

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Vomiting in Infants Up to 3 Months of Age

Variant 1: Bilious vomiting in neonate up to 1 week old.

Radiologic Procedure	Rating	Comments	RRL*
X-ray abdomen	9	Initial x-ray will help determine further workup strategy.	☼ ☼ ☼
X-ray upper GI series	8		☼ ☼ ☼
X-ray contrast enema	7		☼ ☼ ☼ ☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Bilious vomiting in infant 1 week to 3 months old.

Radiologic Procedure	Rating	Comments	RRL*
X-ray upper GI series	9		☼ ☼ ☼
X-ray abdomen	5		☼ ☼ ☼
US abdomen (UGI tract)	3		O
Tc-99m sulfur colloid reflux scintigraphy	1		☼ ☼ ☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 3: Intermittent nonbilious vomiting since birth.

Radiologic Procedure	Rating	Comments	RRL*
X-ray upper GI series	6		☼ ☼ ☼
US abdomen (UGI tract)	4		O
Tc-99m sulfur colloid reflux scintigraphy	3	Seldom indicated for most patient evaluations, but may provide useful information about gastric emptying and GER in select patients if other testing proves unrevealing.	☼ ☼ ☼
X-ray abdomen	1		☼ ☼ ☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition:

Vomiting in Infants Up to 3 Months of Age

Variant 4:

New onset projectile nonbilious vomiting.

Radiologic Procedure	Rating	Comments	<u>RRL*</u>
US abdomen (UGI tract)	9		O
X-ray upper GI series	6		☢ ☢ ☢
X-ray abdomen	2		☢ ☢ ☢
Tc-99m sulfur colloid reflux scintigraphy	1		☢ ☢ ☢
<u>Rating Scale:</u> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

VOMITING IN INFANTS UP TO 3 MONTHS OF AGE

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Summary of Literature Review

Introduction/Background

Vomiting, or the forceful extrusion of gastric contents, is never normal in the neonate and usually occurs because of complete or partial obstruction somewhere along the course of the gastrointestinal (GI) tract between the stomach and cecum [1]. However, there may be difficulty in differentiating clinically between vomiting and regurgitation.

Regurgitation, or gastroesophageal reflux (GER), is normal in the first 3 months of life and resolves in time. It usually has no definitive pathologic cause and, is unrelated to a functional defect. Rarely, regurgitation may be due to displacement of a portion of the stomach into the chest, (ie, hiatal hernia). In other cases, low esophageal sphincter pressures or delays in gastric emptying have been implicated as causative and typically resolve in time [1].

The role of imaging in evaluating the vomiting infant is to define whether and where there is a point of anatomic obstruction. Secondly, one should note whether there is GER or delayed gastric emptying. Diagnostic studies that are complementary to imaging examinations include esophageal pH monitoring, esophageal motility studies, endoscopic evaluation of the esophagus, and multichannel intraluminal impedance.

Parental complaints of vomiting or regurgitation in neonates during the first 3 months of life are common. The cause is usually GER, particularly in the first weeks of life and with overfeeding. Neonates with normal weight gains tend not to have disease as the cause of their vomiting [2]. GER may be diagnosed by medical history, watching an actual feeding, or monitoring esophageal acidity. Other than GER, common causes of vomiting in the first 6 weeks of life include neonatal sepsis, hypertrophic pyloric stenosis (HPS), and pylorospasm. It can occur with necrotizing enterocolitis in premature infants, often with the associated finding of bloody stools. Less common causes exist, with the most important one being the clinically emergent problem of bowel malrotation with midgut volvulus.

Vomiting may also be present in cases of malrotation without volvulus, congenital atresia of the antropyloric area or small bowel or severe stenosis of small bowel (manifested in fetuses by dilated fluid-filled bowel), and functional obstructions caused by Hirschsprung's disease, small left colon syndrome, meconium ileus, or meconium plug syndrome. Causes that are even less common are neonatal appendicitis, intussusception, gastric ulcer disease, and lactobezoars. The less common causes outside the GI tract include intracerebral abnormalities such as subdural collections, drugs or toxic agents, and medical conditions such as kernicterus, metabolic disorders, and renal problems [2-5].

Once the child is 6 weeks of age, the clinician and radiologist must continue to be concerned about the aforementioned conditions, with an increased incidence of formula intolerance and infectious causes such as urinary tract infection, pneumonia, otitis media, meningitis, and gastroenteritis. Less common causes include increased intracranial pressure from tumor or trauma, whooping cough, midgut volvulus, metabolic disorders (phenylketonuria, maple syrup urine disease, galactosemia, diabetes, adrenocortical hyperplasia, methylmalonic acidemia), and diencephalic syndrome [2-4].

Much of the differential diagnosis workup can be determined by good clinical evaluation. Viral gastroenteritis often appears in epidemics, with sudden onset of vomiting, mild fever, diarrhea, and a relatively short duration. Systemic infections and metabolic disorders may be diagnosed by clinical and laboratory criteria. HPS may be diagnosed by feeling the classic olive of hypertrophied muscle. Intussusception, which is unusual in the first 3 months of life, may be diagnosed clinically by crampy abdominal pain sometimes progressing to bloody stools. Patients with increased intracranial pressure often have neurologic signs [2,4].

When the clinical and laboratory assessment provides a definitive diagnosis and treatment plan, radiologic imaging is not required. Clinical diagnostic uncertainty requires use of imaging. The imaging workup of vomiting

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patients in the newborn to 3-month-old age group is discussed with regard to three different and not unusual clinical scenarios:

1. Bilious vomiting.
2. Intermittent nonbilious vomiting since birth.
3. New-onset projectile nonbilious vomiting.

Scenario 1: Bilious Vomiting

Regurgitation of the first few feedings of life is not uncommon. These infants must, however, be watched closely and examined frequently. The quality of regurgitated material gives clues as to the location of possible obstruction [6]. Bilious vomiting is usually due to sepsis or obstruction [2]. It is a radiologic emergency because midgut volvulus about the superior mesenteric artery (SMA) may lead to ischemia and necrosis of the small bowel distal to the point of volvulus. The requirement to treat bilious vomiting as an emergency is valid. In a study of 45 patients with bilious vomiting in the first 72 hours of life (with 32 of them having bilious vomiting in the first 24 hours); only 20% had midgut volvulus, with 69% of cases having an idiopathic cause and a transient course and 11% having a lower GI cause (meconium plug syndrome or left-sided microcolon) [6]. One must be wary to differentiate true bilious vomiting from inconsequential regurgitation of yellow colostrum or vomitus with meconium, which is more indicative of distal bowel obstruction.

Evaluation for Malrotation and Midgut Volvulus

Abdominal Radiographs

Abdominal radiographs may show evidence of upper GI (UGI) tract obstruction with dilatation of the stomach or small bowel to a point of obstruction. Radiographs that show bowel obstruction may direct the subsequent imaging workup. Findings of a distal obstruction can be clarified with contrast enema. Normal abdominal radiographs do not exclude the diagnosis of malrotation. Thus, negative radiographs suggest the need for further evaluation. In a group studied by Lilien et al [6], only 44% of patients who required surgery for bilious vomiting had definitively positive radiograph readings. The majority of patients (56% of the surgery group, and 30 of 31 idiopathic cases) showed normal or nonspecific radiographs [6].

Contrast Upper Gastrointestinal Series

To answer the key imaging question in such patients—that is, whether the child has a mechanical obstruction—requires direct imaging of the stomach and small bowel. Many authors prefer the barium UGI series. A few authors have discussed the use of low-osmolarity contrast agents for extremely ill or very premature infants or those with bilious vomiting. These contrast agents are used to evaluate the stomach, the egress of its contents through the pylorus and into the duodenum, and the course of the duodenum to the ligament of Treitz [4,6-7]. While the UGI series is considered the gold standard for evaluating malrotation, false positive and false negative interpretations may occur. In a retrospective review of

229 cases by Sizemore et al [8] UGI had a sensitivity of 96% with 2 false positives (abnormal jejunal position with no malrotation) and 7 false negatives (normal jejunal position with malrotation). They concluded that jejunal position can lead to inaccurate UGI interpretation, and thus meticulous technique is recommended in these equivocal cases.

Ultrasound

Other authors [9-11] have pointed out that ultrasound (US), with water used as a contrast agent, can be highly successful in imaging gastric emptying, GER, and duodenal abnormalities, including midgut volvulus. Yousefzadeh et al [12] has proposed that US demonstration of the position of the third part of the duodenum between the aorta and the SMA in transverse and sagittal plains can be the most reliable diagnostic method for evaluating malrotation rather than the position of the duodenojejunal flexure by UGI. The major difficulties for some radiologists with regard to the use of US are that its success depends on the skill of the operator and that it is occasionally limited in following the entire course of the normal fluid-filled duodenum. Both the contrast UGI series and the fluid-aided US examination can reveal the dilated small bowel proximal to an atresia or stenosis and the beaked or twisted point of obstruction of the proximal small bowel in cases of midgut volvulus. The ability to follow a contrast column through the duodenum and note its route from right to left of midline and up to the height of the duodenal bulb to the area of the ligament of Treitz helps rule out bowel malrotation, whether the imaging is done with barium in an UGI series or with water in a US examination. Weinberger et al [13] using US noted the relationship of the SMA to the superior mesenteric vein (SMV) in 337 children presenting with nonbilious vomiting. All five of five patients with the SMV to the left of the SMA had bowel malrotation, while one of four patients with the SMV anterior to the SMA had malrotation. In a series by Chao et al [14] sonographic features suggestive of volvulus included duodenal dilation with tapering, fixed midline bowel, whirlpool sign, and dilation of the distal SMV. Other studies have supported the use of the whirlpool sign in assessing volvulus [15-16]. The key necessity is to determine whether obstruction is the possible cause of bilious vomiting. A normal SMV/SMA relationship does not preclude malrotation, with both false positive (21%) and false negative (2%-3%) results reported [17]. Obscuration of the SMA and SMV by bowel gas has been reported to occur in up to 17% of cases [13]. If US evaluation is inconclusive with respect to duodenal position an UGI is indicated in this patient group.

Individual cases of bilious vomiting associated with supradiaphragmatic herniation of the stomach [18] or chronic gastric volvulus [19] have been reported. Although radiograph examinations may be diagnostically useful, as with other causes of bilious vomiting, contrast UGI series or US are necessary to determine a point of obstruction.

X-Ray Contrast Enema

Abnormalities of the lower GI tract that may be causes of bilious vomiting may be demonstrated by barium enema [3,20]. The use of barium enema for analyzing malrotation is less direct than analysis by UGI series. Approximately 20% of barium enemas may be falsely negative, while up to 15% of infants have a high mobile cecum that may cause false positive interpretations of the study [21].

Nuclear Medicine

Nuclear medicine studies, which can be highly effective in analyzing gastric emptying and GER, have no significant role in the evaluation of the neonate with acute bilious vomiting. However, radionuclide gastric emptying studies have been reported to reveal the unexpected presence of a malrotation [22].

Scenario 2: Intermittent Nonbilious Vomiting Since Birth

There are several common causes of intermittent vomiting since birth. In a review of 145 such cases by O’Keeffe et al [23], 43 were due to idiopathic GER, 40 to HPS, 27 to overfeeding, 15 to pylorospasm, 14 to milk allergy, and one to gastroenteritis.

The most common cause for intermittent vomiting or regurgitation since birth is GER. Competence of the lower esophageal sphincter is based on anatomic and physiologic factors that are not perfectly understood. The sphincter mechanism is said to not be fully mature for at least the first 6 weeks of life. The topic of GER has engendered great debate among clinicians and imagers, with continued questions over what a “positive” test is and how one defines “significant” reflux [24].

Other diagnostic possibilities include pylorospasm, gastric volvulus, and gastric ulcers [9,19,25-26].

Evaluation for Gastroesophageal Reflux

The diagnostic workup for GER includes the current gold standard—the extended pH probe. The Tuttle test and esophageal motility studies are said to be unreliable in young children. Imaging studies are done to prove the refluxing of gastric contents into the esophagus, and to exclude any anatomic abnormalities. Depending on the clinical circumstances, the degree of reflux based on number of events over a given period of time, the height of the refluxing column, the quality of the esophageal mucosa, and evidence of aspiration into the lungs are important pieces of information. For the first analysis of a vomiting infant between 1 day and 3 months of age who does not have failure to thrive, many clinicians prefer to simply know whether GER or another phenomenon is the cause of clinical concern.

Radiographs

Although radiographs do not play a role in the diagnosis of GER, in one study mega-aeroesophagus seen as an air-filled esophagus at least 1 cm in diameter on the chest radiographs of 16 chronic vomiters proved to be evidence of GER or esophageal obstruction [27]. A recent clinical practice guideline on GER [28] stated that the sensitivity,

specificity, and positive predictive values of UGI series range from 31% to 86%, 21% to 83%, and 80% to 82%, respectively, when compared to esophageal PH monitoring. The brief duration of the UGI series results in false negative results, while the frequent occurrence of nonpathological reflux results in false positive results. Thus, the UGI series is not a useful test to reliably determine the presence or absence of GER.

A study performed on 469 children demonstrated that even a UGI study that included intermittent fluoroscopy every 3-4 seconds for up to 5 minutes had false negative results for GER of 48% [7].

Contrast Upper Gastrointestinal Series

Imaging evaluation can be done with a UGI series, which is said to be sensitive but less specific than the pH probe [24,29]. The UGI series can analyze esophageal mucosal integrity, but fluoroscopic examination time is limited by concerns about radiation exposure.

Reflux Scintigraphy

Reflux scintigraphy with 99m technetium (Tc-99m)-labeled sulfur colloid mixed in a feeding was noted by Seibert et al [30] to be 79% sensitive—as compared to barium studies (31%-86%) — and is more specific (93% compared with 21%). Nuclear medicine scintigraphy can be used over a prolonged time without increasing radiation exposure and at a lesser radiation dose than the UGI series. Several studies have tried to standardize the methodology of the examination. A 1-hour scintigraphic study formatted in 60-second frames provides a quantitative representation of postprandial GER for children, particularly if they do not have rapid gastric emptying [31]. False negative examinations can be associated with delayed gastric emptying, and in this patient group prolongation of the study beyond 60 minutes or confirmatory pH probe evaluation may be advisable.

Methodology and interpretation criteria are not uniform from center to center [32-33]. In a series of symptomatic and asymptomatic preterm infants who had reached 32-34 weeks postconceptional age, radionuclide scintigraphy demonstrated a high incidence of reflux in both groups that did not correlate with symptoms [34]. Use of this study thus may be limited to patients older than 3 months of age in which other modalities have excluded an anatomic cause for feeding disorders. [29-30,35].

Ultrasound

US diagnosis of reflux is made by noting water placed into the stomach refluxing into the distal esophagus (after tube removal). Because US shows even more episodes of reflux than the UGI series, some consider it to be even less specific in diagnosing GER [6]. Riccabona et al [36] found US to be 100% sensitive and 87.5% specific in diagnosing GER. Cohen et al [10] found US successful in diagnosing 48 true positive and six true negative cases of GER with only one false negative. In a study of 31 preterm infants, US was 100% specific but only 38% sensitive, with a positive predictive value of 100% [37]. US can provide functional as well as morphologic

information [36,38-39]. Thus, when clinicians suspect GER, US may be useful for selecting which cases should be referred for pH-metry. In a recent series by Farina et al [40] contrast-enhanced color Doppler was compared to pH-metry in 120 children and demonstrated a sensitivity of 98% (P<0.0001). The authors suggested that color Doppler US could be used in place of the more invasive pH-metry.

Evaluation for Delayed Gastric Emptying and Pylorospasm

UGI series, as well as US and scintigraphy, can show gastric emptying, which when delayed may indicate pylorospasm as a cause of persistent vomiting. The UGI series is helpful in diagnosing HPS, hiatal hernia, GER, and duodenal abnormalities that result in delayed gastric emptying [27].

Delayed images in standard positions allow scintigraphy to assess gastric transit without additional radiation exposure [32,41]. Delayed gastric emptying has been defined as more than 50% retained labeled liquid within the stomach after 120 minutes in children younger than 2 years of age.

Information about US imaging of pylorospasm is scattered in the literature. Postprandial evacuation of the stomach in infants has been described using functional US by monitoring antral areas [39]. US allows evaluation of normal and abnormal pyloric lengths and muscle wall thicknesses [42]. Antropylic muscle wall thickness measurements are normally 1 mm [23]. In a series by O'Keefe et al [23], of 17 cases diagnosed as having pylorospasm, 15 had wall thickness measurements of >1 mm but <2 mm, and two had pyloric muscle wall thicknesses as great as 2 to <3 mm. They warned that a contracted pyloric canal may appear falsely thickened if the US image is obtained in a tangential plane. In one study of 150 cases sent to sonography for possible HPS, seven cases were identified as "pylorospasm or evolving HPS" [43]. All had delayed gastric emptying as well as pyloric muscle wall thickening (1.3-2.7 mm) and pyloric canal elongation (lengths of 10-14 mm). All those measurements fall below those considered positive for diagnosing HPS. However, another study [42] indicated that the differentiation between HPS and pylorospasm may not be as simple. Of 31 patients diagnosed by US as having pylorospasm (and confirmed as such by clinical follow-up) six had pyloric lengths >18 mm, and 18 had muscle wall thicknesses >4 mm, measurements that simulate HPS, for at least a portion of their US study. Changeability of these measurements and evident gastric emptying of inserted fluid helped confirm the US diagnosis of pylorospasm. Pyloric muscle changeability and incomplete obstruction to fluid flow into the duodenal bulb are US findings suggestive of pylorospasm and allow differentiation from the unchanging thick wall of HPS.

Other Conditions

Gastric ulcers are now typically diagnosed by endoscopy.

Chronic gastric volvulus is not as uncommon as previously thought. In the neonatal and infant group, its primary presentation is recurrent vomiting. While radiographs show no characteristic finding, the UGI series may show a high greater curvature, a greater curvature crossing the esophagus, a downward-pointing pylorus, two airfluid levels, or a lowering of the gastric fundus, all of which are suggestive of gastric torsion [17]. Gastric volvulus has a frequent association with GER. Sudden episodes of cyanosis and apnea, anorexia, or pneumonia in association with recurrent vomiting may indicate this entity [25].

Scenario 3: New-Onset Projectile Nonbilious Vomiting

The most common conditions producing acute vomiting at 6 weeks of age are GER, viral gastroenteritis, pylorospasm, and HPS.

HPS is typically suggested by projectile bile-free emesis in a previously healthy infant around 6 weeks of age [44]. Projectile vomiting may be reported in patients with GER, particularly in overfed patients.

When a classic "olive" of hypertrophied pyloric muscle is palpated, the diagnosis of HPS can be made clinically, and the patient can be sent to surgery for a pyloromyotomy, without the need for imaging examinations [44]. Recent advances in laparoscopic surgery suggest that accurate measurements of pyloric muscle thickening are useful in the planning of surgery, even when the diagnosis is clinically evident [45]. When no "olive" is palpated, imaging by radiographs, US, and/or a UGI series can be performed for diagnosis.

Evaluation for Hypertrophic Pyloric Stenosis

Radiographs

Abdominal radiography may show gastric distension with HPS. On occasion, mass impression of the thickened pyloric muscle on an air-filled gastric antrum may be noted. However, radiographs are most often not helpful in HPS diagnosis and are usually nonspecific in cases of GER or gastroenteritis. Rothrock et al [46], in a retrospective review to determine the utility of abdominal radiography in children presenting to the emergency room, noted that of four children with HPS, none had radiographs that were diagnostic. The radiographs were suggestive of the diagnosis in only one case, while they were apparently normal in two of the cases and misleading in the remaining case.

Upper Gastrointestinal Series

While the contrast UGI series is excellent for diagnosing obstructive causes of vomiting in this age group it should not be considered the imaging study of choice if HPS is a strong clinical concern.

In cases of HPS, one can note the mass impression of the hypertrophied pyloric muscle on the barium-filled antrum ("shoulder sign"), or the filling of the proximal pylorus ("beak sign") or the entire elongated pylorus ("string sign") with barium [3]. The UGI series allows diagnosis of GER as well as less common causes of obstruction such as midgut volvulus, gastric volvulus, or annular

pancreas [2]. Because of delayed gastric emptying in cases of HPS, the demonstration of the beak and string signs can be difficult, require considerable fluoroscopic time, and increase the radiation burden to the patient.

Ultrasonography

US has become a standard and highly accurate method for diagnosing HPS without the need for radiation exposure. It allows imaging of the pyloric muscle and channel, and the constant imaging of an elongated, thick-walled pylorus indicative of HPS [9]. Measurements of pyloric channel length, pyloric diameter, and muscle thickness have been used by several authors for diagnosis [9,23,29,44,47]. Overlap of these measurements between normal patients and those with HPS has been reported. This is particularly true regarding transverse pyloric diameter measurements, which are therefore considered less reliable [48]. Blumhagen et al [47] found muscle thickness to be the most discriminating and accurate measurement, noting it as 4.8 +/- 0.6 mm in HPS patients and 1.8 +/- 0.4 mm in normal patients. Measurements of 4 mm are considered positive for HPS, but measurements between 3 and 4 mm may also be positive, particularly in the premature or younger neonate [49]. Muscle thickness measurement may be obtained on transverse or longitudinal views of the pylorus [44].

Wilson and Vanhoutte [50] considered a 2 cm pyloric length to be definitively abnormal in 33 of 33 HPS patients. Stunden et al [51] felt that pyloric length was the only precise indicator of HPS. Their negative cases had no pylorus lengths longer than 14 mm. Their positive cases were all 18 mm or longer. Swischuk et al [48,52] reviewed several pitfalls of HPS diagnosis by US, including the creation of false thickening of the pyloric muscle wall by tangential views of the pylorus.

Of note, however, is the fact that just as some reports have noted an overlapping of pylorospasm measurements with those of HPS during at least a portion of an US study [42], so too may some of the US signs thought to be specific for HPS be seen in cases of pylorospasm for at least some portion of the study [53]. Changes of pyloric length or muscle wall thickness measurements, or of the actual images of the pyloric area, from those that are normal or those that are not normal but not diagnostic of HPS, are suggestive of pylorospasm. This is particularly true if one can also note significant gastric emptying after the patient has been given a gastric fluid load (eg, 60 cc or half a typical feed).

Diagnostic caution with careful clinical follow-up has been suggested for the diagnosis of pylorospasm in neonates younger than 4 weeks of age or in premature infants who are the equivalent of younger than age 4 (full-term) weeks, to avoid the possibility of underdiagnosing cases evolving into HPS [53]. Pylorospasm is said to be the most common cause of gastric outlet obstruction in this age group and, unlike HPS, it is treated conservatively [9].

Nuclear Scintigraphy

Nuclear scintigraphy has little place in the evaluation of the 6-week-old infant with projectile vomiting. If all other causes of vomiting have been excluded, it may be useful for functional evaluation of gastric emptying, although such patients are typically older than 3 months of age by the time scintigraphy is requested.

Ultrasound versus Upper GI for HPS

US has the advantage over UGI series in that it does not use ionizing radiation. It is the preferred method for diagnosing HPS. However, a negative US leading to a UGI series does not save the patient radiation exposure, and in fact it increases the expense of imaging. Foley et al [54], in reviewing the cost, risk, and benefit of first using US in the analysis of the vomiting child in two pediatric hospitals, found a 33% reduction in the number of UGI series performed, but a 95% increase in overall cost because the remaining patients went on to a UGI series. Forman et al [55] found an increased cost among their patients because only 44% had HPS and the others went on to a UGI series.

Cost analyses that support UGI as the initial imaging study in patients suspected of having HPS may not be generalizable, because the percentage of infants with projectile vomiting who have a US examination and then go on to a UGI series varies greatly with the clinical and US practice of a given institution [56].

In addition, one must continue to bear in mind the necessity for continued vigilance in balancing the need for an exact diagnosis with the need to limit radiation exposure, particularly when time of fluoroscopy is increased by evaluating gastric emptying times for cases of possible pylorospasm [42] or by attempting to image reflux in cases of possible GER. Graif et al [57] noted that prolonged US observation of the passage of gastric contents may be tedious but useful in helping to avoid surgery in cases simulating HPS. Nagita et al [58] reported on the helpfulness of repeated US examinations to analyze gastric emptying and changes in pyloric muscle thickening in cases of HPS that were successfully treated medically.

Summary

- In imaging an infant with bilious vomiting, if malrotation is the diagnosis of exclusion, an UGI series should be the examination of choice. In newborns with bilious vomiting, a distal obstruction such as meconium plug or microcolon can be evaluated with a water-soluble contrast enema. While US can be a complementary tool in confirming the diagnosis of malrotation, obscuration by overlying gas may limit its usefulness in the acute setting.
- The imaging evaluation of intermittent vomiting in infants depends on the clinical scenario. UGI is the preferred imaging when anatomy evaluation is indicated. The role of US for assessing reflux is less well established. Radionuclide scans can also play a

role in assessing the severity of GER and gastric emptying.

- In imaging the 6-week-old infant with projectile vomiting, the choice between UGI series and US depends on careful clinical history and a likely primary diagnosis. If HPS or pylorospasm is likely, sonography alone can be diagnostic. If other causes of vomiting are more likely, performing a UGI series first can be more cost-effective.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☼	<0.1 mSv	<0.03 mSv
☼ ☼	0.1-1 mSv	0.03-0.3 mSv
☼ ☼ ☼	1-10 mSv	0.3-3 mSv
☼ ☼ ☼ ☼	10-30 mSv	3-10 mSv
☼ ☼ ☼ ☼ ☼	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).		

Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

References

1. Stinger DA, Babyn PS, eds. *Pediatric Gastrointestinal Imaging and Intervention*. 2nd ed. Hamilton, Ontario, Canada: Decker; 2000.
2. Hilton S. The child vomiting. In: Hilton S, Edwards D, eds. *Practical Pediatric Radiology*. Philadelphia, Pa.: BC Decker; 1994:297-299.
3. Ryan S, Donoghue V. Gastrointestinal pathology in neonates: new imaging strategies. *Pediatr Radiol* 2010; 40(6):927-931.
4. Hernanz-Schulman M. Imaging of neonatal gastrointestinal obstruction. *Radiol Clin North Am* 1999; 37(6):1163-1186, vi-vii.
5. Kilbride H, Castor C, Andrews W. Congenital duodenal obstruction: timing of diagnosis during the newborn period. *J Perinatol* 2010; 30(3):197-200.
6. Lilien LD, Srinivasan G, Pyati SP, Yeh TF, Pildes RS. Green vomiting in the first 72 hours in normal infants. *Am J Dis Child* 1986; 140(7):662-664.
7. Strouse PJ. Disorders of intestinal rotation and fixation ("malrotation"). *Pediatr Radiol* 2004; 34(11):837-851.
8. Sizemore AW, Rabbani KZ, Ladd A, Applegate KE. Diagnostic performance of the upper gastrointestinal series in the evaluation of children with clinically suspected malrotation. *Pediatr Radiol* 2008; 38(5):518-528.
9. Hernanz-Schulman M. Pyloric stenosis: role of imaging. *Pediatr Radiol* 2009; 39 Suppl 2:S134-139.
10. Cohen HL, Haller JO, Mestel AL, Coren C, Schechter S, Eaton DH. Neonatal duodenum: fluid-aided US examination. *Radiology* 1987; 164(3):805-809.
11. Hayden CK, Jr., Boulden TF, Swischuk LE, Lobe TE. Sonographic demonstration of duodenal obstruction with midgut volvulus. *AJR* 1984; 143(1):9-10.
12. Yousefzadeh DK, Kang L, Tessicini L. Assessment of retroesophageal position of the third portion of the duodenum: an US feasibility study in 33 newborns. *Pediatr Radiol* 2010; 40(9):1476-1484.
13. Weinberger E, Winters WD, Liddell RM, Rosenbaum DM, Krauter D. Sonographic diagnosis of intestinal malrotation in infants: importance of the relative positions of the superior mesenteric vein and artery. *AJR* 1992; 159(4):825-828.
14. Chao HC, Kong MS, Chen JY, Lin SJ, Lin JN. Sonographic features related to volvulus in neonatal intestinal malrotation. *J Ultrasound Med* 2000; 19(6):371-376.
15. Patino MO, Munden MM. Utility of the sonographic whirlpool sign in diagnosing midgut volvulus in patients with atypical clinical presentations. *J Ultrasound Med* 2004; 23(3):397-401.
16. Shimanuki Y, Aihara T, Takano H, et al. Clockwise whirlpool sign at color Doppler US: an objective and definite sign of midgut volvulus. *Radiology* 1996; 199(1):261-264.
17. Orzech N, Navarro OM, Langer JC. Is ultrasonography a good screening test for intestinal malrotation? *J Pediatr Surg* 2006; 41(5):1005-1009.
18. Manning PB, Murphy JP, Raynor SC, Ashcraft KW. Congenital diaphragmatic hernia presenting due to gastrointestinal complications. *J Pediatr Surg* 1992; 27(9):1225-1228.
19. Cribbs RK, Gow KW, Wulkan ML. Gastric volvulus in infants and children. *Pediatrics* 2008; 122(3):e752-762.
20. Rescorla FJ, Grosfeld JL. Contemporary management of meconium ileus. *World J Surg* 1993; 17(3):318-325.
21. Al-Khawari HA, Sinan TS, Seymour H. Diagnosis of gastro-oesophageal reflux in children. Comparison between oesophageal pH and barium examinations. *Pediatr Radiol* 2002; 32(11):765-770.
22. Kovanlikaya A, Miller JH, Williams HT. Malrotation discovered during routine radionuclide gastric emptying study. *Pediatr Radiol* 1996; 26(8):531-533.
23. O'Keeffe FN, Stansberry SD, Swischuk LE, Hayden CK, Jr. Antropyloric muscle thickness at US in infants: what is normal? *Radiology* 1991; 178(3):827-830.
24. Lederman HM, Demarchi G. Disorders of the Esophagogastric Junction. In: Slovis TA, ed. *Caffey's Pediatric Diagnostic Imaging*. 11th ed. St Louis, Mo: Mosby/Elsevier Science; 2008:2042-2055.
25. De Giacomo C, Maggiore G, Fiori P, et al. Chronic gastric torsion in infancy: a revisited diagnosis. *Australas Radiol* 1989; 33(3):252-254.

26. Hayden CK, Jr., Swischuk LE, Rytting JE. Gastric ulcer disease in infants: US findings. *Radiology* 1987; 164(1):131-134.
27. Swischuk LE, Hayden CK, Jr., van Caillie BD. Mega-aeroesophagus in children: a sign of gastroesophageal reflux. *Radiology* 1981; 141(1):73-76.
28. Rudolph CD, Mazur LJ, Liptak GS, et al. Guidelines for evaluation and treatment of gastroesophageal reflux in infants and children: recommendations of the North American Society for Pediatric Gastroenterology and Nutrition. *J Pediatr Gastroenterol Nutr* 2001; 32 Suppl 2:S1-31.
29. Bowen A. The vomiting infant: recent advances and unsettled issues in imaging. *Radiol Clin North Am* 1988; 26(2):377-392.
30. Seibert JJ, Byrne WJ, Euler AR, Latture T, Leach M, Campbell M. Gastroesophageal reflux--the acid test: scintigraphy or the pH probe? *AJR* 1983; 140(6):1087-1090.
31. Orenstein SR, Klein HA, Rosenthal MS. Scintigraphy versus pH probe for quantification of pediatric gastroesophageal reflux: a study using concurrent multiplexed data and acid feedings. *J Nucl Med* 1993; 34(8):1228-1234.
32. Villanueva-Meyer J, Swischuk LE, Cesani F, Ali SA, Briscoe E. Pediatric gastric emptying: value of right lateral and upright positioning. *J Nucl Med* 1996; 37(8):1356-1358.
33. Yapici O, Basoglu T, Canbaz F, Sever A. The role of coughing as a gastroesophageal-reflux provoking maneuver: the scintigraphical evaluation. *Nucl Med Commun* 2009; 30(6):440-444.
34. Morigeri C, Bhattacharya A, Mukhopadhyay K, Narang A, Mittal BR. Radionuclide scintigraphy in the evaluation of gastroesophageal reflux in symptomatic and asymptomatic preterm infants. *Eur J Nucl Med Mol Imaging* 2008; 35(9):1659-1665.
35. Heyman S, Eicher PS, Alavi A. Radionuclide studies of the upper gastrointestinal tract in children with feeding disorders. *J Nucl Med* 1995; 36(2):351-354.
36. Riccabona M, Maurer U, Lackner H, Uray E, Ring E. The role of sonography in the evaluation of gastro-oesophageal reflux--correlation to pH-metry. *Eur J Pediatr* 1992; 151(9):655-657.
37. Pezzati M, Filippi L, Psaraki M, et al. Diagnosis of gastro-oesophageal reflux in preterm infants: sonography vs. pH-monitoring. *Neonatology* 2007; 91(3):162-166.
38. Gomes H, Lallemand A, Lallemand P. Ultrasound of the gastroesophageal junction. *Pediatr Radiol* 1993; 23(2):94-99.
39. Di Ciaula A, Portincasa P, Di Terlizzi L, Paternostro D, Palasciano G. Ultrasonographic study of postcibal gastro-esophageal reflux and gastric emptying in infants with recurrent respiratory disease. *World J Gastroenterol* 2005; 11(46):7296-7301.
40. Farina R, Pennisi F, La Rosa M, et al. Contrast-enhanced colour-Doppler sonography versus pH-metry in the diagnosis of gastro-oesophageal reflux in children. *Radiol Med* 2008; 113(4):591-598.
41. Argon M, Duygun U, Daglioz G, Omur O, Demir E, Aydogdu S. Relationship between gastric emptying and gastroesophageal reflux in infants and children. *Clin Nucl Med* 2006; 31(5):262-265.
42. Cohen HL, Zinn HL, Haller JO, Homel PJ, Stoane JM. Ultrasonography of pylorospasm: findings may simulate hypertrophic pyloric stenosis. *J Ultrasound Med* 1998; 17(11):705-711.
43. Hernanz-Schulman M, Sells LL, Ambrosino MM, Heller RM, Stein SM, Neblett WW, 3rd. Hypertrophic pyloric stenosis in the infant without a palpable olive: accuracy of sonographic diagnosis. *Radiology* 1994; 193(3):771-776.
44. Haller JO, Cohen HL. Hypertrophic pyloric stenosis: diagnosis using US. *Radiology* 1986; 161(2):335-339.
45. St Peter SD, Holcomb GW, 3rd, Calkins CM, et al. Open versus laparoscopic pyloromyotomy for pyloric stenosis: a prospective, randomized trial. *Ann Surg* 2006; 244(3):363-370.
46. Rothrock SG, Green SM, Harding M, et al. Plain abdominal radiography in the detection of acute medical and surgical disease in children: a retrospective analysis. *Pediatr Emerg Care* 1991; 7(5):281-285.
47. Blumhagen JD, Maclin L, Krauter D, Rosenbaum DM, Weinberger E. Sonographic diagnosis of hypertrophic pyloric stenosis. *AJR* 1988; 150(6):1367-1370.
48. Swischuk LE, Hayden CK, Jr., Stansberry SD. Sonographic pitfalls in imaging of the antropyloric region in infants. *Radiographics* 1989; 9(3):437-447.
49. Forster N, Haddad RL, Choroomi S, Dille AV, Pereira J. Use of ultrasound in 187 infants with suspected infantile hypertrophic pyloric stenosis. *Australas Radiol* 2007; 51(6):560-563.
50. Wilson DA, Vanhoutte JJ. The reliable sonographic diagnosis of hypertrophic pyloric stenosis. *J Clin Ultrasound* 1984; 12(4):201-204.
51. Stunden RJ, LeQuesne GW, Little KE. The improved ultrasound diagnosis of hypertrophic pyloric stenosis. *Pediatr Radiol* 1986; 16(3):200-205.
52. Swischuk LE, Hayden CK, Jr., Tyson KR. Short segment pyloric narrowing. Pylorospasm or pyloric stenosis? *Pediatr Radiol* 1981; 10(4):201-205.
53. Cohen HL, Blumer SL, Zucconi WB. The sonographic double-track sign: not pathognomonic for hypertrophic pyloric stenosis; can be seen in pylorospasm. *J Ultrasound Med* 2004; 23(5):641-646.
54. Foley LC, Slovis TL, Campbell JB, Strain JD, Harvey LA, Luckey DW. Evaluation of the vomiting infant. *Am J Dis Child* 1989; 143(6):660-661.
55. Forman HP, Leonidas JC, Kronfeld GD. A rational approach to the diagnosis of hypertrophic pyloric stenosis: do the results match the claims? *J Pediatr Surg* 1990; 25(2):262-266.
56. Olson AD, Hernandez R, Hirschl RB. The role of ultrasonography in the diagnosis of pyloric stenosis: a decision analysis. *J Pediatr Surg* 1998; 33(5):676-681.
57. Graif M, Itzhak Y, Avigad I, Strauss S, Ben-Ami T. The pylorus in infancy: overall sonographic assessment. *Pediatr Radiol* 1984; 14(1):14-17.
58. Nagita A, Yamaguchi J, Amemoto K, Yoden A, Yamazaki T, Mino M. Management and ultrasonographic appearance of infantile hypertrophic pyloric stenosis with intravenous atropine sulfate. *J Pediatr Gastroenterol Nutr* 1996; 23(2):172-177.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.