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ORIGINAL ARTICLE

Bedside upper gastrointestinal series in critically ill low birth weight infants

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Abstract
Background The upper gastrointestinal (UGI) series is the preferred method for the diagnosis of malrotation. A bedside UGI technique was developed at our institution for use in low birth weight, critically ill neonates to minimize the risks of transportation from the neonatal intensive care unit (NICU) such as hypothermia and dislodgement of support lines and tubes.
Objective To determine the ability of a bedside UGI technique to identify the position of the duodenojejunal junction (DJJ) in low birth weight, critically ill infants in the NICU.
Materials and methods We retrospectively reviewed bedside UGI examinations performed in premature infants weighing less than 1,500 g from 2008 to 2013 and correlated the findings with clinical data, imaging studies and surgical findings.
Results Of 27 patients identified (weight range: 633–1,495 g), 21 (78%) bedside UGI series were diagnostic. Twenty of 27 cases (74%) demonstrated normal intestinal rotation. One case demonstrated malrotation with midgut volvulus, which was confirmed at surgery. In six cases (22%), the position of the DJJ could not be accurately determined. No cases of malrotation with midgut volvulus were missed. None of the patients with normal bedside UGI studies was found to have malrotation based on clinical follow-up (mean: 20 months), surgical findings or further imaging.
Conclusion The bedside UGI is a useful technique to exclude malrotation in critically ill neonates and minimizes potential risks of transportation to the radiology suite. Pitfalls that may preclude a diagnostic examination include incorrect timing of radiographs, patient rotation, suboptimal enteric tube position and bowel distention. In cases of diagnostic uncertainty, a follow-up study should be performed.

Keywords Malrotation · Low birth weight infants · Upper gastrointestinal series · Neonatal intensive care unit · Neonate

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Introduction

Intestinal malrotation is a congenital disorder of intestinal rotation and fixation that predisposes patients to midgut volvulus and the potentially fatal complications of bowel ischemia and necrosis. The upper gastrointestinal series has long been established as the preferred method for the diagnosis of malrotation [1–4], although recently sonography has been advocated [5]. Several years ago, a bedside UGI technique was developed at our institution to evaluate unstable neonates who required an UGI series. Currently, we use this technique to assess critically ill, low birth weight infants with bilious aspirates or other clinical signs of malrotation in whom transportation to the fluoroscopy suite poses significant risks including hypothermia and respiratory compromise. To determine the efficacy of this technique, we retrospectively reviewed these studies and correlated the results with available clinical and surgical data.

Materials and methods

Patient population

The Institutional Review Board approved this retrospective study with a waiver of informed consent. All bedside UGI series performed between 2008 and 2013 in premature infants weighing less than 1,500 g were reviewed. Patient weight was determined on or within 24 h of the date of the study.

Bedside UGI technique

A bedside UGI study is performed following discussion between the NICU team, pediatric surgeon and pediatric radiologist to ensure appropriate utilization of the examination. The technique consists of a scout radiograph to identify the location of the enteric tube. This is repositioned, if necessary, to lie within the gastric body. A series of frontal supine radiographs is then obtained at fixed time intervals following administration of 5 cc/kg of isotonic (350 mg/ml), nonionic water-soluble contrast material via the enteric tube. The use of isotonic, nonionic contrast agents is recommended given their known safety profiles in case of aspiration [6, 7]. Oral contrast medium is administered by a NICU fellow or attending. Abdominal radiographs are obtained immediately after contrast medium administration, at 30 s, 1 min, 3 min and 5 min after contrast medium administration. The infant is placed in the right lateral decubitus position between each radiograph to facilitate gastric emptying. The images are immediately reviewed by a pediatric radiologist.

Data collection and review

Two pediatric radiologists (one with 23 years of experience and one with 2 years of experience) retrospectively reviewed the studies in consensus. Reviewers were blinded to the initial interpretation, clinical outcomes, additional imaging studies and surgical findings. Each study was assessed for enteric tube position, bowel gas pattern, the presence or absence of other radiographic abnormalities, study technique and the position of the duodenojejunal junction. A normal DJJ position was strictly defined as: to the left of the left spinal pedicle, over the gastric antrum and at the level of the duodenal bulb [1, 8]. All additional intestinal contrast medium studies were reviewed as were the surgical findings and clinical follow-up.

Results

Twenty-seven bedside UGI series were reviewed (17 males, 10 females) (Table 1). The mean patient gestational age was 27 weeks (range: 23–31 weeks). On average, the studies were performed on day of life 15 (range: 1–49 days). The average infant weight at the time of the UGI study was 1,078 g (range: 633–1,495 g). Clinical indications for the exam included bilious aspirates (18 infants), abdominal distention (4 infants)

Table 1 Bedside upper gastrointestinal series in 27 low birth weight infants

Diagnostic studies

Patient	Age	Weight	DJJ	Follow-up
1	7 days	1,445 g	Abnormal, evidence of volvulus	Ladd procedure
2–21	15 days (mean)	1,089 g (mean)	Normal	Surgical confirmation (6 patients)
				Imaging confirmation (3 patients)
				Clinical follow-up (11 patients)

Nondiagnostic Studies

Patient	Age	Weight	Limitation	Follow-up	Age at follow-up	Indication for follow-up
22	8 days	920 g	Transverse positioning of the stomach, patient rotation	UGI	9 days	Confirmation of portable study
23	3 days	680 g	Dilated bowel	BE	1 month	Assessment for stricture
24	35 days	1,209 g	Delayed initial film	UGI	3 months	Bowel distention
25	49 days	1,495 g	Delayed initial film, low enteric tube	UGI	3 months	Gastrostomy tube placement
26	9 days	633 g	Delayed initial film, patient rotation	Expired	16 days	
27	9 days	940 g	Transverse positioning of the stomach, low enteric tube	Clinical follow-up	16 months	

DJJ duodenojejunal junction, *UGI* upper gastrointestinal series, *BE* barium enema, *m* months

and feeding intolerance (2 infants). Three studies were performed in infants with prior perforated necrotizing enterocolitis in whom there was concern for proximal intestinal obstruction. While not performed for malrotation, these three cases (performed early in the study period) were included in the review as the imaging protocol described above was employed. In five cases, the interpretation of the study radiologists at re-review was discordant with the initial interpretation. All five cases were interpreted as normal at the time of the study; however, they were determined to be nondiagnostic by the study radiologists using the strict criteria established for a normally positioned DJJ. In 20 of the 27 cases (74%), a normal position of the DJJ was demonstrated on the bedside UGI series (Fig. 1). In one, a proximal obstruction at the third portion of the duodenum was demonstrated, consistent with malrotation and midgut volvulus (Fig. 2). This was surgically confirmed. Six of the 27 cases (22%) were classified as nondiagnostic as the position of the DJJ was not clearly visualized or could not be accurately determined. In three of these studies, technical delay in obtaining the correct sequence of abdominal radiographs resulted in contrast medium filling of jejunal loops, bowel overlap and inability to define the position of the DJJ. In two studies, transverse positioning of the stomach altered the position of the duodenal bulb and gastric antrum used as normal landmarks, thus limiting accurate evaluation of the position of the DJJ. In the remaining nondiagnostic case, dilated small bowel loops distorted the position of the DJJ. Other limitations encountered in these six nondiagnostic studies included a low positioned enteric tube

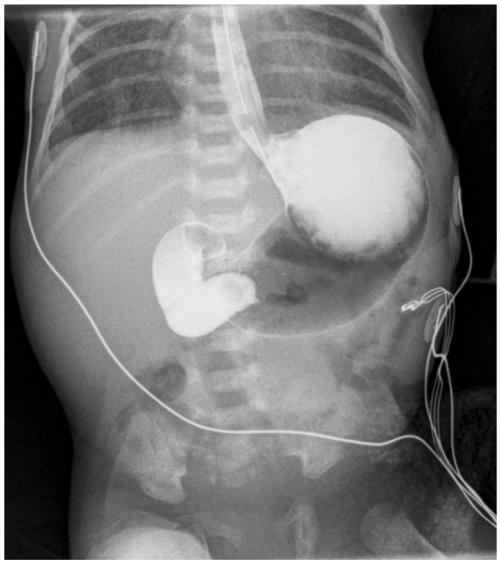

Fig. 2 Image in a 7-day-old boy, 29 weeks' gestational age. A 3-min radiograph from a bedside UGI study demonstrates obstruction of the duodenum, which narrows to a beak, consistent with midgut volvulus. The findings were confirmed at surgery

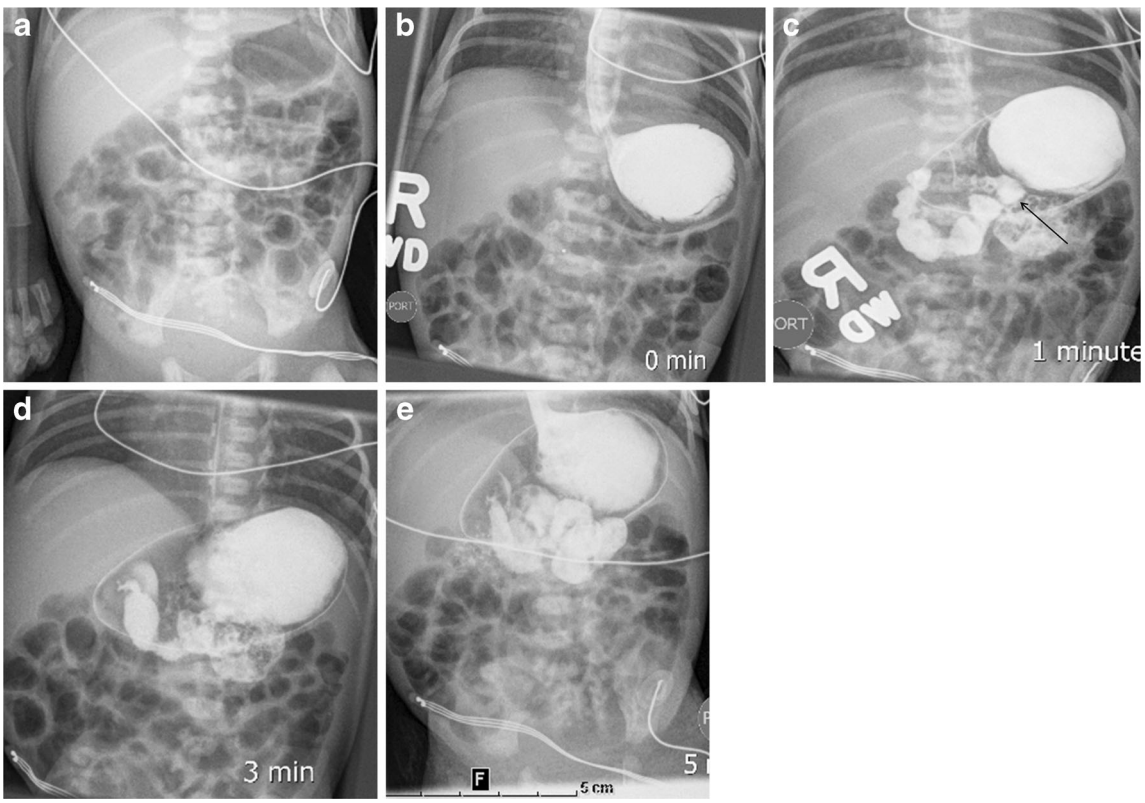

Fig. 1 Images from a bedside UGI examination in a 5-day-old boy, 27 weeks' gestational age, include a scout radiograph (**a**), a radiograph obtained immediately after contrast medium administration via the enteric tube (**b**), at 1 min (**c**), at 3 min (**d**) and at 5 min (**e**). A normal position of the DJJ (*arrow*) is seen best on the 1-min radiograph. Gastroesophageal reflux is noted

and poor patient positioning (Figs. 3, 4 and 5). Follow-up imaging was performed in four of the six nondiagnostic cases. In one case, the bedside study was interpreted as nondiagnostic at the time of initial interpretation and a standard UGI was performed in the radiology department immediately following the bedside exam and was normal. The remaining five nondiagnostic cases were interpreted as normal at the time of the study. In one infant with a history of necrotizing enterocolitis and bowel distention, a contrast medium enema performed 4 weeks after the bedside study demonstrated a normally positioned cecum in the right lower quadrant, which while not confirmatory provided supporting evidence for normal intestinal rotation. Two infants underwent a formal UGI series in the radiology suite for bowel distention and to evaluate for gastrostomy tube placement at 2 months and 1 month, respectively, after the initial bedside study. Both studies demonstrated a normal position of the DJJ. One infant expired due to sepsis and respiratory failure 1 week after the bedside exam and normal rotation was demonstrated at autopsy. One infant has been followed for 16 months and is clinically well.

Of the 20 diagnostic cases demonstrating a normal position of the DJJ, surgical confirmation of normal intestinal rotation was available in six patients who underwent abdominal surgery at a later date. Normal bowel rotation was noted in the operative report of three infants who underwent laparotomy for complications of necrotizing enterocolitis and in three infants who underwent laparotomy for reasons unrelated to their initial presentation. Of the 14 remaining patients with a normal bedside UGI study who did not have surgery, three infants subsequently underwent a formal UGI series or contrast medium enema for other indications including persistent abdominal distention or evaluation for intestinal stricture; these studies all demonstrated normal intestinal rotation.

Clinical follow-up, ranging from 4 months to 5 years (mean: 20 months) was available in the remaining 11 infants without surgical or imaging confirmation of intestinal rotation. All patients were doing well on follow-up.

Discussion

The UGI series is accepted as the preferred method to diagnose malrotation [1–4], though its interpretation can be challenging [3, 8–11]. While there are several causes for bilious vomiting in neonates, malrotation is the most important diagnosis to consider given the dire consequences of a missed diagnosis. A bedside UGI technique was developed at our institution several years ago and has been refined over the years following our experiences with the technique. A similar bedside technique has been briefly described previously for use in low birth weight neonates [12]. At our institution, a neonatology fellow or attending is present during the study. Our clinical staff and technologists are very familiar with the protocol; however, when initially introduced, a pediatric radiologist should monitor the study at the bedside to ensure the study is performed appropriately.

Our technique is in use to assess critically ill, low birth weight infants with suspected malrotation, many of whom are on ventilator support and continuous intravenous infusions. Transportation to the fluoroscopy suite in this group of

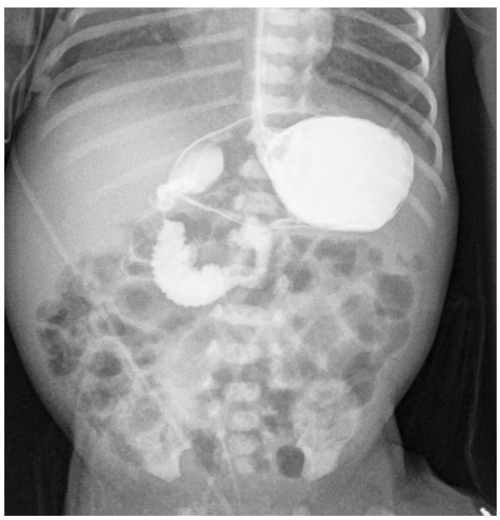

Fig. 3 Image in an 8-day-old male, 31 weeks' gestational age. A 1-min radiograph from a bedside UGI study demonstrates an apparent low and medially positioned DJJ. Transverse positioning of the stomach and patient rotation precludes accurate interpretation of the DJJ position. A formal UGI series performed with barium demonstrated a normally positioned DJJ

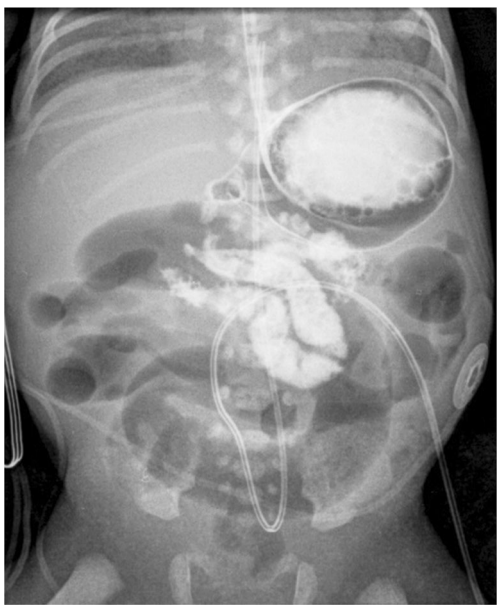

Fig. 4 Image in a 3-day-old boy, 27 weeks' gestational age. A 1-min radiograph from a bedside UGI study demonstrates multiple dilated loops of small bowel distorting the position of the DJJ. The location of the DJJ could not be accurately determined

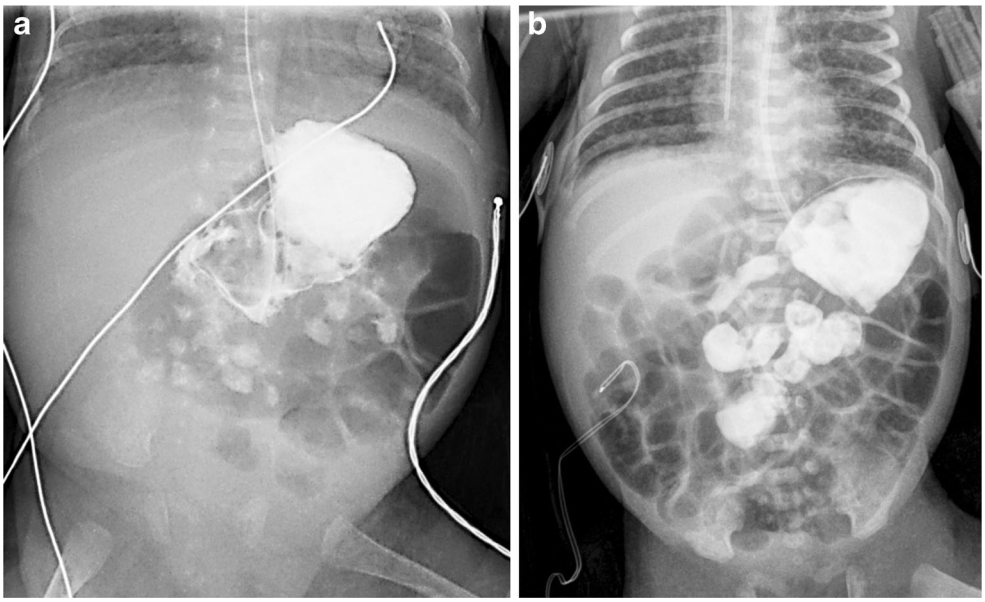

Fig. 5 Radiographs from two nondiagnostic bedside UGI studies. **a** A low-lying feeding tube distorts the position of the duodenal bulb and DJJ in a 49-day-old boy, 24 weeks' gestational age. **b** A delay in obtaining radiographs in a 9-day-old girl, 27 weeks' gestational age, results in filling of jejunal loops, which limits interpretation

patients carries a risk of hypothermia, respiratory compromise and dislodgement of central venous catheters, endotracheal tubes or other support lines [13]. In this subset of patients, a modified UGI study performed at the bedside can be an accurate diagnostic tool to assess intestinal rotation without subjecting the child to the risks of transportation. In our review of 27 low birth weight neonates who underwent a bedside UGI series, the study was diagnostic in 21 cases (78%). One infant had malrotation with volvulus that was correctly identified by the bedside UGI technique and confirmed at surgery. The remaining 20 infants had a normally positioned DJJ.

Six cases (22%) were nondiagnostic as the position of the DJJ could not be accurately determined. In three cases, suboptimal timing of sequential radiographs limited diagnostic accuracy. A delay in obtaining the radiographs led to filling of proximal jejunum with contrast medium, which obscured the position of the DJJ. These cases occurred early in our experience with the technique. We now obtain a more rapid sequence of radiographs including immediate, 30-s and 1-min radiographs, and we have stressed the importance of rigidly adhering to the timing sequence with our technologists and neonatology colleagues. In our series of cases, the DJJ was most often demonstrated on the immediate or 1-min radiograph; however, there were cases in which the 3- or 5-min radiographs added useful information. A few early studies included a lateral view; however, the duodenal loop was difficult to accurately identify among other contrast medium-filled loops of bowel, hence this image was removed from the protocol. Gastroesophageal reflux was noted in a few cases (Fig. 1), but we had no complications related to aspiration. Proper patient positioning and placement of the enteric tube are important factors to consider when performing the bedside UGI study. Rotation of the patient and low enteric tube position led to additional difficulty in determining the location of the DJJ in some cases (Figs. 3 and 5). Careful straight anteroposterior positioning of the patient for each radiograph should be ensured to minimize uncertainty and apparent right or leftward placement of the DJJ. The optimal position of the enteric tube tip is in the gastric mid-body, which allows evaluation of stomach configuration as well as the normal progression of contrast medium into the duodenum. Placement of enteric tubes in the distal antrum or proximal duodenum may distort the position of the DJJ [14] or alter the quantity and timing of passage of contrast medium through the duodenum. The position of the enteric tube should be assessed on the scout radiograph and corrected, if necessary, prior to administration of contrast medium. Transverse positioning of the stomach or distention of small bowel loops also led to difficulty in determining the position of the DJJ. Both falsely distorted the apparent position of the DJJ, which has been well described in the literature [2, 9, 14].

The bedside UGI is a useful technique in high-risk, low birth weight infants in the NICU. In infants in whom the bedside study is not definitive and the diagnosis of malrotation and volvulus is suspected, an immediate follow-up UGI series using barium should be performed in the radiology department. In this particular instance, barium should be used as the difference in density between contrast medium agents allows interpretation of the barium study despite the presence of water-soluble contrast medium in the bowel from the bedside examination. In the majority of cases, the position of the DJJ can be accurately identified using the bedside technique. Pitfalls that may be prevented include incorrect timing of radiographs, patient rotation and suboptimal enteric tube position. Since this retrospective review, our protocol now includes evaluation of the scout radiograph to determine the

position of the enteric tube. Other limitations that cannot be controlled include transverse positioning of the stomach or bowel distention with resultant distortion of the position of the DJJ or normal landmarks. An additional diagnostic limitation is the lack of a lateral view, which in traditional real-time fluoroscopy provides useful information in interpreting the DJJ position [1, 10, 11, 15]. A significant drawback of the bedside UGI technique is its potential for use, and thus overuse, as a screening exam. This should be avoided to prevent unnecessary imaging and strict clinical indications for the exam should be established in conjunction with the clinical team. Currently, prior to the exam, a consensus must be reached among the pediatric surgeon, NICU attending and pediatric radiologist as to the appropriateness of the exam. The study is limited by selection bias and the small number of positive cases. Only one patient in our series was found to have malrotation and midgut volvulus and thus the sensitivity of this technique is unknown. There were no false-positive cases in our series; no patients were diagnosed with malrotation based on the bedside exam with normal rotation demonstrated at surgery. While there were no false-negative cases in our series, it must be emphasized that rigorous attention to detail must be applied when interpreting a bedside study, just as it is critical in correct interpretation of standard UGI series [1, 3, 8–11]. The inherent limitations of a bedside study, namely the lack of a lateral view, increase the potential for false-negative examinations, especially in more subtle cases of malrotation without volvulus. Subtle abnormal findings such as redundancy of the duodenum or the location of the jejunum in the right upper quadrant must alert the radiologist to the possibility of malrotation [1, 9]. The criteria for a correctly positioned DJJ should be strictly applied, and any variation from those criteria, however subtle, should prompt further investigation to avoid a missed diagnosis of malrotation. Additionally, any bedside UGI study that is discordant with the clinical findings may warrant further imaging.

Conclusion

The bedside UGI technique is a useful tool for use in unstable or critically ill premature neonates in whom there is a concern for malrotation. The position of the DJJ can be accurately assessed in the majority of cases, thus reducing the number of infants who must be transported out of the NICU.

Conflicts of interest None.

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