Gastric Band Slippage: A Case-Controlled Study Comparing New and Old Radiographic Signs of This Important Surgical Complication

OBJECTIVE. The purpose of this study was to compare the diagnostic performance of four radiographic signs of gastric band slippage: abnormal phi angle, the “O sign,” inferior displacement of the superolateral gastric band margin, and presence of an air-fluid level above the gastric band.

MATERIALS AND METHODS. A search of the electronic medical record identified 21 patients with a surgically proven slipped gastric band and 63 randomly-selected asymptomatic gastric band patients who had undergone barium swallow studies. These studies were evaluated for the four signs of band slippage by two independent radiologists who were blinded to clinical data. Sensitivity, specificity, and positive and negative predictive values were calculated for each radiographic sign of band slippage. Interobserver agreement between radiologists was assessed using the Fleiss kappa statistic.

RESULTS. In evaluating for gastric band slippage, an abnormal phi angle greater than 58° was 91–95% sensitive and 52–62% specific (κ = 0.78), the O sign was 33–48% sensitive but 97% specific (κ = 0.84), inferior displacement of the superolateral band margin by more than 2.4 cm from the diaphragm was 95% sensitive and 97–98% specific (κ = 0.97), and the presence of an air-fluid level was 95% sensitive and 100% specific (κ = 1.00).

CONCLUSION. We report two previously undescribed radiographic signs of gastric band slippage that are both sensitive and specific for this important surgical complication and recommend that these signs should be incorporated into the imaging evaluation of gastric band patients.

Keywords: bariatric surgery, barium swallow, gastric band complications, gastric band slippage, laparoscopic adjustable gastric band

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 Approximately 340,000 bariatric surgical procedures are performed annually worldwide, with multiple longitudinal studies showing sustainable weight loss and improvement in obesity-related comorbidities [1, 2]. Laparoscopic adjustable gastric banding is a bariatric surgery procedure that accounted for up to 42% of bariatric surgery in 2008 [1, 2]. Early experience with this procedure has shown weight loss comparable to other common bariatric procedures but with favorable morbidity and mortality rates [3–6]. Longer-term results, however, have resulted in growing concern about delayed complications, including gastric band slippage, which has been variably reported in 2–36% of laparoscopic adjustable gastric banding patients [3, 6–10]. When untreated, gastric band slippage can result in gastric stricture, bleeding, volvulus, infarction, and band erosion into the gastric lumen [3, 6, 7, 9, 11–14]. Early recognition and treatment of band slippage is therefore essential in the management of laparoscopic adjustable gastric banding patients.

Previous reports have suggested that a slipped gastric band is more likely to have an abnormal vertical or horizontal orientation relative to the midsagittal plane through thoracic spine (i.e., the phi angle, with a normal range reported as 4–58°) [3, 15–17] or that the band’s central lumen is more likely to be visualized than its superimposed sides (i.e., the “O sign”) [16, 17]. These two signs are classically described as present on barium swallow studies, which are recommended as an essential imaging study for evaluation of gastric band function and complications [13, 15, 16, 18–21].

At our practice in a busy bariatric surgery center, we observed two additional and previously unreported signs of band slippage that complement the phi angle and O sign as indicators of this clinically important complication. The first is inferior displacement of the superolateral gastric band margin from the diaphragm by more than 2.4 cm (corre-
Materials and Methods

This retrospective study was approved by our hospital institutional review board with a waiver of informed consent and was conducted in compliance with the HIPAA. The bariatric surgeons at our hospital order barium swallow studies for laparoscopic adjustable gastric banding patients in two clinical settings: either as a routine study during annual follow-up visits to confirm proper function and positioning or as part of a diagnostic evaluation when patients develop adverse symptoms. Immediate postoperative imaging is not typically performed unless the surgeon is concerned for a postoperative leak, in which case esophagography with water-soluble contrast material is performed.

A search of the electronic medical record identified 248 patients with laparoscopic adjustable gastric bands who had undergone a minimum of one barium swallow study during an 8.5-year period from May 1, 2004, through December 31, 2012.

Twenty-seven patients (25 women and two men) with surgically confirmed slipped gastric bands were identified. Six of these patients were excluded from the study because their available imaging before reoperation did not include a barium swallow study (Fig. 1). The 21 patients with gastric band slippage who had barium swallow studies available for review formed our case population. Of the remaining 221 laparoscopic adjustable gastric banding patients with barium swallow studies, 68 were excluded because their imaging evaluation was performed for adverse symptoms, but they did not undergo surgery during the study period and therefore could provide no definitive clinical correlation for any observed imaging findings. Of the 153 asymptomatic laparoscopic adjustable gastric banding patients remaining, 63 were randomly selected (three times the number of cases) who underwent barium swallow studies as part of routine annual surveillance during a surgical follow-up visit (± 2 months). These patients formed our control population (Fig. 1).

All barium swallow studies were performed by either a radiology resident or an attending gastrointestinal radiologist. Images were obtained with the patient in the upright position. All examinations included a frontal scout image of the chest and upper abdomen before ingestion of oral contrast material. At our institution, barium swallow studies performed for patients with a gastric band include abbreviated imaging of the upper esophagus, with attention to the lower esophagus, gastrosophageal junction, proximal pouch above the band, luminal diameter at the level of the band, and distal stomach beyond the band during ingestion of 30 mL of high-density barium (E-Z-HD or E-Z-HM, Bracco Diagnostics). The examinations were performed on a fluoroscopy unit (Axiom Sirenskop, Siemens Healthcare). Data regarding patient symptoms at the time of examination were extracted from the original barium swallow reports.

The barium studies of the 21 patients with gastric band slippage and the 63 control subjects were placed into a single folder in our PACS. The studies were then reviewed independently by two radiologists who were blinded to all clinical data. Both readers were fellowship-trained abdominal imagers, each with 7 years of postgraduate experience. Each radiologist reviewed each study and completed a datasheet with the following findings: phi angle (measured as the angle created from a vertical line through the spinous processes of the thoracic spine and a line paralleling the long axis of the gastric band on a frontal chest radiograph or scout image) (Figs. 2–4); presence or absence of an O sign, which was defined subjectively as “an O-shaped configuration of the gastric band” [16] (Fig. 4); the distance of the superolateral band margin from the left hemidiaphragm (Figs. 2–5); and the presence or absence of an air-fluid level above the gas-

![Flowchart](image-url)
Results

Twenty-one symptomatic patients who had a surgically proven slipped gastric band and a preoperative barium swallow study were identified and formed the study group. These included 19 women with mean age of 39.1 years (range, 27.9–59.2 years) and two men with mean age of 33.9 years (ages, 32.9 and 35.0 years). The mean length of follow-up after gastric band placement for these patients was 14.9 months (range, 0–37.7 months). Ten of these patients had a Lap-Band System (Allergan) and 11 had a Realize Band (Ethicon Endo-Surgery). Data regarding the study patient demographics are presented in Table 1, and data regarding the symptoms of patients with gastric band slippage are in Table 2.

Sixty-three randomly selected asymptomatic laparoscopic adjustable gastric banding patients with barium swallow studies performed for routine surveillance during annual surgical follow-up visits were identified and formed the control group. These included 53 women with mean age of 44.1 years (range, 22.6–59.6 years) and 10 men with mean age of 51.2 years (range, 39.3–61.8 years). Thirty-three control patients had a Lap-Band and 30 had a Realize Band. The average time from surgery was 11.8 months (range, 10.0–14.1 months).

No patient had a phi angle less than 4°. A phi angle greater than 58° was 91–95% sensitive but 97% specific for gastric band slippage. A phi angle less than 58° had a negative predictive value of 94–98% for band slippage. Interobserver agreement was substantial (κ = 0.78) (Table 3) for identifying normal and abnormal phi angles according to the previously published range. The mean phi angle measured by reader 1 for control patients was 53° (range, 22–84°), whereas for reader 2 the mean was 56° (range, 27–84°). The mean phi angle measured by reader 1 for slipped bands was 86° (range, 44–144°), whereas for reader 2, the mean was 88° (range, 38–145°). Review of discrepant phi angle measurements revealed that slight variations were related to differences in measurement technique as well as differences in the choice of which image from which to measure the angle.

The presence of an O sign was 33–48% sensitive but 97% specific for gastric band slip-
page, with excellent interobserver agreement ($\kappa = 0.82$) (Table 3). This sign was considered present by both readers in only two asymptomatic control patients. Review of discrepant opinions regarding this sign in patients with a surgically proven slipped band revealed that in each case, reader 2 thought the sign was present, whereas reader 1 did not. Some interobserver variation is expected given the subjective nature of this sign, which was originally reported as “an O-shaped configuration of the gastric band” on scout abdominal radiographs.

Inferior displacement of the superolateral gastric band margin by greater than 2.4 cm was 95% sensitive and 97–98% specific for band slippage, with excellent interobserver agreement ($\kappa = 0.97$) (Table 3). The mean measurement in control patients for reader 1 was 1.4 cm (range, 0.1–5.1 cm) and for reader 2 was 1.2 cm (range, 0.0–4.8 cm). Only two control patients were identified as displaced by more than 2.4 cm. One of these was measured as 2.6-cm inferiorly displaced by reader 1 but as only 2.3-cm displaced by reader 2. For the other patient, the measurements were 5.1 cm and 4.8 cm for readers 1 and 2, respectively. Later review of a subsequent abdominal CT showed eventration of the left hemidiaphragm, which accounted for the radiographic appearance of inferior displacement. In contrast, among the 21 cases of gastric band slippage, the mean distance of the superolateral band margin from the diaphragm was 4.7 cm (range, 2.4–8.0 cm) for reader 1 and 5.2 cm (range, 2.4–9.7 cm) for reader 2. Both readers measured a single case as only 2.4 cm below the diaphragm. The next lowest measurement was 2.7 cm for two other slipped bands.

The presence of an air-fluid level above the gastric band was 95% sensitive and 100% specific for gastric band slippage, with perfect interobserver agreement ($\kappa = 1.00$) (Table 3). This sign was only observed in patients who also showed inferior displacement of the superolateral band margin by at least 2.4 cm.

**Discussion**

We evaluated four radiographic signs of gastric band slippage, two of which have not been previously described. Our results constitute the first published data (to our knowledge) regarding the sensitivity, specificity, and predictive values of the phi angle and O sign for diagnosing gastric band slippage. Furthermore, our data suggest that our two new signs—inferior displacement of the superolateral band margin by more than 2.4 cm from the diaphragm and the presence of an air-fluid level above the band on a frontal radiograph—are more sensitive and specific for gastric band slippage.

**TABLE 3: Image Analysis of Diagnostic Performance of Radiographic Signs of Gastric Band Slippage**

<table>
<thead>
<tr>
<th>Radiographic Sign</th>
<th>Reader 1</th>
<th>Reader 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
<td>Specificity (%)</td>
</tr>
<tr>
<td>Phi angle &lt; 4° or &gt; 58°</td>
<td>95.2 (77.3–99.2)</td>
<td>61.9 (49.6–72.9)</td>
</tr>
<tr>
<td>&quot;O&quot; sign present</td>
<td>33.3 (17.2–54.6)</td>
<td>96.8 (89.1–99.1)</td>
</tr>
<tr>
<td>Band &gt; 2.4 cm from diaphragm</td>
<td>95.2 (77.3–99.2)</td>
<td>96.8 (89.1–99.1)</td>
</tr>
<tr>
<td>Air-fluid level above band</td>
<td>95.2 (77.3–99.2)</td>
<td>100.0 (94.3–100.0)</td>
</tr>
</tbody>
</table>

Note—Data in parentheses are 95% CI. PPV = positive predictive value, NPV = negative predictive value.

*Sign present in 20 of 21 patients with slippage at surgery.
*Sign absent in 39 of 63 asymptomatic patients.
*Sign present in 19 of 21 patients with slippage at surgery.
*Sign absent in 33 of 63 asymptomatic patients.
*Sign present in seven of 21 patients with slippage at surgery.
*Sign absent in 61 of 63 asymptomatic patients.
*Sign absent in 10 of 21 patients with slippage at surgery.
*Sign absent in 62 of 63 asymptomatic patients.
*Sign absent in 63 of 63 asymptomatic patients.

Fig. 5—39-year-old woman with chest pain, abdominal pain, and slipped gastric band. **A,** Upright frontal radiograph shows phi angle of 74° (white line), inferior displacement of superolateral band margin by 6.4 cm (black line), and air-fluid level above band (arrow). **B,** Stored fluoroscopy image obtained with patient upright and in slight left posterior oblique position, after having swallowed small bolus of barium shows air, fluid, and barium levels (arrows) within pouch above gastric band and stenosed lumen at level of band. No barium passed into lower pouch for more than 5 minutes.
slippage than the previously described signs. We propose that familiarity with these imaging signs of gastric band slippage will aid radiologists in diagnosing affected bariatric patients who have this important complication.

In the current radiologic literature, the most frequently described normal postoperative findings of laparoscopic adjustable gastric banding include a phi angle of 4–58° [15–17, 23] and a gastric band position 4–5 cm below the diaphragm [15, 17, 23]. A gastric band phi angle of less than 4° has been described as suggesting a posterior or medial eccentric slip, which is predominantly reported in the setting of the outdated peri-gastric surgical technique [9, 10, 13, 15, 17, 18]. On the other hand, a phi angle of greater than 58° reportedly suggests anterior or lateral eccentric slippage and is associated with the modern pars flaccida surgical technique, which has been the surgical standard of care for almost a decade [9, 15–17].

In our series, all patients underwent gastric band placement with the pars flaccida technique and no patient had a phi angle less than 4° on any barium swallow study. This supports prior assertions that posterior or medial eccentric band slip is unlikely with this modern surgical technique. We found that a phi angle greater than 58° was 91–95% sensitive but only 52–62% specific for gastric band slippage. This contradicts prior articles that have described a phi angle of greater than 58° as characteristic of slippage. Although our asymptomatic patients showed an average phi angle of 55°, the range was from 22° to 84°. Nevertheless, slipped gastric bands did generally have higher phi angles, with a mean of 87° (range, 38–145°).

The indication in prior publications within the past decade that a normal gastric band should project 4–5 cm below the diaphragm [15, 17] is confusing and potentially misleading given that the modern pars flaccida surgical technique intentionally places the band at or within 2 cm of the esophagogastric junction [6, 14, 24–29]. We evaluated the distance of the superolateral margin of the band from the diaphragm and found the threshold of greater than 2.4 cm (corresponding to two times the width of the band) inferior displacement to be 95% sensitive and 97–98% specific for gastric band slippage requiring surgery. We expect a normally positioned band to project near the diaphragm on frontal radiographs.

The O sign was described by Pieroni et al. [16] in 2010 as a new radiographic sign of gastric band slippage that can be seen on frontal radiographs. In a retrospective review of 55 consecutive laparoscopic adjustable gastric banding patients, four patients with surgically proven gastric band slippage showed this sign on preoperative contrast-enhanced upper gastrointestinal examinations, whereas none of the other 51 patients were found to have this sign on upper gastrointestinal examinations regardless of symptoms. In each case of gastric band slippage, an O configuration of the gastric band replaced what the authors described as a normal rectangular appearance, in which the anterior and posterior band segments are superimposed. We found this sign to be 97% specific but only 33–48% sensitive for band slippage.

The presence of an air-fluid level above the gastric band was 95% sensitive and 100% specific for gastric band slippage. We believe this sign corresponds with functional obstruction resulting from a slipped band (Fig. 5B). In support of this is the observation that this sign only occurred in patients who also showed inferior displacement of the superolateral band margin by more than 2.4 cm. Furthermore, Swenson et al. [20] reported that the mean pouch emptying time in asymptomatic gastric band patients undergoing barium swallow evaluation was only 36.1 seconds. Because a patient undergoing a radiographic examination would not be expected to have ingested liquids within such a short interval before image acquisition, the presence of fluid above the band suggests obstruction. Although several publications have quoted an expected emptying time of 15–20 minutes [15, 17], these authors reference a study by Pretolosi et al. [30] from 1998, in which only the emptying time of a solid meal was investigated.

Other authors have suggested that band slippage likely results from overeating and recurrent vomiting [9, 13, 23, 31]. Because the band is displaced inferiorly from its intended site around the proximal stomach near the esophagogastric junction, it necessarily encompasses a larger volume of gastric tissue at the fundus or body of the stomach. Although the fluid-distensible inner lumen of the adjustable gastric band may be pliable, the firm outer ring can only allow a fixed volume of tissue to reside within it. Therefore slippage would be expected to coincide with luminal narrowing at the level of the band. In addition, the act of vomiting occurs with powerful gastric contractions that may cause mucosal irritation at the level of the constricting gastric band, resulting in edema that further compounds the luminal narrowing and leading to functional obstruction. This may be the reason our patients with surgically proven gastric band slippage so commonly showed an air-fluid level above the inferiorly displaced band.

Similar to the practice at our institution, the imaging evaluation for gastric band slippage typically involves a barium swallow study. It is therefore notable that all four signs of gastric band slippage are evident on upright frontal scout radiographs (Figs. 3–5) and may not be significantly better characterized after patients ingest barium. Although our study did not evaluate the performance of frontal radiographs alone for the diagnosis of gastric band slippage, this observation is significant given that some patients with gastric bands may present as outpatients or in an emergency department setting with symptoms that prompt clinicians to order chest or abdominal radiography. For example, in our series, chest pain, shortness of breath, and dysphagia were reported in a significant minority of patients, whereas nausea, vomiting, and abdominal pain were present in the majority (Table 2). If radiologists are familiar with the four radiographic signs of gastric band slippage, an accurate diagnosis may be suggested from chest or abdominal radiography alone.

Our study is limited by its retrospective nature, with potential for selection bias and interpretation bias. However, we sought to address this issue by performing a blinded, case-controlled review of imaging by two independent radiologists. Although our patients were surgically proven to have gastric band slippage, our control patients were not evaluated by surgery to prove appropriate band positioning, which is an unavoidable limitation. Although the cohort of patients in our study was relatively small (21 with a slipped band and 63 control patients), we were limited by the size of the patient population at our bariatric surgery center. In addition, we did not evaluate the radiographic findings in laparoscopic adjustable gastric banding patients who were asymptomatic but who did not undergo repeat surgery during the course of this study. These patients were excluded because there could be no definitive surgical diagnosis to correlate with any observed radiographic findings. Nevertheless, this does present a limitation to our study because it omits a cohort of patients who might show a spectrum of imaging findings that overlap with those seen in patients with gas-
Radiographic Signs of Gastric Band Slippage

In conclusion, we offer two previously undescribed radiographic signs of gastric band slippage that were sensitive and specific in our patient cohort and can be easily identified on upright frontal radiographs during barium swallow evaluation: first, inferior or displacement of the superolateral gastric band margin from the diaphragm by more than 2.4 cm and, second, the presence of an air-fluid level above the gastric band on an upright frontal radiograph. We suggest that these signs should be considered along with the phi angle and O sign in the imaging evaluation of gastric band patients.

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APPENDIX 1: AJR JOURNAL CLUB

Study Guide

Gastric Band Slippage: A Case-Controlled Study Comparing New and Old Radiographic Signs of This Important Surgical Complication

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Introduction
1. What is the research question being asked with this study?
2. Do the authors explicitly state a hypothesis for the study? What is the null hypothesis of this study?
3. Is this study timely and relevant? Do the authors provide a rationale for performing the study? Is the study based on an appropriate re-view of the medical literature?

Methods
4. What study design was used?
5. What were the inclusion criteria? What were the exclusion criteria?
6. What is the implication of excluding the nonsurgically confirmed cases of band slippage?
7. What variables did the two radiologists measure?
8. Are there any additional variables relevant to determining gastric band slippage?
9. How did the study acknowledge and resolve rating disagreements between the two radiologists?
10. What are the limitations of this study? Are these limitations adequately discussed?

Results
11. Did the study achieve its purpose?
12. How do the results of this study compare to similar studies?

Physics
13. What strategies can be used to minimize patient, operator, and technologist-observer dose during fluoroscopic studies?

Discussion
14. Are study findings sufficiently strong to impact clinical practice?
15. To what degree does this study impact your approach to determining whether a patient has gastric band slippage?

Background Reading

FOR YOUR INFORMATION
For more information on Journal Clubs, see “Evidence-Based Radiology: A Primer in Reading Scientific Articles” in the July 2010 AJR at www.ajronline.org/cgi/content/full/195/1/W1.

*Please note that the authors of the Study Guide are distinct from those of the companion article.