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Audit of upper gastrointestinal tract series examinations for diagnosing intestinal malrotation in a resource-limited radiology department in Southern Africa

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ABSTRACT

Background: Intestinal malrotation is a congenitally acquired condition of abnormally rotated proximal small bowel in neonates and infants. Prompt recognition prevents lifethreatening complications. A structured approach to diagnosing malrotation at UGIS is required for accurate diagnosis.
Objectives: Retrospective analysis of the images and radiological reports of UGIS, with the aim of identifying potential shortfalls in diagnosing malrotation. A secondary objective is to formulate a reporting template to improve overall quality of UGIS reports, specifically in cases of suspected malrotation.
Method: Identification and retrospective review of UGIS studies which were subsequently re-read by a blinded consultant radiologist using the proposed reporting template adapted from the literature.
Results: 367 UGIS studies between 1 January 2016 and 31 December 2021 were included in the study cohort, which were then re-read. Using McNemar's chi-square test, we found discrepancy between the number of studies positive for malrotation on the original reports versus the re-read studies, highlighting shortfalls in our current practise.
Conclusion: A structured approach is paramount to the correct diagnosis of malrotation at UGIS. The position of the DJ-flexure (on frontal and lateral projections) proves most sensitive and specific in the diagnosis of malrotation at UGIS. Dedicated true lateral images were often found to be excluded in daily practise. We propose a structured inclusive reporting template.
Contribution: Our proposed standardized reporting template aims to improve radiological, clinical, and surgical outcomes at UGIS, specifically in patients with suspected malrotation.

Introduction

Intestinal malrotation, commonly referred to as malrotation, is defined as a congenitally abnormal position of the bowel within the peritoneal cavity and may affect both the small and large bowel [1,2]. It occurs in approximately 1 in 500 births and may be associated with other gastrointestinal abnormalities, in particular duodenal and jejunal stenosis or atresia, annular pancreas, Hirschsprung disease and intussusception [1,3]. It is invariably present in patients with omphalocele, gastroschisis or congenital diaphragmatic hernia. Long-term complications of malrotation include feeding difficulties, diarrhoea, malnutrition, failure to thrive, small bowel obstruction, and short-gut syndrome to name but a few [1]. An important and potentially life-threatening complication of malrotation is midgut volvulus, representing a surgical emergency. Astute recognition and diagnosis are paramount to avoiding mortality, and, in view of this, the evaluation for intestinal malrotation should be considered an essential component for every upper gastrointestinal tract radiological examination in the paediatric population, in particular neonates and infants [1,4].

Anomalies in rotation occur during embryonal development [4]. In early embryological development, the gut develops from the yolk sac and divides into three sections: the foregut, midgut and hindgut supplied by the coeliac trunk, superior mesenteric artery (SMA) and inferior mesenteric artery respectively [4]. The SMA is important, not only

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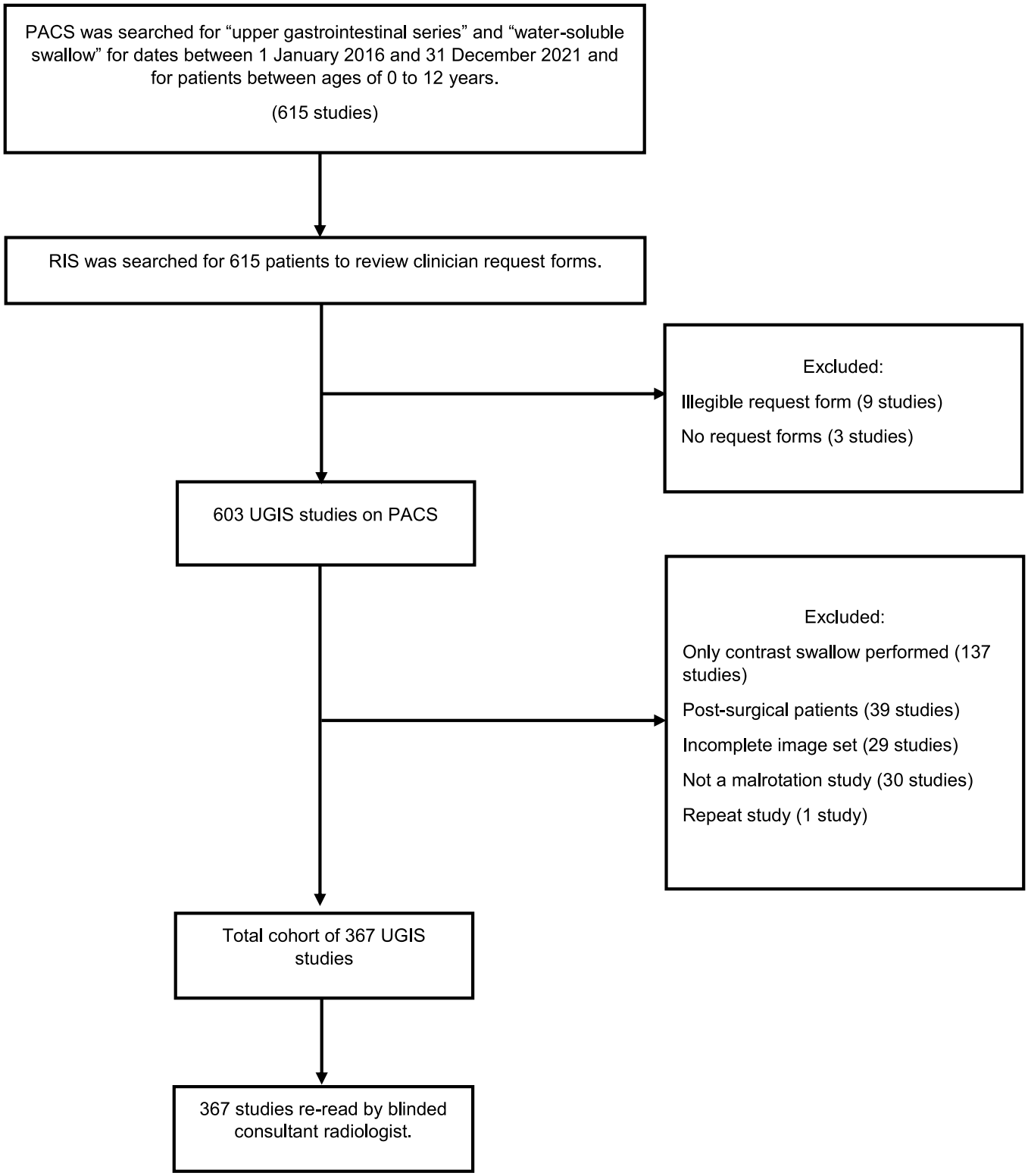


Fig. 1. Flowchart of data collection method. UGIS = Upper gastrointestinal tract series.

because it is the arterial supply of majority of the small intestine, but also because it serves as the axis for the normal embryologic rotation of the bowel during development [4]. Incomplete rotation of the small bowel during embryological development causes foreshortening of the mesenteric root, which can result in twisting of small bowel around this axis, thus leading to complications [4]. Two main types of rotational abnormalities have been described as malrotation: 1. Incomplete rotation giving the classic features of Ladd’s bands which represent indirect attempts at retroperitoneal fixation, and 2. Non-rotation where neither portion rotates more than 90°, resulting in under-rotation leaving the proximal foregut fixated anterior to the right of the SMA and the caecum anterior to the left of the SMA with narrowing and foreshortening of the mesentery [1,5].

While a systematic approach is recommended for the diagnosis of

Table 1
Demographics of included patients.

Age	Median	426 days[¶]
	Mean	905.4 days[§]
Gender	Male	197 (53.7%)
	Female	165 (45.0%)
	Unknown	5 (1.4%)
Years	2016	49 (13.4%)
	2017	83 (22.6%)
	2018	69 (18.8%)
	2019	59 (16.1%)
	2020	34 (9.3%)
	2021	73 (19.9%)

[¶] IQR 1403.3 [§]SD 1163.1.

malrotation using plain film and occasionally ultrasound [1,4,5], the upper gastrointestinal series (UGIS) is the imaging modality of choice and is performed under fluoroscopy. At our institution, the current practice is to routinely assess for malrotation in all paediatric patients referred for UGIS, using fluoroscopy. Paediatric patients are vulnerable to the effects of ionising radiation. Limiting exposure will limit the stochastic effects thereof. Subsequently, as specific criteria are utilised in diagnosing malrotation on UGIS, it is vital that the radiologist have a structured approach to make the correct diagnosis whilst limiting exposure to ionising radiation.

Grey's Hospital is a tertiary institution which offers both radiological and paediatric surgery services. It services the western half of KwaZulu-Natal, a province of South Africa, which includes five health districts [6]. It is currently the only hospital within its own and immediate surrounding districts offering fluoroscopy. This further necessitates the need for a systematic approach and replicable format to accurately diagnose malrotation and effectively serve the catchment area.

At Grey's Hospital, an academic teaching institution, fluoroscopy is a component of the junior rotation, performed predominantly by new radiology trainees. The junior registrars and medical officers are taught, for the most part, by senior registrars, with imaging studies, reports and complicated cases overseen by consultant radiologists. Whilst no official standardised criteria or reporting templates are currently in place, there are various guidelines available. Katz et al. proposed nine findings in the UGIS which may assist in the diagnosis of malrotation [7]. These criteria are based on visualising the normal anatomy of the pylorus, duodenum, duodenojejunal (DJ) flexure, and jejunum [7]. However, in practice, these criteria are complicated and difficult to consistently apply, in particular when variant anatomy and other pathology such as gastric distention, are present. This lack of uniformity can lead to misinterpretation of the imaging findings and thus misdiagnosis.

Our study aimed to retrospectively analyse all paediatric cases referred to Grey's Hospital Radiology Department for upper gastrointestinal fluoroscopic examinations during the period 1 January 2016 to 31 December 2021.

The primary objective of this study was to retrospectively analyse the diagnostic criteria used during the UGIS and reporting and thus identify shortfalls in the fluoroscopic examinations. Possible misdiagnosed cases of intestinal malrotation would also be identified. A secondary objective was to then formulate a reporting template aimed to improve overall quality of reports of UGIS, specifically in cases of suspected intestinal malrotation.

Methods

Study design and participants

This was a single-centre, retrospective study conducted in the Radiology Department at Grey's Hospital, in Pietermaritzburg, South Africa. A retrospective analysis of the radiological request forms, images, radiology reports and, when possible, patient records, was undertaken on paediatric patients under the age of 12 years who underwent UGIS examination in our department between 1 January 2016 and 31 December 2021.

Data collection

During the data collection process, which is summarised in Fig. 1, radiographic images and reports for patients who presented to the radiology department for UGIS studies under fluoroscopy during the stipulated timeframe were obtained using the Radiology Information System (RIS) and the Picture Archiving and Communication System (PACS). The referring clinicians' request forms as well as the radiological reports were retrieved from RIS, and radiographic images were retrieved from PACS. Demographic-related data, including age and sex, were retrieved from these databases (Table 1). This was anonymously recorded on a database using a data collection sheet created by the authors, available only to the authors on a password protected computer.

The clinician request forms, and fluoroscopic reports were evaluated by a radiology registrar with 2 years of experience. All fluoroscopic images included in the study period were re-evaluated by a consultant radiologist with 10 years of experience using our proposed reporting template which we formulated from the literature. This was considered as the "gold-standard" of our study. The consultant radiologist was blinded to the clinical history and surgical outcomes of the patients as well as the final imaging report issued at the time the examination was performed. The proposed reporting template (appendix 1) utilises nine pre-determined radiological parameters to diagnose intestinal malrotation, which assesses the position of the upper gastrointestinal system, that is, the pylorus, duodenum, and jejunum. Ancillary features were also evaluated, which included the presence of gastrointestinal reflux, stomach distension and hiatus hernia. Note was made if another pertinent finding or differential diagnosis was found, such as partial bowel obstruction, large bowel distension or an abnormal stomach position.

Additionally, the data included whether markers were utilised to identify the midline of the patient. Correct positioning is crucial for the diagnosis of malrotation. Improper positioning of the child during the examination may lead to false-positive diagnoses, which may be reduced with the proper placement of radio-opaque (metal) markers [8].

Statistical analysis

McNemar's chi-square test was used to determine whether there was agreement between the original radiology reports and re-read reports by the blinded consultant radiologist (gold-standard).

The descriptive statistics were recorded as frequencies and percentages for categorical variables. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated. The data were analysed using the IBM SPSS version 28 statistical software.

Ethical considerations

Ethical approval was obtained from the Biomedical research Ethics Committee of the University of KwaZulu-Natal (BREC/00,003,773/2022) and site approval was obtained from Grey's Hospital. Informed consent was not required for this study.

Results

Demographics

A total of 615 upper gastrointestinal series examinations were performed at our institution, during the study period 1 January 2016 to 31 December 2021. Of these UGIS examinations, 248 studies were excluded from our study, as outlined in Fig. 1 and a total of 367 patients were ultimately included in the study cohort. One-hundred and sixty-five

(45%) studies were performed on female patients and 197 (53.7%) studies were on male patients and in 5 (1.4%) studies the sex was unknown. The demographic data are represented in Table 1.

Parenthetically, the least number of UGIS examinations were performed in 2020. This is thought to be a consequence of the COVID-19 pandemic and the state of emergency disaster management plan as implemented by the South African government, which included varying levels of lockdown, resulting in poor patient follow-up and patient reluctance or fear to present to hospitals.

Study findings

Utilising McNemar's chi-square test (with a *p-value* of 0.001) to measure the correlation between the findings documented on the original reports at the time the studies were performed and the re-read reports by the consultant radiologist, it was found that there was no agreement, and that the latter was more likely to diagnose intestinal malrotation. Subsequently, we refer to it as the gold-standard for our study.

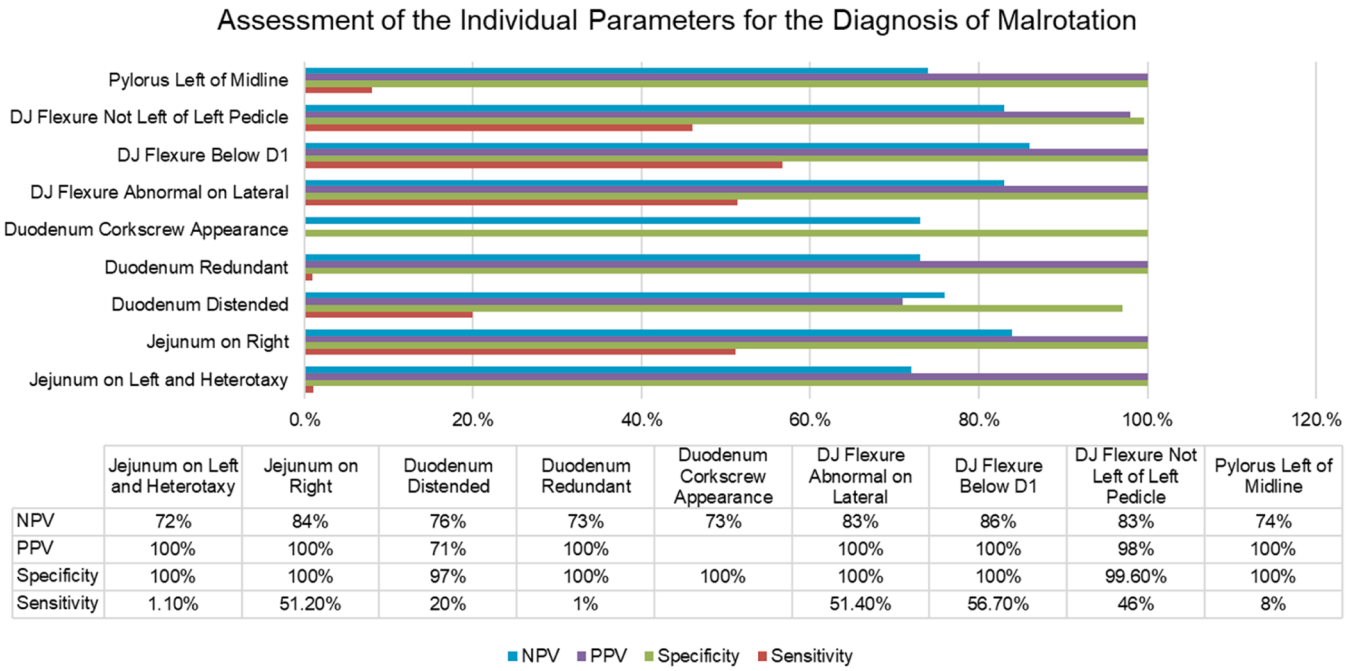
Discussion

Intestinal malrotation is a congenitally acquired abnormal fixation of the bowel in children, predominant in neonates and infants younger than one year old [1,9]. If recognition and management is delayed, midgut volvulus, a potentially life-threatening complication of malrotation, classified as a surgical emergency, can ensue [1,4,10,9]. On ultrasound, the "whirlpool" sign, which is the abnormal configuration of the mesenteric vessels, indicates malrotation [4,11]. Although ultrasound is an emerging modality for the initial evaluation of malrotation, owing, in part, to its lack of ionising radiation [10,11], UGIS examination remains the gold-standard for the diagnosis of malrotation [9]. UGIS utilises oral contrast and real-time fluoroscopy, to opacify the stomach and small bowel, thereby assessing the position of the upper gastrointestinal tract from the pylorus to the jejunum [11].

At our institution, an UGIS examination is performed when the clinicians' differential diagnosis includes intestinal malrotation as well as in cases where a differential diagnosis is not provided, and only patient history and symptomology are documented on the clinician request form. The doctor performing the study is encouraged to place metallic markers (usually two paperclips, one on the anterior chest wall and one posteriorly, meant to be superimposed on one another) to demarcate the patient's midline, and maintain a true anterior-posterior relationship. The following sequence of events occurs: acquisition of a control (scout) image followed by instillation of contrast (Omnipaque is the contrast agent of choice) either orally or via a nasogastric tube. Pulsed images are obtained which follow the passage of contrast through the pylorus and duodenum. The patient should be rotated to a right-lateral position to coax contrast into the duodenum as well as to visualise the posterior inferior position of the DJ flexure on the lateral projection. Finally, contrast is visualised within the jejunum. Gastro-oesophageal reflux may also be assessed for. Images are sent to and stored on PACS following the examination.

Our study retrospectively analysed the radiology reports issued at the time the studies were performed. Of the 367 studies included in our patient cohort, malrotation was confirmed in 49 studies (13.4%) and excluded in 300 studies (81.7%). Malrotation could not be excluded in 18 (4.9%) studies. Reasons for this as documented on reports were due to technical factors, situs inversus, scoliosis, proximal bowel obstruction, normal variant anatomy, and duodenal distension, of which technical factors had the highest frequency of 12 studies (66.7% of studies in which malrotation could not be excluded).

The re-read studies, using our adapted reporting template (appendix 1), yielded significantly different results in that of the 367 studies, malrotation was confirmed in 100 (27.2%) and excluded in 153 studies (41.7%). As the reader was blinded to clinical information as well as the findings and diagnosis documented on the original reports, by utilising the reporting template, they regarded 114 studies (31.1%) to be inconclusive. This was mainly owing to the lack of lateral and "follow-through" images where the duodenojejunal (DJ) flexure and position of the jejunum could not be adequately visualised, respectively. Forty-one studies (36%) of the 114 inconclusive studies did not visualise the position of the jejunum and 96 studies (84.2%) did not have a lateral image. Studies which lacked lateral images and/or images delineating the position of the jejunum but had at least one other positive finding for malrotation, for example, definitive frontal (AP) malposition of the pylorus, were considered positive for malrotation. Examples of malrotation are demonstrated in Figs. 3, 4 and 5.



	Jejunum on Left and Heterotaxy	Jejunum on Right	Duodenum Distended	Duodenum Redundant	Duodenum Corkscrew Appearance	DJ Flexure Abnormal on Lateral	DJ Flexure Below D1	DJ Flexure Not Left of Left Pedicle	Pylorus Left of Midline
NPV	72%	84%	76%	73%	73%	83%	86%	83%	74%
PPV	100%	100%	71%	100%		100%	100%	98%	100%
Specificity	100%	100%	97%	100%	100%	100%	100%	99.60%	100%
Sensitivity	1.10%	51.20%	20%	1%		51.40%	56.70%	46%	8%

Fig. 2. Graphical representation of data collected when assessing the individual parameters for the diagnosis of malrotation.

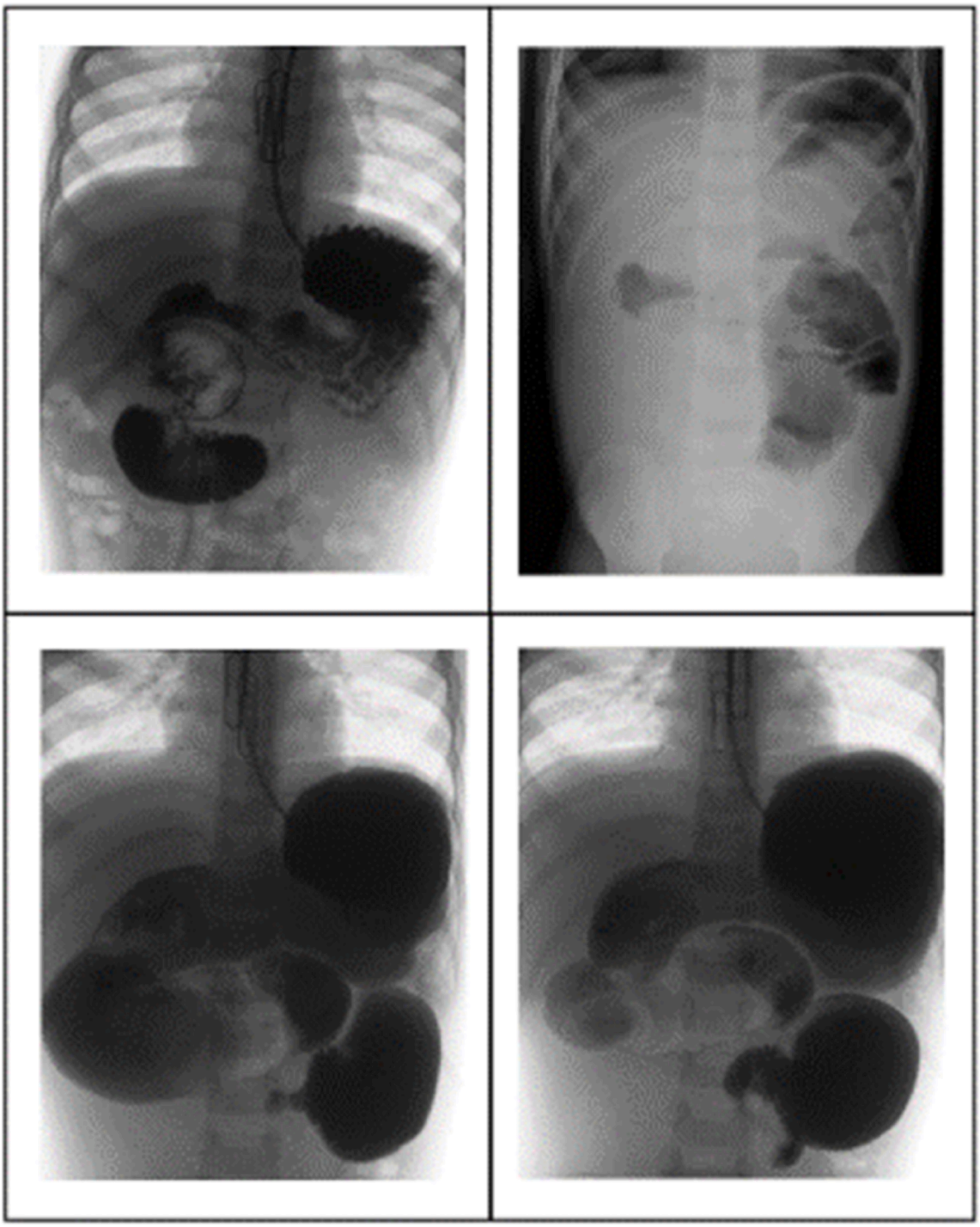


Fig. 3. Peri-operative image of a 3 year 5 month old child with clinical concern of malrotation demonstrating contrast within the stomach and duodenum in (a). Pre-operative images: a nasogastric tube was used to instil contrast. Note the placement of metallic markers to demarcate the midline. The DJ flexure is right of the midline and the duodenum is distended consistent with malrotation which was surgically confirmed. Images (b), (c) and (d) are post-operative images. Abdominal radiograph (b) shows dilated loops of small bowel in the left abdomen. Fluoroscopic images (c and d) demonstrate a tight stenosis in the proximal jejunum with subsequent marked dilatation of the duodenum. The duodenum has a cork-screw appearance suggestive of duodenal volvulus. DJ = Duodenojejunal.

Sizemore et al. suggested that the position of the duodenum on true lateral is vital during UGIS [9]. Of the 367 studies included in our cohort, lateral projections were not performed in 122 (33.2%) studies. This may be attributed to lack of insight on the trainee radiologists or that these specific images were not archived on PACS. Currently, at our institution, templates for reporting radiographic studies, those performed at fluoroscopy as well as other modalities such as CT, MRI, and ultrasound, are used mainly by the junior radiology doctors for the reporting of cases. These templates should also serve as reminders of "blind spots" to evaluate during these studies. Our current reporting template for UGIS examinations neither includes information on the lateral projections nor the jejunum specifically. This highlights certain biases, particularly in the medical field, like omission bias [12], thus calling attention to the need for a structured and comprehensive

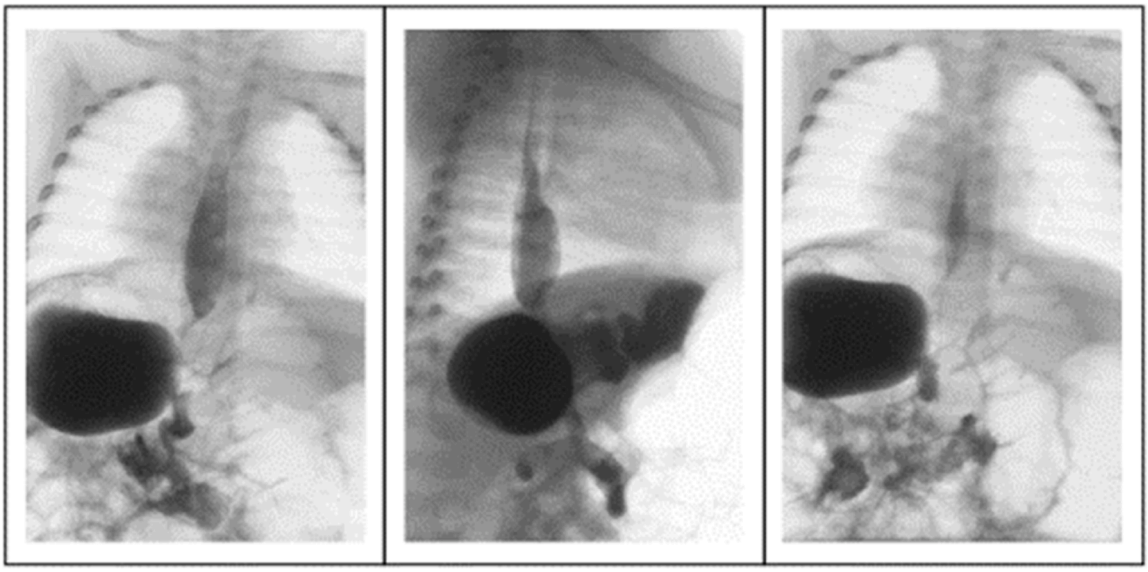


Fig. 4. Two month old patient who presented with upper gastrointestinal symptoms. Fluoroscopic images demonstrate situs inversus and an abnormal configuration of the proximal duodenum. Intestinal malrotation was surgically confirmed. (a) The pylorus is right of the midline and the duodenal-jejunal flexure is right of the right pedicle. In addition, the duodenum follows an anterior course on the lateral image (b). The jejunum is right of the midline (c).

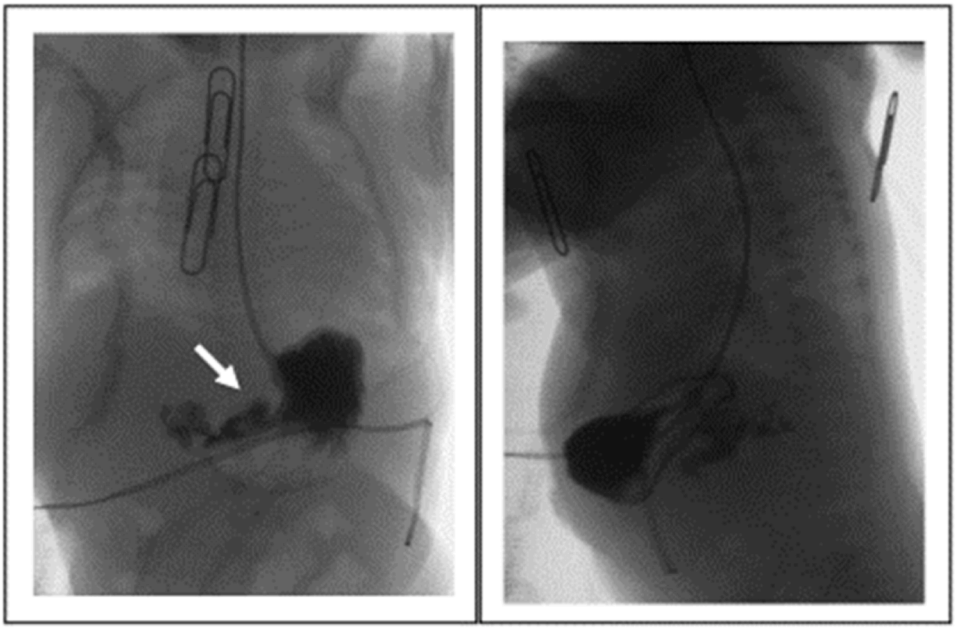


Fig. 5. Images in suspected intestinal malrotation. (a) Frontal image demonstrates the DJ flexure not truly left of the left pedicle. (b) Lateral image demonstrates an anterior course of the duodenum. Although surgical correlation was not known in this patient, the imaging findings are in keeping with malrotation. DJ = Duodenojejunal.

template.

The study conducted by Katz et al. recognised that whilst in most cases, the diagnosis of malrotation is usually straight-forward at real-time fluoroscopy, subtle cases may prove problematic, stimulating them to propose nine features on the UGIS which may assist in diagnosing malrotation [7]. However, the practical application of these nine Katz criteria in our study proved arduous to consistently and retrospectively implement, due to malpositioning, variant anatomy and other differential diagnoses (e.g., gastric volvulus or distention). Furthermore, upon showcasing ultrasound as an initial modality for the assessment of malrotation, Nguyen et al. proposed potential disadvantages of the UGIS. One of which was that UGIS is projection of a 3D phenomenon in a two-dimensional format [11]. A study by Sizemore et al. highlighted differences between the literature and their local practice, of what is considered normal variation and what is considered abnormal, malrotated bowel [9]. These studies, together with the discrepancy between the findings on the original versus the re-read reports at our study, emphasise the need for a standardised reporting template for UGIS examinations in cases of suspected malrotation, in order to improve the detection of malrotation and the quality in reporting such cases. The parameters used to re-analyse all studies in our patient cohort were adapted from the literature, more specifically from the study by Sizemore et al. with supplementation to a lesser extent using the criteria proposed by Katz et al. These parameters are outlined in appendix 1.

Consequently, a secondary objective was to assess these individual parameters. The position of the DJ flexure, specifically in its relation to the left pedicle as well as the first part of the duodenum (D1), proved most sensitive with sensitivity of 46% and 56.7% respectively. Although many studies were inconclusive based on the lack of lateral images, where the lateral images were available, the position of the DJ flexure on lateral projection had a sensitivity of 51.4% in diagnosing malrotation. The position of the DJ flexure on lateral projection and in relation to the left pedicle and D1 on frontal projections yielded specificities of 100%, 99.6% and 100% respectively. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for each parameter are detailed in the graph (Fig. 2). Our findings therefore correspond favourably with the literature in that the identification and assessment of the position of the DJ flexure is considered crucial during UGIS examination.

Appendix 1 illustrates our proposed template for reporting UGIS examinations. This template includes all parameters assessed in this study. Whilst certain criteria have been proposed in the literature as pertinent findings at UGIS namely: pylorus left of midline, duodenum corkscrew appearance, duodenum redundant and jejunum on left and heterotaxy [7,9], it is postulated that their lack of statistical significance in our study is likely due to the small study sample and incomplete UGIS examinations. We propose them as ancillary signs, which may indicate a differential diagnosis. In addition, gastro-oesophageal reflux, stomach distension and hiatus hernia are also included, as important correlatives to evaluate during UGIS.

Study limitations

The limitations of this study include its retrospective study design. Technical errors with the incorrect labelling of studies on PACS also negatively impacted our sample size prior to statistical analysis. Lastly, surgical correlation as the gold-standard would solidify the best parameters when assessing for malrotation at UGIS examinations. The difficulty in accessing patient files and surgical confirmation of malrotation were significant limiting factors in this regard.

Conclusion

Malrotation, and by extension its complications, is considered a surgical emergency. When evaluating for malrotation at UGIS examination, it is imperative that a complete structured imaging analysis is performed so as not to over- and more importantly underdiagnose intestinal malrotation. Further highlighted, was the importance of dedicated true lateral views delineating the duodenal contour, an essential added parameter in assessing for malrotation, often found to be excluded in previous practice. Our proposed reporting template, adapted from the literature and supported by our study findings, is considered essential to consistently and systematically diagnose malrotation, or where appropriate, allude to a potential differential diagnosis. We are encouraged that this structured approach will assist in guiding junior radiology trainees in confidently performing a focussed UGIS examination, thereby reducing radiation exposure and confidently diagnosing malrotation or a reasonable alternative, to circumvent morbidity and mortality in this vulnerable population. We suggest a future project to assess the efficacy of the reporting template with surgical correlation as gold-standard for diagnosing malrotation.

Authors' contributions

L.K. was the principal investigator and prepared this manuscript. T.S. made a conceptual contribution and was the supervisor of L.K.'s Master's research and was also involved in the editing of the manuscript.

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Data availability

Data pertaining to this research are available from the principal investigator and corresponding author, L.K.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Reporting template for the diagnosis of intestinal malrotation at upper gastrointestinal series

Patient name:
Hospital number:
Date of study:

Study performed: UGIS

History and Indication:
Technical Aspects and Procedure:

Markers Placed: YES NO

Findings:

Definitive Findings:

Definitive Findings:	Yes	No
Pylorus left of the midline		
DJ Flexure not left of left vertebral body pedicle		
DJ Flexure below D1		
Duodenum position abnormal on lateral§		
Duodenum with a corkscrew appearance		
Ancillary Findings:	**Yes**	**No**
Redundant duodenum		
Distended duodenum		
Jejunum on right		
Jejunum on left and heterotaxy		

Additional Findings:	Yes	No
Gastrointestinal Reflux		
Stomach Distension		
Hiatus Hernia		
Other		

Reported by: _____

Note:
If "yes" to 1 or more definitive finding, then positive for malrotation
If "yes" to 1 or more ancillary finding, consider an alternative diagnosis for patient symptoms

DJ = Duodenojejunal
§Not posterior and inferior in configuration

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