoms may have abnormal positioning of their stomach within a large hiatal hernia without having gastric volvulus.

CT findings of overt ischemia including gastric wall edema, poor gastric wall enhancement, perigastric fluid, pneumatosis, pleural effusion, and pneumoperitoneum (Fig. 3) were uncommonly seen in our study and, though insensitive, were highly specific for volvulus with near complete agreement. Among these findings of ischemia, perigastric fluid and pleural effusion had the highest sensitivities (30–47% and 27–37%, respectively) for gastric volvulus. Gastric wall edema (reader 1, five patients; reader 2, nine patients), perigastric fluid (reader 1, nine patients; reader 2, 13 patients) and pleural effusion (reader 1, eight patients; reader 2, 11 patients) were the most frequently identified findings of ischemia in the 30 patients with gastric volvulus. The low, variable sensitivity data for individual CT signs supports our experience in clinical practice, namely that although the CT findings described in the literature are highly specific for gastric volvulus, they may be insensitive, particularly in patients with large hiatal hernias.

CT is not only the first study performed in many patients with gastric volvulus but also the preferred modality for evaluation of complications such as ischemia and perforation, which are reported in 5–28% of cases with a mortality rate up to 50%, emphasizing the importance of early diagnosis and treatment [14, 15]. In our series, perigastric fluid and presence of a pleural effusion were significantly more frequent in patients with ischemia at surgical pathology, underscoring the need to observe these findings on CT when gastric volvulus is suspected.

This study has several limitations. The first is the retrospective nature of the analysis. Second, the small sample size may limit the observations and conclusions drawn from the data. The size was due to the rarity of gastric volvulus, which also affects the available literature that is based on limited experience with the associated imaging findings. This study is the largest series to our knowledge for the evaluation of CT findings of gastric volvulus, with the largest previously published imaging study having 10 cases [10]. Future studies could include multiple institutions to increase the number of patients with surgically proven gastric volvulus. Third, we only included surgically proven cases of gastric volvulus, which might have introduced a selection bias toward more severe cases. Patients who were only managed conservatively or endoscopically or who had surgery without CT were excluded, but the current study was specifically designed to evaluate the degree of association of each of the analyzed CT findings with gastric volvulus in cases with surgical confirmation. We consider surgical exploration to be the only reference standard test to effectively include or exclude the presence of gastric volvulus. The distinction between organoaxial and mesenteroaxial volvulus, though evaluated on CT by the readers as part of

this study, was not confirmed at surgery, because the distinction can be challenging intraoperatively and was not discussed in most surgical reports. Fourth, although all control subjects were without abdominal symptoms at the time of imaging and had no admission or intervention in the 30 days after their imaging, it is possible, though very unlikely, that they had admissions or interventions for gastric volvulus in that time period at outside institutions that could not be accounted for in this study.

In conclusion, we report the performance of CT in distinguishing between gastric volvulus and hiatal hernia. CT findings of gastric volvulus are reproducible with substantial to excellent interobserver reliability in nearly all CT findings. In patients with gastric volvulus, CT findings of transition point of the pylorus and stenosis at the hernia neck were among the two most frequent findings for both readers with high positive likelihood ratios, high specificity, and moderate interreader agreement. The presence of perigastric fluid and a pleural effusion were less frequent in our overall cohort but were significantly more frequent in patients with ischemic change from gastric volvulus at surgical pathology. These findings may be useful to radiologists in distinguishing gastric volvulus from large hiatal hernias.

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Fig. 1— 76-year-old man with nausea and vomiting.

A, Coronal contrast-enhanced CT image shows intrathoracic stomach with greater curvature (GC) superior and to right of left curvature (LC) with associated gastric distention, findings seen in organoaxial volvulus.

B, Coronal contrast-enhanced CT image shows stenosis at hernia neck (*arrow*). Patient was found to have gastric obstruction and volvulus at time of surgery.

Fig. 2— 69-year-old woman with epigastric pain, vomiting, and WBC count of $20,000 \times 10^9/L$. **A** and **B**, Coronal (**A**) and axial (**B**) contrast-enhanced CT images show antropyloric junction (APJ), superior and anterior to gastroesophageal junction (GEJ), feature seen in mesenteroaxial volvulus. Transition point at APJ is marked by arrow in **A**. Small amount of perigastric fluid is also seen (*arrow*, **B**). **C**, Axial contrast-enhanced CT image shows gastric distention with air-fluid levels (*arrows*) with decompressed duodenum (**D**).

Fig. 3— 67-year-old man with 3 days history of coffee ground emesis.

A and B, Coronal (**A**) and axial (**B**) contrast-enhanced CT images show vertical lie of stomach with antropyloric junction (APJ) superior to gastroesophageal junction (GEJ), CT findings seen in mesenteroaxial gastric volvulus. There is gastric wall hypoenhancement (*solid arrow, B*), gastric wall pneumatosis (*dashed arrow*), perigastric fluid (*asterisk, B*) and portal venous gas. Gastric mucosal necrosis was confirmed at endoscopy and surgery.

TABLE 1:**Gastric Volvulus Subtypes, Definitions, and CT Features**

Volvulus Subtype	Definition	CT Features
Organoaxial	Rotation of stomach along its long axis passing through the gastroesophageal junction and pylorus resulting in gastric obstruction; most common subtype (approximately two-thirds of all cases); associated with paraesophageal hernia and diaphragmatic hernia [4]	Inverted stomach has a horizontal lie, greater curvature lies superior to the lesser curvature
Mesenteroaxial	Rotation of stomach along its short axis, perpendicular to the long axis	Stomach has a vertical lie, antropylooric junction is displaced above the gastroesophageal junction
Mixed	Combination of rotations in both the long and short axes	Combination of findings for organoaxial and mesenteroaxial subtypes

TABLE 2:
Interobserver Reliability, Incidence, Sensitivity, Specificity, and Likelihood Ratios of CT Findings in Patients With Gastric Volvulus

CT Finding	κ	Frequency						Sensitivity (%)				Specificity (%)				PLR				NLR	
		Volvulus Group (n = 30)			Control Group (n = 31)			R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2		
		R1	R2		R1	R2															
Volvulus type	0.51																				
Type																					
Organoaxial		14	14	0	0	0												17.00 ^b	17.00 ^b	0.24 ^b	
Mesenteroaxial		8	9	0	0	0															
Mixed		2	1	0	0	0															
Not identified as volvulus		6	6	0	0	0															
Presence of volvulus	0.71							80 ^a	80 ^a	100 ^a	100 ^a										
Nasogastric tube location	0.87			0						100	100										
In esophagus		1	3					3	10									1.6 ^b	3.0 ^b	0.97 ^b	
In stomach		6	7			3		20	23									5.0 ^b	5.6 ^b	0.80 ^b	
Not present		23	20																		
Severe gastric distention	0.58	22 (73)	15 (50)	1 (3)	1 (3)			70	40	94	94							11.66	6.66	0.32	
Transition point at the pylorus	0.64	24 (80)	21 (70)	0	0	0		80	70	100	100							17.00 ^b	15.00 ^b	0.24 ^b	
Antrum in the left hemithorax	0.61	19 (63)	13 (43)	0	0	2 (6)		63	37	100	94							13.6 ^b	6.16	0.40 ^b	
API above the GEJ	0.61	13 (43)	24 (80)	0	0	0		43	43	100	94							9.6 ^b	7.16	0.59 ^b	
GC superior and right of the LC	0.57	10 (33)	14 (47)	0	0	1 (3)		33	47	100	97							7.6 ^b	15.66	0.68 ^b	
Stenosis at the hernia neck	0.51	25 (83)	21 (70)	1 (3)	1 (3)	2 (6)		80	77	97	94							26.66	12.83	0.21	
Gastric wall edema	0.71	5 (17)	9 (30)	0	0	1 (3)		17	30	100	97							4.40 ^b	10.00	0.84 ^b	
Perigastric fluid	0.77	9 (30)	13 (43)	0	0	1 (3)		30	47	100	97							7.00 ^b	15.66	0.71 ^b	
Pleural effusion	0.74	8 (27)	11 (37)	0	0	3 (10)		27	37	100	90							6.40 ^b	3.70	0.74 ^b	
Pneumatosis	0.93	2 (7)	4 (13)	0	0	0		7	13	100	100							2.40 ^b	3.60 ^b	0.93 ^b	
Poor gastric wall enhancement	0.84	1 (3)	4 (13)	0	0	0		3	13	100	100							1.60 ^b	3.60 ^b	0.97 ^b	

CT Finding	κ	Frequency				Sensitivity (%)		Specificity (%)		PLR		NLR	
		Volvulus Group (<i>n</i> = 30)		Control Group (<i>n</i> = 31)		R1	R2	R1	R2	R1	R2	R1	R2
		R1	R2	R1	R2								
Celiac compromise and other organ ischemia	0.97	0	1 (3)	0	0	0	3	100	100	1.00 ^b	1.60 ^b	1.00 ^b	0.97 ^b
Pneumoperitoneum	0.97	2 (7)	3 (10)	0	0	7	10	100	100	2.40 ^b	3.00 ^b	0.93 ^b	0.90 ^b

Note—Numbers in parentheses are percentages. PLR = positive likelihood ratio, NLR = negative likelihood ratio, R1 = reader 1, R2 = reader 2, APJ = antropyloric junction, GEJ = gastroesophageal junction, GC = greater curvature, LC = lesser curvature.

^aThere was no reference standard for distinguishing type of gastric volvulus. The surgical reports infrequently confirmed or refuted type and rather stated only the presence or absence of volvulus.

^bSpecificities of 100% are adjusted by adding 0.05 to both the numerator and denominator when calculating likelihood ratios.

TABLE 3:
Frequency of CT Findings of Ischemia and Comparison of Patients With and Without Ischemia at Surgical Pathology

CT Finding	Reader 1				Reader 2			
	Frequency			<i>p</i>	Frequency			<i>p</i>
	Volvulus Group (<i>n</i> = 30)	Patients With Ischemia (<i>n</i> = 8)	Patients Without Ischemia (<i>n</i> = 22)		Volvulus Group (<i>n</i> = 30)	Patients With Ischemia (<i>n</i> = 8)	Patients Without Ischemia (<i>n</i> = 22)	
Gastric wall edema	5 (17)	3 (38)	2 (9)	0.10	9 (30)	5 (63)	4 (18)	0.03 ^a
Perigastric fluid	9 (30)	6 (75)	3 (14)	0.003 ^a	13 (43)	7 (88)	6 (27)	0.009 ^a
Pleural effusion	8 (27)	5 (63)	3 (14)	0.016 ^a	11 (37)	7 (88)	4 (18)	0.001 ^a
Pneumatosis	2 (7)	0	2 (9)	1.00	4 (13)	2 (25)	2 (9)	0.28
Poor gastric wall enhancement	1 (3)	1 (13)	0	0.27	4 (13)	3 (38)	1 (5)	0.048 ^a
Celiac compromise and other organ ischemia	0	0	0	1.00	1 (3)	0	1 (5)	0.27
Pneumoperitoneum	2 (7)	1 (13)	0	0.27	3 (10)	2 (25)	1 (5)	0.17

Note—Numbers in parentheses are percentages.

^aStatistically significant ($p < 0.05$).