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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Ultrasound as a feasible method for the assessment of malrotation

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Summary

Background: In malrotation the position of third portion of duodenum (D_3) is always intramesenteric. Demonstration of normal retromesenteric-retroperitoneal position of D_3 on ultrasound (US) can rule out malrotation. The aim of this study was to evaluate the feasibility of US in demonstrating the retroperitoneal D_3.

Material/Methods: Abdominal US study was done for various indications in 60 newborns and infants (mean age: 33 days [range: 4–100 days]; 56.7% male) by an expert pediatric radiologist. The position of D_3 and its adjacent structures was evaluated in axial and longitudinal planes by linear and curved transducers.

Results: A normal retromesenteric-retroperitoneal D_3 located between the superior mesenteric artery and the aorta was seen on US in all patients, including those with extensive gas in the bowel. The mean time of D_3 observation was 47.8 s (10–180 s). Ultrasound was also capable of demonstrating D_3 structure, diameter, content, adjacent structures, relative position of the superior mesenteric artery and vein.

Conclusions: Ultrasound is a simple, fast and highly accurate tool to confirm the retroperitoneal position of D_3. Ultrasound can be used as a screening method for malrotation eliminating the need for unnecessary barium studies.

Keywords: Duodenum • Malrotation • Ultrasound

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Background

Malrotation with abnormal bowel fixation with mesenteric bands or the absence of bowel segment fixation carry increased risk of intestinal obstruction and volvulus [1]. Any delay in the diagnosis of malrotation may lead to bowel necrosis, short bowel syndrome and the dependence on total parenteral nutrition [1–3]. Seventy-five percent of symptomatic cases are diagnosed during neonatal period and up to 90% of cases become symptomatic during the first year of life [1,4,5].

Among the various diagnostic methods for malrotation [6–12], upper gastrointestinal barium study (UGI series) is the most popular one [1,6]. The study is difficult to performed in neonates as it needs an optimal gastric barium filling, a direct fluoroscopic visualization of the contrast

agent movement, multiple projection radiographs, manipulation, and, in doubtful cases, delayed images or repeated exams [1].

The false positive and false negative results of UGI series has been reported up to 15–30% and 6%, respectively [13]. Furthermore, some studies have shown deficiency of UGI series in ruling out the malrotations [1–6,14,15].

Ultrasound is a widely available, noninvasive and inexpensive diagnostic tool that has been used for the diagnosis of malrotation in some studies [8,10–12]. If the ultrasound could be used to diagnose or exclude malrotation with acceptable precision, it would allow this serious abnormality to be diagnosed quickly without the need for further costly and difficult studies. The position of duodenum, especially its third segment (D_3), and its adjacent structures

should be considered while evaluating malrotation [3]. The D_3 is located retroperitoneally between the superior mesenteric artery (SMA), anteriorly and the aorta, posteriorly. In malrotations, the D_3 is always intramesenteric and located anterior to the mesenteric vessels [1]. An US study, in contrast to UGI series, may demonstrate retromesenteric and retroperitoneal position of D_3 and therefore rule out malrotation [16].

The aim of this study was to assess the feasibility of US in the diagnosis of the position of D_3 and its ability to exclude or diagnose bowel malrotation or malrotation with volvulus.

Material and Methods

A total of 60 consecutive newborns and infants who were referred for abdominal sonography with various indications in March 2012 were included in the study. All ultrasound examinations were performed by an expert pediatric radiologist using MEDISON, ACCUVIX10 system with linear (5–8 MHz) and curved (3–5 MHz) transducers. The structures between the SMA and the aorta were studied in the axial and longitudinal planes. The position of the D_3 and its adjacent structures were recorded: superior mesenteric vein (SMV); left renal vein and its drainage into IVC; first left jejunal vein; D_3 anterior and below the renal vein, posterior to the jejunal vein and adjacent to uncinate process of the pancreas. The position of the D_3 between the SMA, the SMV and the abdominal aorta was also evaluated in the longitudinal plane.

Ultrasound examinations were performed without prior preparation, including bowel preparation, without contrast agent and without sedatives. The duration of ultrasound examination was recorded from the beginning of the examination until the visualization of the retromesenteric D_3, as well as the entire duration of the study.

Results

Thirty-four (56.7%) males and 26 (43.3%) females were included in the study. Mean age of the subjects was 33 ± 23 days (range: 4–100 days). Vomiting (58.3%) was the most common indication for an abdominal US, followed by gastro-esophageal reflux (23%).

Various amounts of bowel gas were observed in most (73%) of the newborns and graded abdominal compression was needed for the identification of the position of D_3. However, D_3 was seen in all patients and its position along with the adjacent structures was fairly assessible in all cases (Figures 1–4). Detailed ultrasound findings are summarized in Table 1.

In all patients, the D_3 was seen in the retroperitoneum, posterior to the SMA and anterior to the aorta. Left renal vein, jejunal vein and uncinate process were seen in all cases.

It was possible to examine the structure of the D_3 in all cases. It appeared as a homogenous or slightly hypoechoic structure. The mucosa (relatively hyperechoic) and muscularis (relatively hypoechoic) were also recognized in some
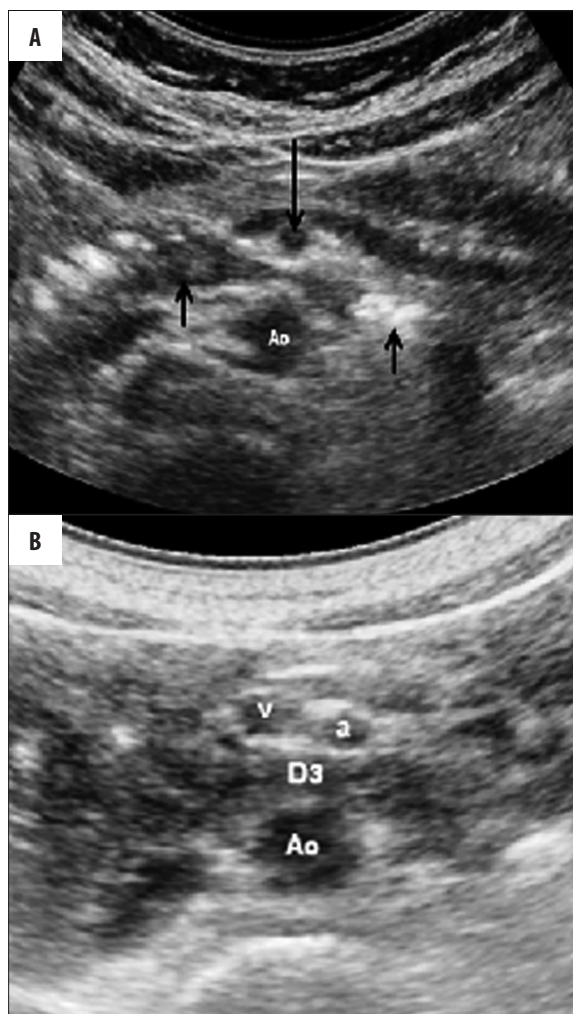
Figure 1. Axial sonogram of 2 neonates. (**A**) D_3 (short arrows) is seen between the SMA (long arrow) and the aorta (Ao), containing some gas in its distal part. (**B**) D_3 is located posterior to the SMA (a) and the SMV (v) and anterior to the aorta (Ao). The SMV is located on the right side of the SMA.

cases. The contents of the D_3 were also examined and included gas and fluid (53%), gas (20%), fluid (20%) and collapsed bowel (7%).

The position of the SMA and the SMV relative to each other and to aorta was evaluated in 100% of cases. In 90% of cases SMV was seen in right side of SMA, in 10% SMA was anterior to SMV. It was also possible to study the position of the SMA and the SMV relative to the aorta in 100% of cases.

Since all the mentioned variables were successfully observed in all newborns, the diagnostic accuracy (normal anatomy as the gold standard) of an ultrasound for the detection of the position of the D_3 and its adjacent structures, thereby excluding malrotation, was 100%. The negative predictive value was also 100%.

The mean time of finding the retromesenteric-retroperitoneal D_3 was 47.8 ± 40 s (10–180 s). The mean time of the entire duration of the study was 168 ± 106 s (22–360 s). An abundant bowel gas overshadow was observed in 5
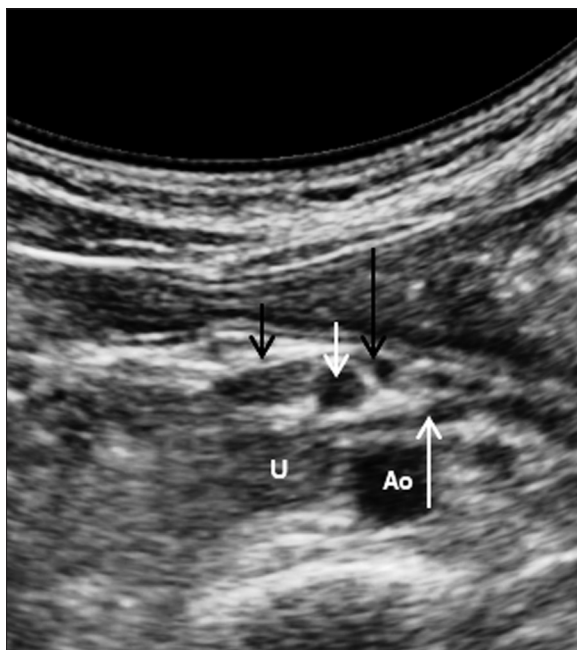
Figure 2. Axial sonogram of a 5-day-old boy demonstrating the SMA (short white arrow), the SMV (short black arrow), the aorta (Ao) and the uncinate process (U). The jejunal vein (long black arrow) is draining to the SMV and the retromesenteric left renal vein (long white arrow) is coursing between the SMA and the aorta to drain into the inferior vena cava.
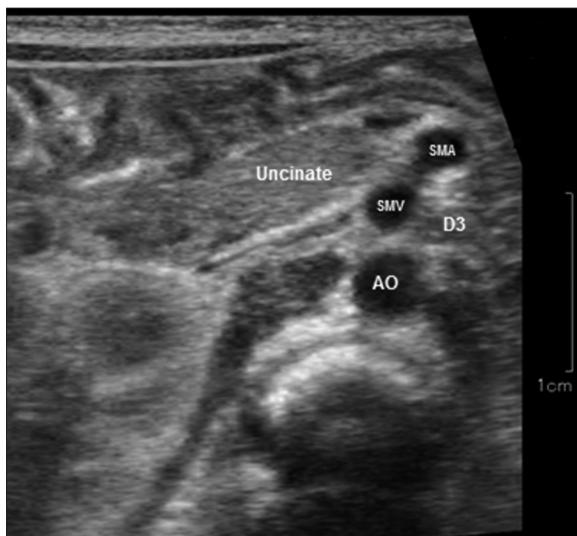

Figure 3. In this axial ultrasound image of a 6-day-old girl, retromesenteric D_3 is seen between the SMA, the SMV and the aorta (Ao). Note that the uncinate process does not cross the midline and has homogenous echotexture identical to the remainder of the pancreas.

cases which resulted in a prolonged duration of the study. Elimination of these 5 cases would decrease the mean time of observing the D_3 and the entire duration of study to 32 s and 112 s, respectively.

There were no statistically significant differences between the male and female patients in terms of all the variables studied.
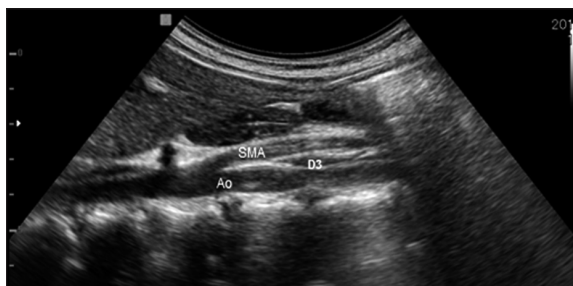

Figure 4. Longitudinal ultrasound image of a 10-day-old boy showing retromesenteric D_3 between the SMA and the aorta (Ao).

No significant differences were observed in the time required to find the retromesenteric-retroperitoneal D_3 and the duration of entire study between the different groups in terms of D_3 contents (Table 2).

Discussion

Position of the duodenum, especially the D_3 and its adjacent structures, should be considered when evaluating midgut malrotation [3]. In malrotation, the D_3 is always intraperitoneal and anterior to the mesenteric vessels [1].

In the current study, the D_3 was successfully observed in all patients in its natural retroperitoneal position, posterior to the SMA and anterior to the aorta. Its adjacent structures, such as the renal vein and the uncinate process of pancreas, were also completely visible. Furthermore, it was possible to evaluate other features, such as the diameter of the D_3, its structure and contents. In fact, the diagnostic accuracy of an ultrasound for the detection of D_3 position was 100%. These findings were similar to the study of Yousefzadeh et al. [6] who reported 100% success rate of ultrasound by demonstrating retromesenteric position of the D_3 between the SMA anteriorly and the aorta posteriorly in 33 newborns.

In another study, Yousefzadeh et al. [17] demonstrated that in most cases, ultrasound properly displays the retromesenteric position of the D_3 and could be used to rule out malrotation and volvulus. In that study, the ultrasound has yielded to better results compared to UGI series. The authors preferred the US because it displayed the position of the D_3 precisely through the axial planes, while barium studies did not have such capability.

In the first fetal trimester, the D_3 is fixed posteriorly to the peritoneum after fetal displacement, which prevents the formation of volvulus. Pathological and surgical evidence indicates that in case of volvulus and malrotation, the D_3 is always intramesenteric and has not reached its final destination. Therefore, the observation of a retromesenteric D_3 proves the completion of fetal displacement and excludes malrotation. In this manner, it is possible to comment on the negative predictive value of the ultrasound. In the current study, the negative predictive value of ultrasound for malrotation was 100%. Therefore, observing the D_3 in its natural position in the retroperitoneum on an ultrasound would indicate no malrotation and no need for more investigations with barium UGI series or radiation.

Table 1. Results of ultrasound examination of the third portion of the duodenum (D_3).

Variable examined	Success rate	Results
D_3 position	100%	Posterior to the SMA, anterior to the aorta
Adjacent structures	100%	Left renal vein, jejunal vein, uncinate process of the pancreas
D_3 structure	100%	Homogenous or slightly hypoechoic, $\pm$ detectable mucosa and muscularis
D_3 contents	100%	53% gas and fluid; 20% gas; 20% fluid; 7% collapsed
D_3 anteroposterior diameter	100%	Mean: 5.5$\pm$1.3 mm; range: 3–8 mm
Position of the SMA and the SMV relative to each other	100%	SMV right to SMA 90%; SMA anterior to SMV 10%
Position of the SMV and the SMA relative to the aorta	100%	100% anterior to the aorta (40% on the right; 30% on the left; 30% anterior in the midline)
SMA – aorta distance	100%	Mean: 8$\pm$1.8 mm; range: 4–11 mm

Table 2. Duration of ultrasound examination in infants with verious D_3 contents.

D_3 content	Time until detection of retroperitoneal D_3 (s)	Time of the entire study (s)
Gas and fluid	55$\pm$51	180$\pm$117
Gas	42$\pm$16	191$\pm$100
Fluid	38$\pm$24	125$\pm$95
Collapsed	35$\pm$21	130$\pm$70
P value	>0.05	>0.05

Similarly to Yousefzadeh et al. [6], in our study the amount of bowel gas had no effect on the result of ultrasound examination, and the D_3 was seen in all patients (even those with significant bowel gas) between the SMA and the aorta. In fact, the shadows of bowel gas that interfered with the examination were easily displaced through a maneuver of gradual abdominal compression with an ultrasound probe.

The D_3 is the only bowel structure with retromesenteric-retroperitoneal position and can be easily identified. Furthermore, the identification of its adjacent anatomic structures confirms that what is assumed to be the D_3 is truly the D_3. In this study, we identified the main adjacent structures of the D_3 in all patients, including the left renal vein, the jejunal veins and the uncinate process of pancreas. The D_3 lies near the uncinate process, anteroinferiorly to the left renal vein and posteriorly to the jejunal veins. Due to its course between the SMA and the aorta, and its drainage into the IVC, the left renal vein can be confidently identified. Jejunal veins also pass posteriorly to the SMA and anteriorly to the D_3 and the aorta. However, the first jejunal vein may pass anteriorly to the SMA [6]. Due to echogenicity similar to other portions of the pancreas, the uncinate process can also be distinguished. In order to avoid mistaking the uncinate process for the D_3, the examiner should be remembered that besides echogenicity similar to other portions of the pancreas, this structure does not cross the midline and its echogenicity is more than that of the D_3. The absence of the uncinate process suggests bowel malrotation [16].

Malposition of the SMA and the SMV is another sign of malrotation [18–21]. Usually, the SMV is located to the right of the SMA before entering the mesentery anteriorly to the SMA [22]. Recent studies indicate various positions of the SMA and the SMV, i.e. they are not reliable signs for the detection or exclusion of malrotations [23,24]. In our study, no reversal of SMA and SMV positions was observed.

In some studies, the accuracy of an ultrasound examination for the detection or exclusion of malrotation in terms of SMA and SMV position has been reported to be lower than in our study and other similar studies. For example, Orzech et al. [11] indicated that 21% of children had abnormal US and normal UGI (false positive), and 5 patients had normal US despite abnormal UGI (2% false negative). In cases of abnormal ultrasound, the reversed position of the SMA/SMV and the whirlpool sign had more predictive value than the anterior/posterior position of the volvulus. Furthermore, Weinberger et al. [21] demonstrated abnormal position of mesenteric vessels in 9 out of 249 patients. All 5 cases with the SMV located to the left of the SMA had malrotation in UGI series, while 3 out of 4 patients with the SMV anterior to the SMA were false positive and just 1 case presented with malrotation. In fact, position of the

SMV anterior to the SMA should not be considered as a criterion indicative of malrotation.

Besides high accuracy of an ultrasound in demonstrating retromesenteric-retroperitoneal D_3, the ultrasound is a simple, inexpensive and a quick diagnostic tool that can be performed at the bedside without radiation exposure. In this study, the mean time of finding retroperitoneal D_3 segment was less than 1 minute, while the mean duration of entire examination was less than 3 minutes.

Conclusions

An ultrasound can easily show the retroperitoneal position of the D_3. It can be used as a routine screening method for malrotation and eliminate the need for more difficult and time-consuming unnecessary barium studies and radiation exposure of the newborns.

Conflict of Interest

None.

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