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REVIEW

# Selecting appropriate gastroenteric contrast media for diagnostic fluoroscopic imaging in infants and children: a practical approach

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**Abstract** In our experience, questions about the appropriate use of enteric contrast media for pediatric fluoroscopic studies are common. The purpose of this article is to provide a comprehensive review of enteric contrast media used for pediatric fluoroscopy, highlighting the routine use of these media at a large tertiary care pediatric teaching hospital.

**Keywords** Adolescents · Children · Enteric contrast · Infants · Pediatric · Fluoroscopy

## Introduction

The American College of Radiology (ACR) provides an extensive review on the use of enteric contrast media for fluoroscopy studies in adults, but there is a relative paucity of information on its appropriate use in children [1]. Many pediatric gastrointestinal diseases differ from those in adults, therefore, special considerations are necessary when choosing enteric contrast media for pediatric fluoroscopic studies. Perhaps more importantly, children are more susceptible to fluid shifts and aspiration pneumonitis from enteric administration of hyperosmolar iodinated contrast media, requiring specific consideration by the practicing radiologist. This is particularly true for neonates, infants of very low birth weight, and older children with cardiac and renal impairment.

In the authors' experience, questions regarding appropriate use of enteric contrast media for pediatric fluoroscopy are common. Choosing appropriate contrast media is critical to ensure patient safety and diagnostic accuracy for pediatric fluoroscopy. The purpose of this article is to provide a comprehensive review of gastroenteric contrast media used for pediatric fluoroscopy, highlighting the routine use of these media at a large tertiary care pediatric teaching hospital.

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## Contrast media

### Barium sulfate

Barium sulfate is an inorganic compound derived from the element barium (atomic number 56) and is an inert white crystalline solid that is radiopaque and poorly soluble in water. It can be administered as a suspension either orally, rectally or via an ostomy or catheter for fluoroscopic studies. Barium sulfate suspension is neither absorbed nor metabolized in the gastrointestinal tract and is excreted unchanged in the feces. The density of barium sulfate suspension is expressed in a weight/weight (w/w) or weight/volume (w/v) ratio. The w/w ratio indicates the number of grams of active ingredient per 100 g of product, and the w/v equals the number of grams of active ingredient per 100 mL.

We use a variety of barium sulfate suspensions for diagnostic pediatric fluoroscopic studies including Liquid E-Z-Paque, (60% w/v, 41% w/w; E-Z-EM Inc., Westbury, NY), Varibar thin liquid (40% w/v, after reconstitution; E-Z-EM Inc., Westbury, NY) and E-Z-HD (98% w/w; E-Z-EM Inc., Westbury, NY). Varibar and E-Z-HD are typically used for modified barium swallow studies [2] and E-Z-Paque is typically used for the performance of contrast esophagrams and upper gastrointestinal examinations [3], and contrast examinations of the small bowel [4]. These media can be effectively administered to a child orally, via a transesophageal catheter, a gastrostomy, jejunostomy or ileostomy. Barium sulfate suspension can also be administered for certain cecostomy, colostomy or colonic mucous fistula studies [5, 6]. Although barium sulfate suspension can be safely administered rectally, our institution does not routinely use it for fluoroscopic contrast enema studies [5].

Barium sulfate is an extremely versatile gastroenteric contrast medium. It can be effectively used for a wide range of patient sizes and for many types of pediatric fluoroscopic examinations described above. Figure 1 demonstrates the high image contrast achieved with barium sulfate suspension under a range of acquisition conditions compared to other enteric contrast media utilizing phantoms that simulate small and large patients, imaged both with and without a grid. Image contrast decreases with increased scatter at the image intensifier as a result of increased patient size and removal of the anti-scatter grid (Fig. 1), although barium sulfate suspension is clearly seen on all images. Figure 2 demonstrates the relative image contrast of barium sulfate suspension under both fluoroscopy last image hold and fluorography single-shot fluorography techniques. The increased contrast of barium sulfate relative to iodine-based media is more noticeable in smaller volumes and under low-noise conditions in the single-shot fluorography image (Fig. 2).

Barium sulfate suspension is well tolerated orally by most children and is typically administered with the addition of commercially based flavoring or flavored by individual radiology practices to improve its palatability. This contrast media can also be administered by syringe or transesophageal catheter, if necessary. Barium sulfate suspension is considerably less expensive than most iodinated non-ionic contrast media for a given volume of contrast.

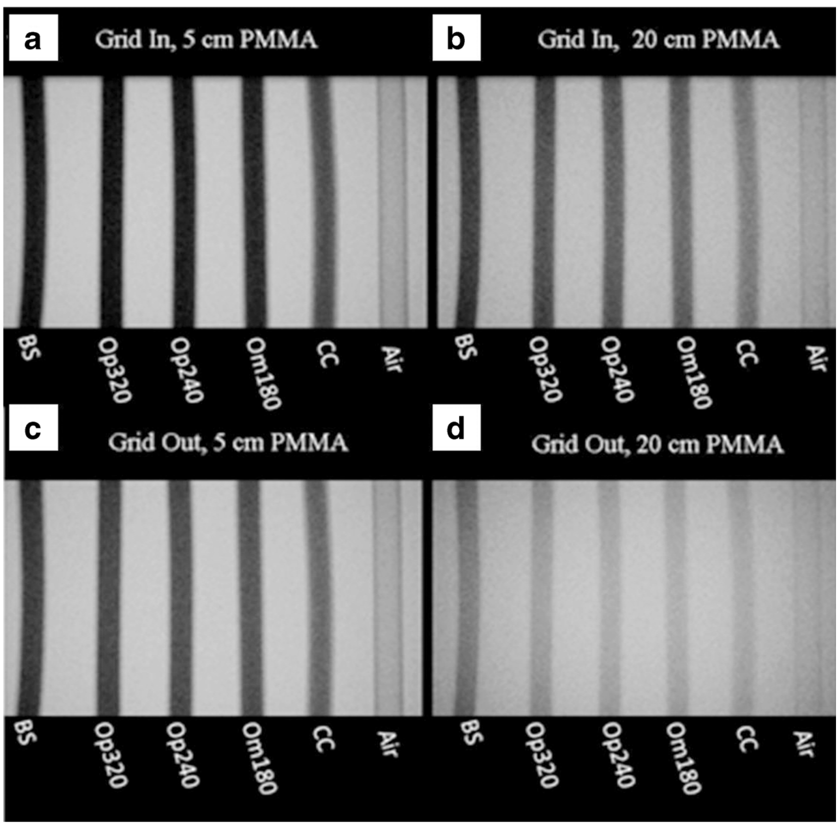


**Fig. 1** Last image hold frames of polyvinyl chloride tubing (wall thickness ~ 2 mm, inside diameter = 1.5 cm) filled with enteric contrast of varying density acquired under four different fluoroscopy modes. The acquisition mode was based on the manufacturer's recommended protocol for imaging of the esophagus with enteric contrast. Enteric contrast is labeled as: *BS* barium sulfate suspension, *Op320* Optiray (ioversol) 320, *Op240* Optiray (ioversol) 240, *Om180* Omnipaque (iohexol) 180, *CC* Cysto-Conray II (iothalamate meglumine) and air (as labeled). The image intensifer was locked at 20 cm above table top and imaged under fluoroscopy with 5 cm (simulating a small patient) and 20 cm (simulating a large patient) of Polymethyl Methacrylate (PMMA) stacked over the contrast tubes with both the grid inserted and removed. **a** Image with parameters of 44 kV, 6 mA and 10 ms fluoroscopy pulse width shows similar relative contrast for BS, Op320, Op 240, Om180, and CC in a low-scatter environment. **b** Image with parameters 68 kV, 20 mA and 15 ms shows noticeably reduced relative contrast for all media and greater separation between contrast materials as a result of increased scatter from thicker PMMA. **c** Image with parameters 40 kV, 5 mA and 5 ms shows similar relative contrast to (**a**) with only slightly lower overall contrast as a result of the marginal increase in scatter from 5 cm PMMA without an anti-scatter grid. **d** Image with parameters 58 kV, 10 mA and 4 ms shows drastically reduced overall contrast in a high-scatter environment, in a large patient without a grid

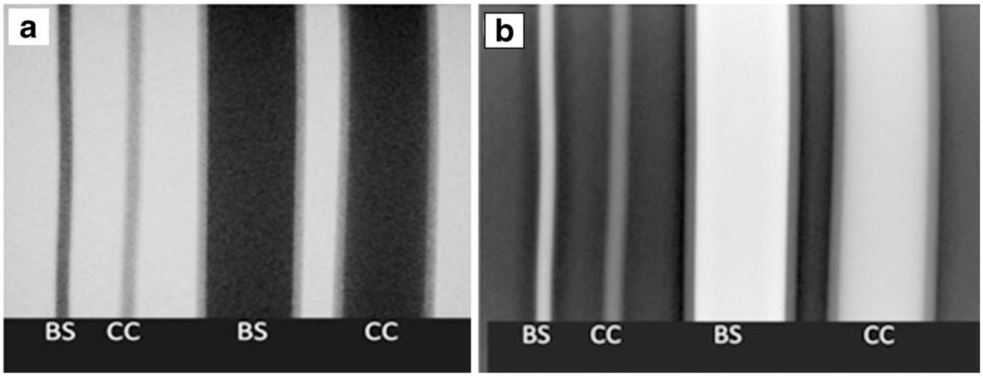


**Fig. 2** Polyvinyl chloride tubing (inner diameter = 0.5 cm for smaller caliber tubes and 1.5 cm for larger tubes) each filled with barium sulfate suspension (BS) and iothalamate meglumine (Cysto-Conray [CC]). Image (**a**) was acquired under fluoroscopy last image hold and image (**b**) was acquired under single-shot fluorography (i.e. spot film). Both demonstrate the difference in density between barium sulfate suspension and iothalamate meglumine (Cysto-Conray II [CC]) in the smaller lumen tubes, which would simulate a neonatal esophagus or sinus tract versus a larger lumen tube, which would simulate a loop of colon. The relative difference in contrast is more noticeable using single-shot fluorography due to decreased noise

Although the lack of solubility of barium sulfate suspension in water is an advantage in certain situations, it is disadvantageous in the evaluation of a suspected perforated viscus. If barium sulfate suspension exits the gastrointestinal tract into surrounding soft tissues, it will remain there permanently unless surgically removed and may produce an inflammatory response. The use of barium sulfate suspension for suspected postoperative esophageal leaks, however, has been described in adults [7].

## Iodinated water-soluble contrast media

With the exception of barium sulfate suspension, all other manufactured enteric contrast media for fluoroscopy are derived from the element iodine (atomic number 53). Because of its relatively low level of toxicity, water solubility and ability to bind to organic compounds, iodinated compounds are also commonly used as enteric contrast media in pediatric diagnostic imaging. Many iodine-based contrast media have a noxious or bitter taste [8]. This can create a challenge for oral administration in young children, and syringe or transesophageal catheter administration is sometimes required for effective administration.

Although iohexol (Omnipaque; GE Healthcare, Cork, Ireland) is the only iodine-based low-osmolality contrast media (LOCM) approved by the United States Food and Drug Administration (FDA) for enteric use, virtually any LOCM can be used off-label as enteric contrast media in children, and according to Version 10.2 of the ACR Manual on Contrast Media, any iodinated contrast media supplied for intravenous use can be administered safely by mouth or per rectum [1]. A full list of these media are provided in Appendix A of the ACR Manual on Contrast Media, Version 10.2 [1].

In this article, the term "low-osmolar" will be used to encompass both LOCM and near iso-osmolar contrast media (IOCM), although only near IOCM have an osmolality that is similar to human serum (Table 1). LOCM are so named because of their osmolality relative to high-osmolality contrast media (HOCM); however, many of these contrast media still have approximately double the osmolality of human serum (Table 1). Iodinated contrast media can be subclassified by the number of milligrams of organically bound iodine in 1 mL of solution (e.g., 240, 320, 370), and by the percentage weight of the contrast molecule in solution (e.g., 17.2%, 51%, 68%). Notably, at a given iodine concentration, nonionic monomers have about half the osmolality of ionic monomers.

Diatrizoate meglumine diatrizoate sodium solution, distributed as Gastrografin (Bracco Diagnostics Inc., Monroe Township, NJ) and Gastroview (Mallinckrodt Inc., St. Louis, MO), are considered HOCM and are FDA approved for enteric use. These media are frequently used for adult

**Table 1** Iodine content and osmolality of enteric contrast media at Boston Children's Hospital

| Contrast media | Iodine content (mg/ml) | Osmolality[a] (mOsm/kg water) |
|---|---|---|
| Iothalamate meglumine (Cysto-Conray II)[b] | 81 | 400 |
| Iohexol (Omnipaque) 180 | 180 | 331 |
| Ioversol (Optiray) 240[c] | 240 | 502 |
| Ioversol (Optiray) 320[c] | 320 | 702 |
| Diatrizoate meglumine (Gastrografin or Gastroview) | 370 | 1940 |
| Barium sulfate suspension | NA | NA |

*NA* not applicable

[a] Normal serum osmolality is 275-295 mOsm/kg

[b] Alternate is dilute Cystografin (diatrizoate meglumine)

[c] Can substitute with similar low-osmolality contrast media listed in Appendix A, American College of Radiology Manual on Contrast Media 10.2 [1]

fluoroscopy examinations but can be dangerous when administered to infants and small children. Because of their high osmolality, it is the authors' opinion that HOCM should never be administered full strength to an infant or child. Aspiration of orally administered HOCM may cause significant pneumonitis. In addition, dangerous fluid shifts can occur even when diluted HOCM is administered orally or rectally.

## Air

Air can serve as natural contrast in the gastrointestinal tract; however, its presence and radiographic appearance are inconsistent. The appearance of air on fluoroscopic images can vary widely from patient to patient and even within the same patient over a relatively short period of time. Therefore, air has a limited role as enteric contrast in diagnostic examinations. Double-contrast upper gastrointestinal and enema examinations using both air and enteric contrast media can be performed using bicarbonate powder and barium sulfate suspension for upper gastrointestinal studies, and a combination of rectally administered barium sulfate suspension and insufflated air can also be administered for a double-contrast diagnostic enema examination. Notably, double-contrast studies are rarely, if ever, performed in children at the authors' institution.

In the setting of ileocolic intussusception, air can be administered under pressure in a controlled manner with fluoroscopic guidance to successfully reduce an idiopathic intussusception in a majority of cases [9–14]. Air is easily visualized during an air contrast enema. If used properly, its administration is relatively safe, although bowel perforation remains an important complication to consider. Surveys of the Society for Pediatric Radiology [13] and the European Society of Paediatric Radiology [15] have demonstrated that air reduction is the most common technique for intussusception reduction in infants and children, and air is generally thought to be cleaner, quicker and more effective than liquid enteric contrast media [16, 17]. However, the efficacy of radiopaque enteric contrast media for the reduction of pediatric ileocolic intussusception has also been described [14].

## Technical considerations

The relative radiopacity of iodinated contrast media is directly proportional to its iodine concentration (Table 1), although when focused in a large enough volume, most iodinated contrast media have a similar radiographic density (Fig. 1). This is particularly true when using the last image hold technique (Fig. 2), where the dose per frame is lower and noise level is higher than on a single-shot fluorography (i.e spot film) image, which minimizes patient exposure to ionizing radiation. The difference between iodine concentrations is most noticeable when using smaller contrast volumes (Fig. 2) or in high-scatter environments, particularly when the anti-scatter grid is removed (Fig. 1).

Image contrast in a fluoroscopic image, characterized by the contrast-to-noise ratio, varies widely with fluoroscopic technique and physical properties of contrast media. These physical properties, including density, concentration and volume, determine the level of subject contrast and therefore the maximum level of image contrast in the contrast-to-noise ratio equation. The fluoroscopic technique (e.g., kV, mA, pulse rate, anti-scatter grid) determines the amount of scatter and noise in a fluoroscopic frame. Scatter reduces the image contrast and hence the contrast-to-noise ratio of all objects in an image. As a result, differences in subject contrast will be much more apparent under high scatter conditions (Fig. 1). A reduction in image noise also improves image contrast by increasing the contrast-to-noise ratio (Fig. 2).

For small patients, who would represent a low scatter scenario, the relative radiopacity of commonly used enteric contrast media appears very similar (Fig. 1) and as a result, the anti-scatter grid should be removed if possible to decrease radiation dose. For larger patients with increased scatter (Fig. 1), the grid should be inserted to improve overall contrast visualization. Tight collimation to a limited field of view will also improve contrast visualization by reducing scatter and has the added benefit of reducing overall patient radiation dose.

## Adverse and allergic-like reactions to gastroenteric contrast media

Adverse reactions to orally or rectally administered barium sulfate suspension and nonionic iodinated contrast have been described, but are rare [18–21], particularly allergic-like reactions. There is a slightly increased incidence of adverse side effects such as diarrhea, vomiting, cramping, nausea and, rarely, urticaria, associated with iodinated contrast agents relative to barium sulfate suspension [22, 23].

A small percentage of ingested iodinated contrast media is absorbed by the bowel [24]. Theoretically, iodinated contrast media can be absorbed from any surface or cavity of the body. Even small volumes of enterically absorbed iodinated contrast media can cause an anaphylactoid-like reaction, and these events are more likely in patients with a prior history of such reactions to iodinated contrast media [24]. Davis [21] provides recommendations and general guidelines for the nonvascular administration of iodine-based contrast media, including enteric use. It should be noted that severe reactions can occur with the enteric administration of iodine-based contrast media, and properly trained staff must be present to treat these potential reactions [21]. Although premedication does not prevent all anaphylactoid-like reactions to iodine-based contrast media, the authors recommend a standard premedication regimen if the patient has a past history of moderate to severe anaphylactoid-like reactions to an intravascular administration of an iodinated contrast media. In these patients, iodine-based enteric contrast media should only be administered after premedication if it is not feasible to attain the same clinical information with barium sulfate suspension or similar media.

The U.S. Food and Drug Administration also reports hypothyroidism and transient thyroid suppression as uncommon adverse reactions to iodinated contrast media for both adults and children, including infants [25].

## Gastroenteric studies

### Contrast esophagram, upper gastrointestinal examinations and contrast examinations of the small bowel

Contrast esophagram and upper gastrointestinal examinations are among the most commonly requested studies in pediatric gastrointestinal imaging, and appropriate indications for these studies are well described. In the authors' experience, the most common clinical requests for a contrast esophagram are dysphagia, tracheoesophageal fistula or leak, esophageal stricture or evaluation of extrinsic mass effect on the esophagus, as in the case of a vascular ring. The most common requests for upper gastrointestinal examinations are vomiting, including bilious emesis, concern for upper gastrointestinal tract obstruction, acute or chronic abdominal pain, recent gastric or small bowel surgery, or suspected upper gastrointestinal tract bowel injury (Table 2). Indications for upper gastrointestinal examinations with associated contrast examination of small bowel are chronic abdominal pain, diarrhea, weight loss or evaluation of known inflammatory bowel disease [1, 26]. The principles for choosing an enteric contrast media are similar for these three studies.

The vast majority of contrast esophagrams, upper gastrointestinal examinations and contrast examinations of the small bowel at our institution are performed using barium sulfate suspension. In cases where there is concern for luminal leak or perforation, barium sulfate suspension is typically not used because of its lack of water solubility. Therefore, we routinely use water-soluble LOCM to evaluate the upper abdominal hollow viscera in the setting of recent esophageal (Fig. 3), gastric (Fig. 4) or proximal small bowel surgery, particularly if there is clinical suspicion for a hollow visceral perforation (Fig. 5), in the setting of foreign body ingestion or anastomotic leak. Dedicated single-shot fluorography can help demonstrate a subtle leak, and is superior to fluoroscopic last image hold for this indication (Figs. 3 and 4).

In premature newborns, it is the authors' opinion that either barium sulfate suspension or near IOCM such as iohexol 180 can be used for diagnostic upper gastrointestinal studies. However, in the setting of suspected small bowel obstruction, the authors prefer iohexol 180 over barium sulfate suspension (Table 2), which tends to flocculate in the setting of obstruction. Disadvantages of iohexol 180 are its relatively lower density (Fig. 6), limiting its use in larger term infants and small children (Fig. 1), and its increased cost relative to barium sulfate suspension.

**Table 2** Indications for oral contrast media in pediatric fluoroscopy

| Study | Indication | Contrast media |
|---|---|---|
| Upper gastrointestinal examination or esophagram | vomiting (especially bilious) | barium sulfate suspension or iso-osmolar water soluble (premature infant) |
| | acute or chronic abdominal pain | barium sulfate suspension |
| | choking sensation or dysphagia | barium sulfate suspension |
| | recent esophageal, gastric or small bowel surgery | low osmolar water soluble |
| | suspected esophageal, gastric or small bowel injury (blunt, penetrating or iatrogenic trauma) | low osmolar water soluble |
| Upper gastrointestinal examination with small bowel follow through | abdominal pain or obstruction | barium sulfate suspension or iso-osmolar water soluble (premature infant) |
| | weight loss or suspected inflammatory bowel disease | barium sulfate suspension |
| | premature infant with concern for necrotizing enterocolitis | iso-osmolar water soluble |
| Tube study | check placement of enteric or cecostomy tube | low osmolar water soluble or barium sulfate suspension |
| | placement of nasojejunal tube | low osmolar water soluble or barium sulfate suspension |
| Small bowel enteroclysis | suspected small bowel disease | barium sulfate suspension +/− hydroxypropyl methylcellulose, $CO_2$, or air |
| Modified barium swallow | dysphagia, suspected aspiration, pneumonia, choking with feeding, developmental delay | barium sulfate suspension (various consistencies: thin, nectar, honey, purée, solid foods) |

*$CO_2$* carbon dioxide

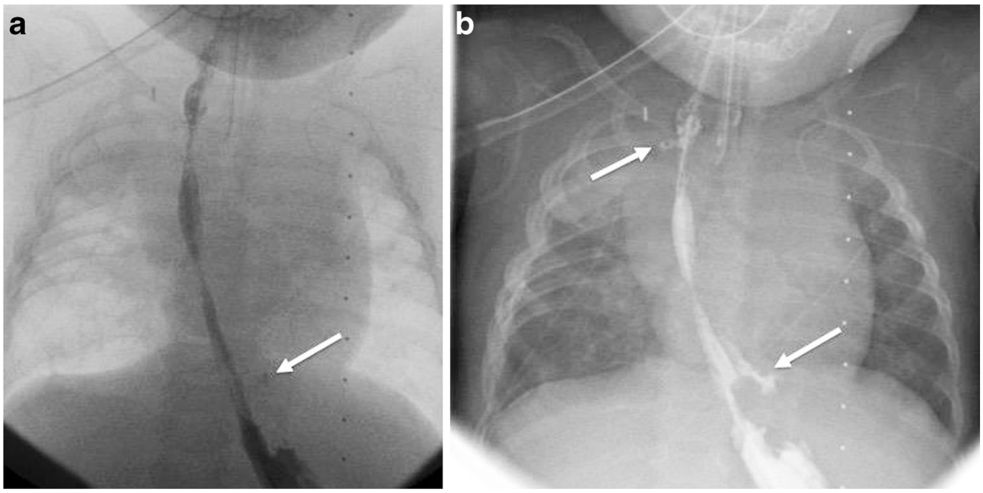


**Fig. 3** An esophagram in a 6-month-old girl with a history of long gap esophageal atresia. Iohexol 180 was administered via transesophageal catheter. Last image hold (**a**) demonstrates an esophageal leak along the distal esophagus (*arrow*). Contrast is more easily visible with a dedicated single-shot fluorography (**b**), where two esophageal leaks are now visible (*arrows*), both proximally and distally. When utilizing real-time fluoroscopy and last image hold technique, contrast media defaults to a black or dark gray display of the contrast media. When utilizing dedicated single-shot fluorography, our contrast media display defaults to white. Increased signal to noise through the use of more photons, in addition to the inverted display, improves conspicuity of contrast media when using spot images, particularly for a small collection

If possible, children should fast prior to a routine upper gastrointestinal examination. At our institution, we request fasting for 2 h if <1 year of age, 4 h for ages 1–4 years, and 6 h for children 5 years of age and older. Hunger from brief periods of fasting can often facilitate voluntary ingestion of oral contrast in most patients, particularly infants and young children. Fasting also promotes gastric emptying and minimizes food residue in the stomach and proximal small bowel.

Enteroclysis requires the placement of a transesophageal tube directly into the proximal small bowel, and is less commonly performed in children than adults [4], particularly for fluoroscopic small bowel studies. Enteroclysis (Table 2) studies have the potential advantage of more optimal distension of small bowel and better delineation of mucosal detail relative to conventional upper gastrointestinal examinations. Both single- and double-contrast enteroclysis techniques have been described [27] utilizing medium-density barium for single-contrast technique and high-density barium for the double-contrast technique with additional administration of hydroxypropyl methylcellulose, carbon dioxide or air.

## Enteric and ostomy catheter evaluations

Localization of gastrostomy, jejunostomy, gastrojejunostomy, nasojejunostomy and cecostomy catheters as well as orally and nasally inserted catheters and stomal catheters are commonly requested at our institution (Table 2). For these studies, we perform a catheter injection of either LOCM or barium sulfate suspension via a syringe. If an ostomy catheter was recently placed, or if there is a clinical concern that an ostomy catheter may be extraluminal, LOCM is used (Table 2). When an ostomy catheter is actively being utilized for patient feeding, in general, barium sulfate solution can be safely administered through this catheter.

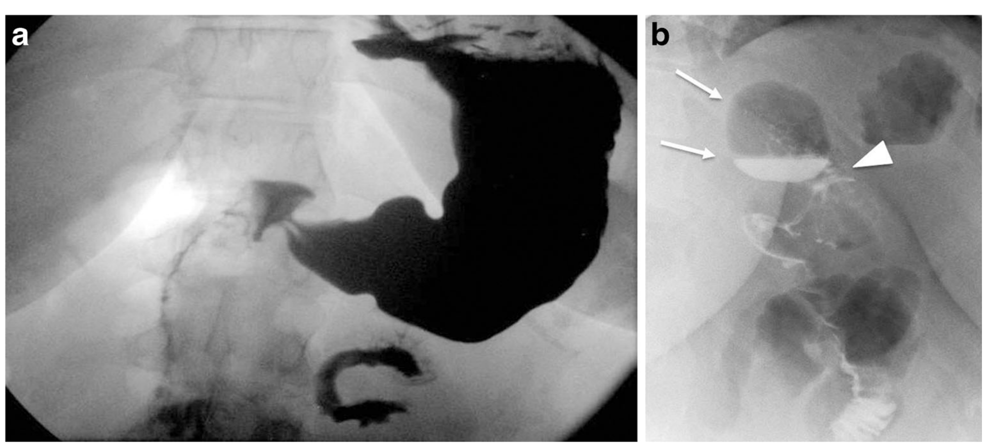


**Fig. 4** A 19-year-old woman with morbid obesity. Preoperative upper gastrointestinal series was performed with barium sulfate suspension (**a**) using last image hold technique. Postoperative upper gastrointestinal series after gastric bypass was performed using ioversol 320 (**b**), adequately demonstrating the residual stomach after bypass (*arrows*) and the gastrojejunal anastomosis (*arrowhead*) using single-shot fluorography

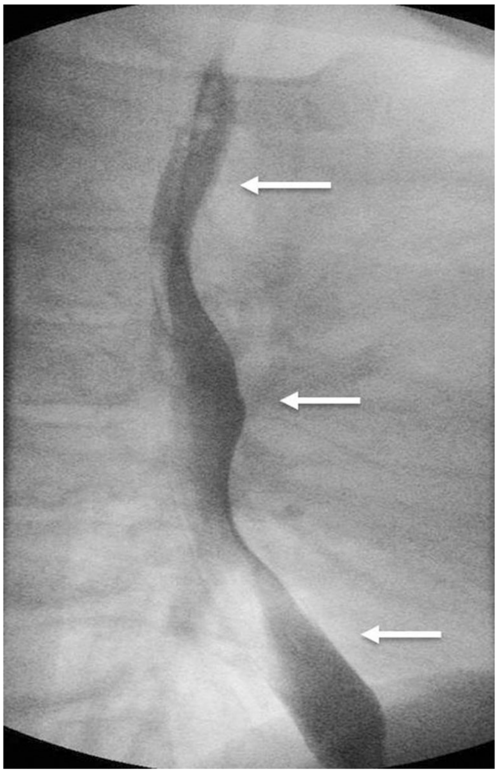

**Fig. 5** A 13-year-old girl swallowed a metal foreign body. An esophagram was requested to exclude esophageal perforation. The study was performed using ioversol 320, providing adequate visualization of the esophagus (*arrows*) and exclusion of perforation using last image hold technique

## Modified barium swallow

The modified barium swallow (Table 2) is a specialized fluoroscopic exam performed jointly by a radiologist and speech pathologist at our institution. Real-time fluoroscopy is performed to evaluate oral, pharyngeal and upper esophageal phases of swallowing. Various consistencies of liquid, semi-solid, and solid foods are mixed with barium sulfate powder and are administered to the patient in an upright or semi-upright lateral position. One-half cup of thin barium is mixed with 1½ teaspoons of thickener to create a nectar consistency, and 1½ tablespoons of thickener is used to create a honey-like consistency. Although our speech pathologists use thickener to create these nectar and honey consistencies, commercially available barium sulfate suspensions are available (e.g., Varibar® Thin Liquid, Varibar® Nectar, Varibar® Honey, Varibar® Pudding; Bracco/E-Z-EM Inc., Lake Success, NY). Water-soluble LOCM and IOCM iodinated contrast media can become relatively radiolucent when diluted with thickener, limiting their utility for modified barium swallow studies. In addition, given the risks of aspiration of certain water-soluble iodinated contrast in infants and small children, especially HOCM, these media are not used for modified barium swallow studies at our institution.

## Diagnostic contrast enema

Appropriate indications for contrast enema studies in infants, children and adolescents include low intestinal obstruction in the newborn, intractable constipation, evaluation of stricture in the setting of necrotizing enterocolitis [28, 29], or for post-surgical evaluation of the colon and/or lower small intestine (Table 3). At our institution, the majority of diagnostic contrast enemas are performed in newborns to evaluate clinical and radiographic signs of low intestinal obstruction. The differential diagnosis for low intestinal obstruction in the newborn includes Hirschsprung disease [30–32], small left colon syndrome [33, 34], meconium ileus or ileal/colonic atresia.

We routinely use iothalamate meglumine (Cysto-Conray

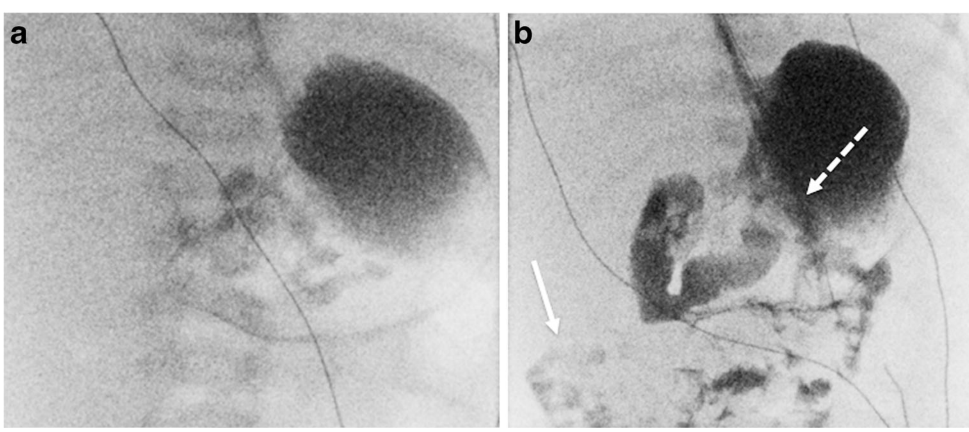


**Fig. 6** An upper gastrointestinal examination in a 1-day-old boy with bilious emesis performed with iohexol 180 (**a**). Because the water-soluble contrast was difficult for the radiology fellow to visualize with confidence, the study was electively repeated several hours later with barium sulfate suspension (**b**), which attenuates the x-ray beam substantially more than iohexol 180. Note the residual water-soluble contrast within more distal small bowel (*arrow*). Duodenojejunal junction is better demarcated with barium sulfate suspension (*dotted arrow*)

**Table 3** Indications for rectal contrast media in pediatric fluoroscopy

| Study | Indication | Contrast media |
|---|---|---|
| Diagnostic enema | low intestinal obstruction in newborn | ionic low osmolar water soluble |
| | concern for NEC stricture | ionic low osmolar water soluble |
| | intractable constipation | ionic low osmolar water soluble |
| Therapeutic enema | meconium ileus | dilute high osmolar water soluble (diluted 50% with water) |
| | Distal intestinal obstruction syndrome, also known as meconium ileus equivalent | dilute high osmolar water soluble (diluted to 25% with iothalamate meglumine) |
| Defecography | intractable constipation | barium sulfate suspension paste |
| Air enema | intussusception | air (pneumatic reduction) |

*NEC* necrotizing enterocolitis

II; Mallinckrodt, St. Louis, MO) for virtually all contrast enemas (Fig. 7) regardless of patient age. Because of its near-physiological osmolality (Table 1), iothalamate meglumine can be safely administered rectally in infants and, unlike barium sulfate solution, does not tend to complicate symptoms of constipation. Iothalamate meglumine or similar media can also be safely used as rectal contrast media in premature infants with suspected or known necrotizing enterocolitis [28, 29] for evaluation of stricture or perforation. In certain clinical situations, such as small left colon syndrome, meconium ileus and functional constipation, rectal administration of iothalamate meglumine may also be therapeutic, aiding in the evacuation of retained meconium or stool.

**Fig. 7** Last image hold technique from an enema using iothalamate meglumine in a 2-day-old boy with failure to pass meconium. Notice the small caliber of the rectum relative to the sigmoid colon. Rectal biopsy was diagnostic of Hirschsprung disease

Iohexol 180 has a similar osmolality to iothalamate meglumine (Table 1), but is approximately 30 times more expensive per unit volume at our institution, making it a less practical choice when a large volume of contrast is needed (e.g., diagnostic enema or stomagram study). Although iothalamate meglumine has a lower iodine content than other iodinated water-soluble contrast media (Table 1), the larger volume of contrast used in enemas allows for adequate visualization (Fig. 2).

The authors exclusively use iothalamate meglumine for contrast enema studies. However, barium sulfate suspension and diatrizoate meglumine (Dilute Cystografin; Bracco Diagnostics Inc., Princeton, NJ) can also be used effectively for diagnostic enemas in children and adolescents. Contrast media choice is based upon an individual radiologist's preference and specific clinical indication. Barium sulfate suspension, diatrizoate meglumine and iothalamate meglumine are easily visualized during enema studies in all age groups.

If iothalamate meglumine or similar contrast media are in short supply or temporarily unavailable, the authors dilute one part ioversol 320 with three parts normal saline to create a dilute contrast mixture that is similar in iodine content and substantially lower in osmolality to iothalamate meglumine 17.2%. Because any intravenous iodinated contrast media can be administered by mouth or per rectum [1] theoretically, any water-soluble iodinated contrast media could be appropriately diluted with saline to create a dilute mixture with similar iodine content to iothalamate meglumine or diatrizoate meglumine. The choice of media for dilution will likely depend on multiple factors, including cost, and which media are readily available.

Barium sulfate suspension has superior mucosal coating when compared with water-soluble enteric contrast agents; however, it is the authors' opinion that mucosal detail is not necessary when performing a diagnostic enema in a newborn or the majority of pediatric patients. Additionally, the use of barium sulfate suspension can be problematic in the setting of neonatal low intestinal obstruction, given the possibility of perforation and retained contrast. Double-contrast enemas and enemas for vague abdominal pain or rectal bleeding are rarely indicated in children and are not performed at the authors' institution. Occasionally, when the level of obstruction is unclear in a neonatal patient, both a contrast enema with water-soluble iodine-based contrast media and an upper gastrointestinal study with barium sulfate suspension can be performed consecutively. In this situation, the relative difference in density between rectally administered water-soluble iodine-based contrast media and orally administered barium sulfate suspension may help one to differentiate these media if used consecutively.

It is the opinion of the authors that full-strength, undiluted diatrizoate meglumine and diatrizoate sodium solution (Gastrografin or Gastroview) should never be administered for a diagnostic enema study in infants, children or adolescents because of its extreme hyperosmolarity (Table 1), and potential for serious physiological derangements, including significant fluid shifts, hypertonic dehydration and colonic necrosis [35–37].

Defecography (Table 3) is a study that can evaluate anorectal and pelvic floor function in children with defecation disorders [38]. While not performed at all pediatric centers, defecography can be a useful tool to evaluate children with refractory defecation disorders. Studies are generally performed with a thick barium paste (Anatrast; Lafayette Pharmaceuticals, Lafayette, IN) that is manually injected into the rectum with a caulking gun.

### Stomagrams

We perform stomagram studies (Table 4) using a technique similar to contrast enemas. Because a relatively large volume of enteric contrast is needed to perform a stomagram, we administer iothalamate meglumine via gravity after a Foley catheter tip is gently advanced into the ostomy. We most commonly perform these procedures with a Foley catheter with the balloon inflated outside the patient's stoma.

Evaluation of a known or suspected enterocutaneous fistula can be performed with a fistulogram or sinogram (Table 4), which can provide rapid information and can often be performed with minimal patient discomfort. In an effort to minimize patient risk and maximize benefit, water-soluble contrast media can be injected initially to exclude extravasation, followed by barium sulfate suspension if additional detail is required [39].

### Therapeutic contrast enema

In the authors' opinion, the only two indications for the use of HOCM in performing a therapeutic enema (Table 3) are newborn infants with meconium ileus causing low intestinal obstruction [40, 41], and in older children or adolescent patients with cystic fibrosis and meconium ileus equivalent, also known as distal intestinal obstruction syndrome (DIOS). While there is literature supporting the use of high osmolar iodine-based contrast media for the treatment of meconium ileus and DIOS, there is no consensus on the appropriate contrast concentration [40, 42, 43]. The use of n-acetylcystine to treat meconium ileus and DIOS has also been described [44]. In infants, the authors use equal volumes of diatrizoate meglumine and diatrizoate sodium solution and water to create a diluted mixture. Since even this half-strength contrast mixture is relatively hypertonic, special care should be taken to ensure the patient is well hydrated prior to the enema, as fluid shifts are common and can be clinically significant. In our experience, half-strength diatrizoate meglumine and diatrizoate sodium solution work as well as full strength to reduce meconium ileus.

**Table 4** Indications for stomal, sinus or enterocutaneous fistula contrast media in pediatric fluoroscopy

| Study | Indication | Contrast media |
|---|---|---|
| Stomagram | evaluation of parastomal stricture or obstruction | ionic low osmolar water soluble |
| Fistulogram or sinogram | suspected enterocutaneous fistula or cutaneous sinus | low osmolar water soluble, followed by barium sulfate suspension if necessary |

Older children and adolescent patients with DIOS frequently have chronic recurrent abdominal pain and occasionally become acutely obstructed due to viscous distal small bowel contents [43]. In this setting, the authors use diatrizoate meglumine and diatrizoate sodium solution diluted with iothalamate meglumine, mixing one part diatrizoate meglumine and diatrizoate sodium solution to three parts iothalamate meglumine. For refractory cases, a 50% mixture of diatrizoate meglumine and diatrizoate sodium solution and iothalamate meglumine can be used. Diatrizoate can also be diluted with water for similar effectiveness, but the contrast mixture will be slightly more dilute.

## Conclusion

Despite the relatively frequent use of enteric contrast media for pediatric imaging, in our experience, questions about the appropriate use of enteric contrast media for pediatric fluoroscopic studies are common. Many of the contrast media discussed in this paper are regularly used at a large tertiary care pediatric hospital and have worked well over an extended period of time for diagnostic pediatric fluoroscopy studies. We hope this article will serve as a useful resource for the safe and effective use of gastroenteric contrast media for infants, children and adolescents.

**Compliance with ethical standards**

**Conflicts of interest** None

## References

1. ACR (2016) American College of Radiology manual on contrast media, Version 10.2
2. ACR (2014) American College of Radiology practice parameter for the performance of the modified barium swallow
3. ACR (2015) American College of Radiology ACR-SPR practice parameter for the performance of contrast esophagrams and upper gastrointestinal examinations in infants and children

4. ACR (2013) American College of Radiology ACR-SPR practice parameter for the performance of pediatric contrast examinations of the small bowel
5. ACR (2014) American College of Radiology ACR-SPR practice parameter for the performance of pediatric fluoroscopic contrast enema examinations
6. ACR (2013) American College of Radiology ACR practice parameter for the performance of fluoroscopic contrast enema examination in adults
7. Gollub MJ, Bains MS (1997) Barium sulfate: a new (old) contrast agent for diagnosis of postoperative esophageal leaks. Radiology 202:360–362
8. McNamara MM, Lockhart ME, Fineberg NS et al (2010) Oral contrast media for body CT: comparison of diatrizoate sodium and iohexol for patient acceptance and bowel opacification. AJR Am J Roentgenol 195:1137–1141
9. Meyer JS (1992) The current radiologic management of intussusception: a survey and review. Pediatr Radiol 22:323–325
10. del-Pozo G, Albillos JC, Tejedor D et al (1999) Intussusception in children: current concepts in diagnosis and enema reduction. Radiographics 19:299–319
11. Fiorito ES, Recalde Cuestas LA (1959) Diagnosis and treatment of acute intestinal intussusception with controlled insufflation of air. Pediatrics 24:241–244
12. Gu L, Alton DJ, Daneman A et al (1988) John Caffey Award. Intussusception reduction in children by rectal insufflation of air. AJR Am J Roentgenol 150:1345–1348
13. Stein-Wexler R, O'Connor R, Daldrup-Link H et al (2015) Current methods for reducing intussusception: survey results. Pediatr Radiol 45:667–674
14. Sorantin E, Lindbichler F (2004) Management of intussusception. Eur Radiol 14:L146–L154
15. Schmit P, Rohrschneider WK, Christmann D (1999) Intestinal intussusception survey about diagnostic and nonsurgical therapeutic procedures. Pediatr Radiol 29:752–761
16. Meyer JS, Dangman BC, Buonomo C et al (1993) Air and liquid contrast agents in the management of intussusception: a controlled, randomized trial. Radiology 188:507–511
17. Sargent MA, Wilson BP (1991) Are hydrostatic and pneumatic methods of intussusception reduction comparable? Pediatr Radiol 21:346–349
18. Glover JR, Thomas BM (1991) Hypersensitivity reaction to oral iohexol. AJR Am J Roentgenol 156:197
19. Janower ML (1986) Hypersensitivity reactions after barium studies of the upper and lower gastrointestinal tract. Radiology 161:139–140
20. Skucas J (1997) Anaphylactoid reactions with gastrointestinal contrast media. AJR Am J Roentgenol 168:962–964
21. Davis PL (2015) Anaphylactoid reactions to the nonvascular administration of water-soluble iodinated contrast media. AJR Am J Roentgenol 204:1140–1145
22. Cohen MD, Towbin R, Baker S et al (1991) Comparison of iohexol with barium in gastrointestinal studies of infants and children. AJR Am J Roentgenol 156:345–350
23. Eisenberg RL, Hedgcock MW, Shanser JD et al (1979) Iodine absorption from the gastrointestinal tract during hypaque-enema examination. Radiology 133:597–599
24. Beckett KR, Moriarity AK, Langer JM (2015) Safe use of contrast media: what the radiologist needs to know. Radiographics 35:1738–1750
25. U.S. Food and Drug Administration. Iodinated Contrast Media (ICM) Products. http://www.fda.gov/Safety/MedWatch/SafetyInformation/ucm458066.htm Accessed 3 March 2016
26. Stringer DA (1987) Imaging inflammatory bowel disease in the pediatric patient. Radiol Clin North Am 25:93–113
27. ACR (2013) American College of Radiology ACR-SAR practice parameter for the performance of an enteroclysis examination in adults
28. Costin BS, Singleton EB (1978) Bowel stenosis as a late complication of acute necrotizing enterocolitis. Radiology 128:435–438
29. Kao SC, Smith WL, Franken EA Jr et al (1992) Contrast enema diagnosis of necrotizing enterocolitis. Pediatr Radiol 22:115–117
30. Berdon WE, Baker DH (1965) The roentgenographic diagnosis of Hirschsprung's disease in infancy. Am J Roentgenol Radium Therapy Nucl Med 93:432–446
31. Cremin BJ (1974) The early diagnosis of Hirschsprung's disease. Pediatr Radiol 2:23–28
32. Rosenfield NS, Ablow RC, Markowitz RI et al (1984) Hirschsprung disease: accuracy of the barium enema examination. Radiology 150:393–400
33. Berdon WE, Slovis TL, Campbell JB et al (1977) Neonatal small left colon syndrome: its relationship to aganglionosis and meconium plug syndrome. Radiology 125:457–462
34. Davis WS, Allen RP, Favara BE et al (1974) Neonatal small left colon syndrome. The Am J Roentgenol Radium Therapy Nucl Med 120:322–329
35. Leonidas JC, Burry VF, Fellows RA et al (1976) Possible adverse effect of methylglucamine diatrizoate compounds on the bowel of newborn infants with meconium ileus. Radiology 121:693–696
36. Rowe MI, Furst AJ, Altman DH et al (1971) The neonatal response to gastrografin enema. Pediatrics 48:29–35
37. Poole CA, Rowe MI (1976) Clinical evidence of intestinal absorption of Gastrografin. Radiology 118:151–153
38. Mugie SM, Bates DG, Punati JB et al (2015) The value of fluoroscopic defecography in the diagnostic and therapeutic management of defecation disorders in children. Pediatr Radiol 45:173–180
39. Lee JK, Stein SL (2010) Radiographic and endoscopic diagnosis and treatment of enterocutaneous fistulas. Clin Colon Rectal Surg 23:149–160
40. Kao SC, Franken EA, Jr. (1995) Nonoperative treatment of simple meconium ileus: a survey of the Society for Pediatric Radiology. Pediatric radiology 25:97–100
41. Noblett HR (1969) Treatment of uncomplicated meconium ileus by Gastrografin enema: a preliminary report. Journal of pediatric surgery 4:190–197
42. Colombo C, Ellemunter H, Houwen R, et al. (2011) Guidelines for the diagnosis and management of distal intestinal obstruction syndrome in cystic fibrosis patients. Journal of cystic fibrosis: official journal of the European Cystic Fibrosis Society 10 Suppl 2:S24–28
43. Houwen RH, van der Doef HP, Sermet I, et al. (2010) Defining DIOS and constipation in cystic fibrosis with a multicentre study on the incidence, characteristics, and treatment of DIOS. Journal of pediatric gastroenterology and nutrition 50:38–42
44. Perman J, Breslow L, Ingal D (1975) Nonoperative treatment of meconium ileus equivalent. Am J Dis Child 129:1210–1211