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ORIGINAL ARTICLE

Identifying intestinal malrotation on magnetic resonance examinations ordered for unrelated indications

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Abstract

Background Anatomical imaging findings indicating normal bowel rotation can be identified on cross-sectional imaging, including magnetic resonance imaging (MRI) performed for non-related indications.

Objective The goal of our study was to assess whether non-targeted MRI can accurately assess intestinal malrotation.

Materials and methods Four anatomical landmarks were assessed on MRIs of the chest, spine or abdomen performed from January 2006 to June 2014, on patients who also had upper gastrointestinal series (UGI) performed within 10 years of the MRI date: 1) retroperitoneal duodenum, 2) left upper quadrant duodenojejunal junction, 3) superior mesenteric artery to the left of the superior mesenteric vein, and 4) right lower quadrant cecum. Two attending radiologists, one pediatric and one abdominal radiologist, independently reviewed the MR images. The pediatric radiologist reviewed images from UGI (considered the gold standard) to determine the intestinal rotation for each case. Validation of the criteria was performed on new patients imaged through January 2016.

Results The original cohort included 109 MRIs (15 chest, 41 spine and 53 abdomen) done on 109 patients (42% males, mean age: 10.2 years). If each of the 4 anatomical questions were answered "yes" (4-YES), specificity was 100% for each radiologist and malrotation was appropriately excluded. Using the 4-YES criteria, the pediatric radiologist excluded malrotation in 71 patients (65%) and the abdominal radiologist excluded it in 65 (60%), with concurrence for 57 patients. Validation of the 4-YES criteria in 23 new patients appropriately proved the 4-YES rule, with neither labeling the one new malrotation case 4-YES.

Conclusion If a radiologist can confidently answer "yes" to the four questions evaluated in this study, then intestinal rotation can be safely considered normal. Normal bowel rotation should be commented upon in MRI reports when these four anatomical locations are imaged, thus helping patients avoid unnecessary UGI and radiation exposure.

Introduction

Intestinal malrotation occurs in approximately 1 in every 2,000 live births. Patients with malrotation are at risk for intestinal volvulus. Current clinical guidelines state that if there is clinical concern for volvulus, such as bilious emesis, an emergent upper gastrointestinal series (UGI) should be performed [1].

Non-emergent UGI studies are performed for patients with recurrent vomiting or prior to percutaneous endoscopic gastrostomy placement. Many cases of malrotation are associated with other anatomical anomalies, particularly cardiac abnormalities [2, 3]. In one study of 1,163 patients assessed with UGI prior to percutaneous endoscopic gastrostomy placement, 39 cases of malrotation were found, and all of the children with malrotation had either major congenital anomalies or cystic fibrosis [4]. Of the 315 patients with cardiac abnormalities, 8% had malrotation [4]. Patients with cardiac or other abnormalities may undergo magnetic resonance imaging (MRI) evaluation of the chest, abdomen or spine prior to a request for UGI.

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Various studies have identified anatomical imaging findings suggestive of malrotation [3, 5, 6]. Each has variable sensitivity and specificity for malrotation when compared to the gold standards of surgical exploration and UGI evaluation. Some of these findings can be evaluated on cross-sectional imaging, such as MRI, even when done for other indications.

Upper gastrointestinal series require radiation exposure, with an effective dose estimated as 1-3 mSv [7, 8]. In an exposed population, a dose of 3 mSv would potentially increase the lifetime risk of fatal cancer by approximately 0.01% [8]. Our hypothesis is that patients with non-targeted MRI can be accurately assessed for malrotation. If MRI can exclude malrotation, upper GI fluoroscopic studies may not be necessary in such patients, thereby reducing their radiation exposure.

Materials and methods

Institutional Review Board approval was obtained prior to performing this study. An electronic medical record search was performed at a pediatric hospital for patients younger than 21 years old, who had MRI performed of the chest/cardiac, thoracic or lumbar spine, and abdomen from January 2006 to June 2014 and also had a barium study performed within 10 years of the MRI date. Our institution established a PACS system in 2006. MRI examinations before that time would not be available for review on PACS. A retrospective review was performed of the MRI studies yielded by this search. Upper GI exam imaging for these patients was also retrospectively reviewed and used as the gold standard for diagnosing malrotation.

Two attending radiologists, one pediatric radiologist (B.H.T., 12 years of post-fellowship training) and one abdominal radiologist (V.C., with 11 years of post-fellowship training) specializing in MRI, were blinded to patients' names, diagnoses and non-MRI imaging. Each attending independently reviewed the MRIs to determine:

1. Is the transverse duodenum retroperitoneal, between the aorta and the superior mesenteric artery (SMA)? (Fig. 1)
2. Is the duodenojejunal junction in the left upper quadrant abdomen?
3. Is the SMA to left of the superior mesenteric vein (SMV)?
4. Is the cecum in the right lower quadrant abdomen?

Each attending then independently determined if, based on the above information, intestinal rotation was normal, unclear or abnormal.

At a separate session, the pediatric radiologist reviewed the UGI images to determine if the rotation was normal or abnormal (gold standard). When UGI imaging was not available on PACS, electronic medical record reports from those studies were reviewed. If reports were unclear, film retrieval was performed. If film retrieval was not possible, the patient was excluded.

A resident radiologist (J.F.) tabulated attending responses and performed statistical analysis to calculate sensitivity and specificity, negative predictive values and kappa statistic for interobserver correlation. If a barium study was deemed insufficient to determine rotation because the images could not be retrieved or the duodenal sweep was not imaged, or if all four regions of interest were not visualized on an MRI by both

Fig. 1 Retroperitoneal duodenum (arrows) in a 5-day-old boy with normal rotation on (a) axial and (b) sagittal T2-weighted. The boy has caudal regression syndrome with agenesis of the sacrum and a blunted appearing conus medullaris ending at the T10 level. The axial image (a) also demonstrates a retroaortic left renal vein
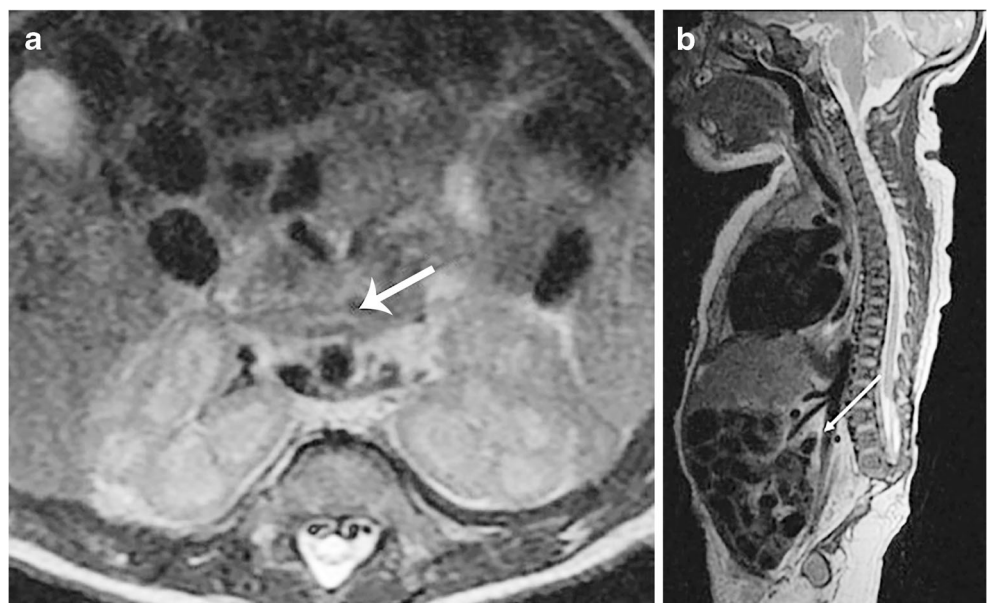
attendings, a case was excluded. If either radiologist identified one to three regions as visualized on the MRI, the case was included.

Clinical data was reviewed for diagnoses including if intestinal volvulus or surgery to correct malrotation had occurred prior to MRI. Original MRI reports were reviewed to ascertain if rotation was mentioned. Dates of the MRI and UGI imaging were reviewed to determine which occurred first.

An electronic medical record search was then performed for additional patients fulfilling the same criteria from June 2014 to January 2016 (patient set 2). The same image review and analysis were performed, as a validation group for the 4-YES criteria described below.

Results

The original cohort included 145 patients (Fig. 2), with 21 patients excluded because the barium study was not sufficient to diagnose rotation. This occurred when a barium swallow evaluation did not assess the stomach or duodenum (18 patients), when the patient was postoperative for gastric or duodenal resection at the time of imaging (2 patients), or when barium study film retrieval could not be performed (1 patient). In addition, 15 of the remaining MRI studies demonstrated insufficient imaging of all 4 of the regions of interest on independent review by both attending radiologists and were excluded. This was predominately due to saturation bands on spine imaging (12 patients), as well as cardiac imaging that did not extend into the abdomen (3 patients). Of the remaining 109 studies, 15 were chest MRIs (including cardiac), 41 spine

and 53 abdominal, performed on 109 disparate patients (42% males, mean age: 10.2 years). Four patients (4%) had abnormal rotation proven on UGI (Figs. 3 and 4), and 105 had normal rotation. One patient with abnormal rotation had nonrotation, with all small bowel restricted to the right side of the abdomen and all large bowel to the left.

The abdominal radiologist demonstrated 75% sensitivity and 76% specificity for abnormal rotation, with a negative predictive value of 99% (Table 1). The pediatric radiologist demonstrated 100% sensitivity and 92% specificity, with a negative predictive value of 100%. Because missing a case of malrotation was not considered acceptable, individual responses to each of the four questions were then reviewed (Table 2). For both attending radiologists, if all four of the regions of interest were visible on the MRI exam and could be confidently answered "yes" (4-YES), this corresponded to normal rotation on UGI. Thus, the negative predictive value was 100% for each radiologist if the 4-YES criteria were used, and malrotation was appropriately excluded. Using the 4-YES criteria, the pediatric radiologist excluded malrotation in 71 patients (65%) and the abdominal radiologist in 65 (60%), with concurrence for 57 patients.

Interobserver agreement for 4-YES was moderate (kappa statistic=0.57, 96% confidenc interval [CI] 0.40-0.73). Kappa statistic was also applied to the radiologists' responses for each of the four regions of interest, demonstrating moderate interobserver agreement for each region as well, ranging from 0.51 for right lower quadrant cecum to 0.59 for retroperitoneal duodenum.

For comparison, the data were reanalyzed to identify the effect of accepting "yes" to any three regions of interest

Fig. 2 Flow chart depicts patients included in the original cohort group, with types of MRI listed in adjacent boxes
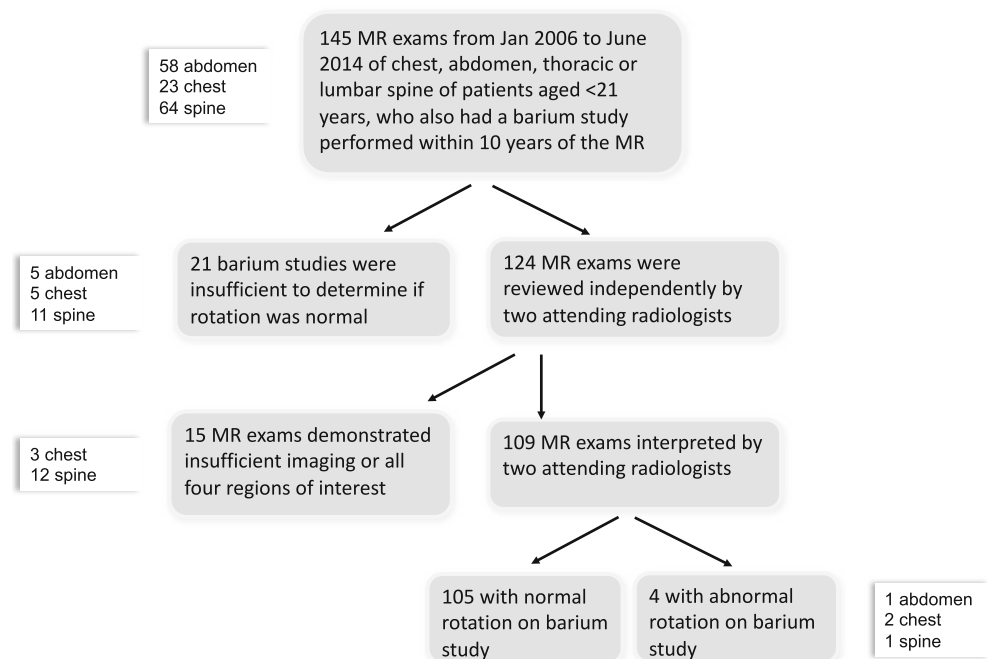
Fig. 3 Nonrotation in a 19-year-old woman on coronal T2-weighted MRI (**a**) and UGI (**b**), with small bowel restricted to the right side of the abdomen and colon to the left
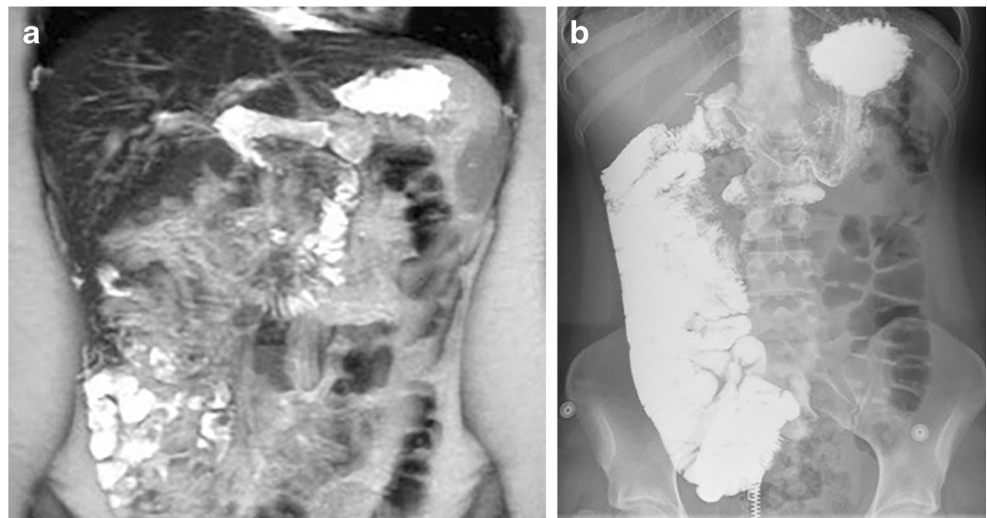
Fig. 4 Malrotation in a 17-year-old girl on coronal T2-weighted MRI (**a**) and UGI (**b**), with the duodenum restricted to the right abdomen, and not demonstrated to cross midline
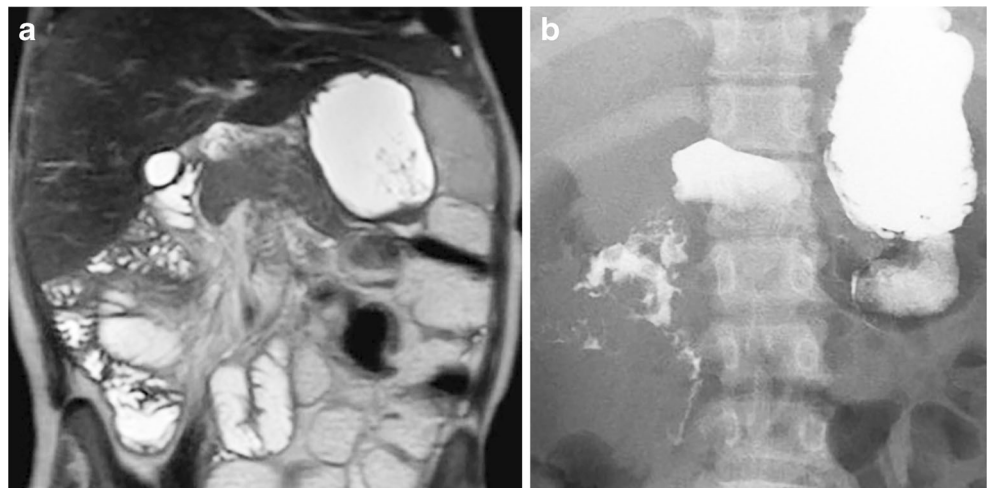
(ANY-3-YES). With such criteria, the pediatric radiologist would have considered an additional 18 patients to have normal rotation, and the abdominal radiologist an additional 15 patients. However, one case of malrotation (Fig. 5) would then have been missed and inappropriately called normal. For the pediatric radiologist, the region that was not answered "yes" was inverse or unclear SMA/SMV relationship for 13 patients, unclear cecum position for 4 patients and unclear left upper quadrant duodenojejunal junction for 1 patient. For the abdominal radiologist, all 15 patients demonstrated unclear

cecum position, including the malrotation case. Thus, it was concluded that no one criterion is satisfactory to determine if rotation is normal, but rather that all four criteria need to be evaluated and considered normal (4-YES) for malrotation to be excluded. Although any MRI cases that imaged one to three regions of interest were included in the study (for example, a cardiac or chest MRI that did not image the right lower quadrant), they could not be considered 4-YES.

The validation group (patient set 2) identified 28 new patients imaged through January 2016. The 4-YES

Table 1 Original cohort group individual results for the adult and pediatric radiologist, respectively

Pediatric radiologist	Normal rotation on UGI	Abnormal rotation on UGI
Normal on MR	97	0
Unclear or abnormal on MR	8	4
Abdominal radiologist	Normal rotation on UGI	Abnormal rotation on UGI
Normal on MR	80	1
Unclear or abnormal on MR	25	3

UGI upper gastrointestinal series

Table 2 Original cohort group regions of interest responses for the adult and pediatric radiologist, respectively

Pediatric radiologist	Retroperitoneal duodenum?	LUQ DJJ?	SMA to left of SMV?	RLQ cecum?
yes	95	94	85	92
no	3	4	18	3
not imaged	4	4	4	9
unclear	7	7	2	5
Abdominal radiologist	Retroperitoneal duodenum?	LUQ DJJ?	SMA to left of SMV?	RLQ cecum?
yes	84	83	92	70
no	1	1	3	1
not imaged	8	9	6	21
unclear	16	16	8	17

DJJ duodenojejunal junction, *LUQ* left upper quadrant, *RLQ* right lower quadrant, *SMA* superior mesenteric artery, *SMV* superior mesenteric vein

criteria were applied to this validation group, with each attending radiologist reviewing studies in the same manner as in the original cohort. Five patients were excluded because the barium study was insufficient to determine rotation. The pediatric radiologist labeled 14 patients 4-YES, and the abdominal radiologist labeled 6 patients 4-YES. Neither labeled the one new malrotation case 4-YES; each radiologist only labeled cases of normal rotation 4-YES, appropriately proving the 4-YES rule.

The timeline of imaging studies was reviewed for all 132 MRIs reviewed in the study (original cohort and validation group). MRI preceded UGI in 40 cases (30%) with 17 of these rated 4-YES by both the pediatric and adult radiologists. Less than 2% of original MRI reports described bowel rotation. Only one patient's MRI report commented on rotation before UGI was performed.

Discussion

While many patients requiring a gastrostomy or with cardiac disease currently undergo UGI to exclude malrotation, this may not be necessary if an MRI including the abdomen has been previously performed, even if performed for unrelated indications. If a radiologist can review the study and confidently answer "yes" to all four regions of interest evaluated in this study, then the patient's intestinal rotation can be safely considered normal and the patient can avoid radiation from UGI.

The two radiologists in our study demonstrated moderate interobserver agreement for each of the four regions of interest. By requiring all four regions of interest to be normal (4-YES) in order to consider a case to have normal rotation, the chance of missing a case of malrotation is minimized.

The primary limitation to our study is the small sample size of patients with abnormal rotation who underwent MRI. Therefore, the diagnosis of malrotation should not be made solely upon the basis of MRI, but rather the confirmation of normal rotation. Normal bowel rotation can be confirmed on 54-64% of MRIs performed for non-related indications, depending on the subspecialty of the radiologist. In our cohort, 30% of MRIs preceded UGIs (40 patients) and applying the 4-YES criteria and commenting on normal rotation in the report could have eliminated the need for UGI in 17 of these patients. If the regions are not well-imaged on MRI, or if the radiologist cannot confidently evaluate all four regions, an UGI is an appropriate next step.

Fig. 5 Malrotation in a 12-year-old girl was missed on original review by one radiologist. Axial T2-Weighted MRI (**a**) demonstrates only the left renal vein (*arrow*) passing between the aorta and superior mesenteric artery and (**b**) axial T2-Weighted MRI demonstrates a cecum (*arrow*) that is high in position and not within the right lower quadrant
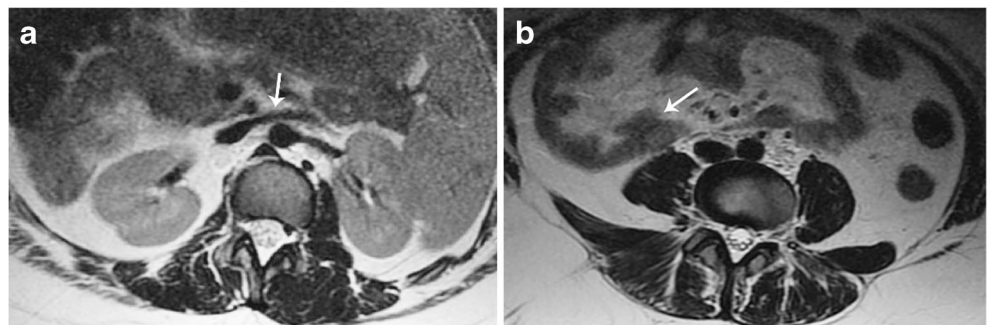
Conclusion

If a radiologist can confidently answer "yes" to the four questions evaluated in this study, then intestinal rotation can be safely considered normal. Normal bowel rotation should be commented upon in MRI reports when these four anatomical locations are imaged, thus helping patients avoid unnecessary UGI and radiation exposure.

Compliance with ethical standards

Conflicts of interest   None

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