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Saline-Aided Ultrasound as a Primary Investigation Tool in Diagnosis of Duodenal Obstruction in Preterm Infants

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ABSTRACT

Background: Congenital duodenal obstruction (CDO) is among the most prevalent causes of neonatal intestine blockage, with an incidence reported as 1 in 2,500 to 10,000 live births.

Objective: To evaluate the role of ultrasound (US) with saline infusion in detection of duodenal atresia in preterm infants. **Patients and Methods:** This prospective cross-sectional study included 50 preterm neonates, aged 1 to 35 days, of both sexes, at the incubation and had repeated bilious vomiting. The neonates underwent saline-aided US and were evaluated using intraoperative findings as the reference standard. US features, such as the double bubble sign, hyperechogenic band, and duodenal web, were assessed.

Results: The saline-aided US accurately diagnosed duodenal obstruction in 41 (82%) neonates, with a double bubble sign observed in all cases. The causes of obstruction included annular pancreas (AP) (34%), duodenal atresia (8%), duodenal web (30%), and duodenal malrotation (28%). For detecting AP, the hyperechogenic band had a sensitivity of 76.5%, specificity of 100%, and accuracy of 92% (AUC=0.882), with a perfect agreement ($P < 0.001$, Kappa = 0.811) between two sonographers. US and surgery had moderate agreement for duodenal atresia detection but perfect agreement for duodenal web and malrotation, with 100% accuracy for both.

Conclusions: Saline-aided US is an effective, radiation-free primary diagnostic tool for detecting duodenal obstruction in preterm infants, offering high diagnostic accuracy and excellent agreement with surgical findings.

Keywords: Saline-aided ultrasound, Duodenal obstruction, Preterm, Neonatal intestinal obstruction, CDO.

INTRODUCTION

Intestinal obstruction in neonates is a significant clinical challenge, requiring prompt diagnosis and treatment to prevent serious complications. Among the various causes, CDO is one of the most common, accounting for nearly 50% of neonatal intestinal obstruction cases. According to reports, duodenal blockage affects one in 2,500-10,000 live births [1,2].

Traditionally, abdominal radiography has been a popular imaging modality for identifying upper gastrointestinal (UGI) obstruction [3]. However, its accuracy may be restricted in pediatric patients, particularly those who have experienced repeated emesis or who have a nasogastric tube in place for decompression. In these circumstances, the UGI series is considered the gold standard for identifying UGI obstruction in children [4]. Nevertheless, concerns have been raised about the potential risks of radiation exposure, particularly in neonates, whose developing organs are more sensitive to radiation. As a result, there is an increasing need to explore alternative imaging modalities that reduce radiation exposure [5].

Ultrasound (US) has become a widely available, radiation-free diagnostic technique for assessing upper gastrointestinal blockage in newborns [6]. Certain causes of UGI obstruction, including as malrotation and hypertrophic pyloric stenosis, have been successfully diagnosed by conventional US [7]. To further enhance diagnostic capabilities, saline solution is used as a contrast agent during ultrasound examinations. Saline-aided ultrasound provides dynamic imaging by tracking fluid flow, evaluating bowel dilation, and improving the visualization of the intestinal lumen [8].

Beyond its use in UGI obstructions, the US has demonstrated potential in other gastrointestinal conditions. Saline-aided US offers the advantage of real-time assessment, which allows for rapid decision-making in the critical care setting, potentially reducing the need for more invasive diagnostic procedures [9].

This study was designed to evaluate the role of ultrasound with saline infusion in detection of duodenal atresia in preterm infants.

PATIENTS AND METHODS

Patients:

50 preterm neonates at the incubation who were prospectively evaluated by upper GI saline-aided US at our institution, between January 2023 and June 2024, participated in this prospective cross-sectional study. Preterm neonates aged 1 to 35 days, of both sexes, and had repeated bilious vomiting were sent to the Radiology Department for saline-aided ultrasound evaluation due to suspected duodenal obstruction.

Inclusion criteria:

- Patients who had repeated bilious vomiting.

Exclusion criteria:

- Neonates older than 40 days.
- Neonates with non-bilious vomiting.
- Obstructions located in parts of the digestive tract other than the duodenum.

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METHODS

Important data was documented, such as the surgical techniques, intraoperative observations, clinical presentations, and characteristics of upper gastrointestinal saline-assisted US.

***Ultrasonographic examination**:*

Preterm neonates were kept in their incubators during the procedure to ensure minimal stress and maintain a stable environment. In supine position, Ryle tubes were inserted to allow saline injection into the stomach and was consoled by a pacifier when required. Prior to saline administration, the Ryle tube was utilized to evacuate air from the stomach and duodenum, followed by meticulous abdominal scans conducted on sonographic sections encompassing the stomach, duodenum, surrounding structures of the stenotic duodenum, head of the pancreas, jejunoileum, and colorectum.

A controlled volume of sterile saline solution was injected into the stomach through the Ryle tube to artificially distend the upper gastrointestinal tract. The volume of saline was tailored based on the neonate's clinical condition, ensuring adequate visualization of the stomach and duodenum without causing overdistention.

After saline intake, complete serial ultrasound examinations were performed using an Sonoscape E1EXP (2020 edition; Sonoscape Medical; China) with a microconvex and linear probe, immediately after saline injection and at 10-minute intervals. The initial ultrasound was performed immediately after the saline injection to evaluate the configuration of the stomach and duodenum. The ultrasound aimed to detect the double bubble sign, which refers to the distended stomach and proximal duodenum appearing as two fluid-filled, bubble-like structures.

Following saline administration, comprehensive abdominal scans were conducted once more, revealing ultrasound characteristics including a hyperechoic band resembling pancreatic tissue encircling the stenotic duodenum, a web within the duodenal lumen, and the rotation of the superior mesenteric vein (SMV) around the superior mesenteric artery (SMA) (Figure 1).

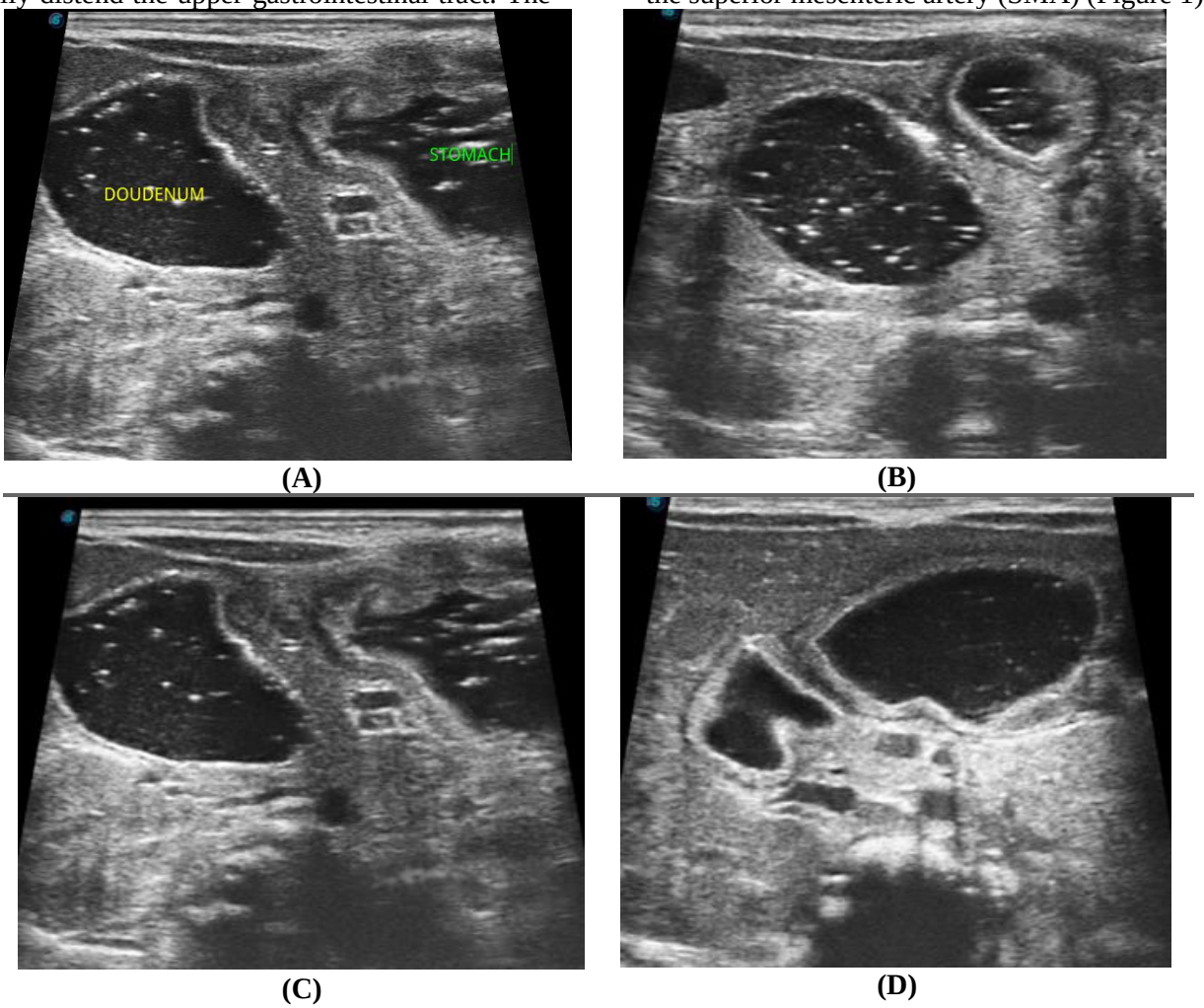
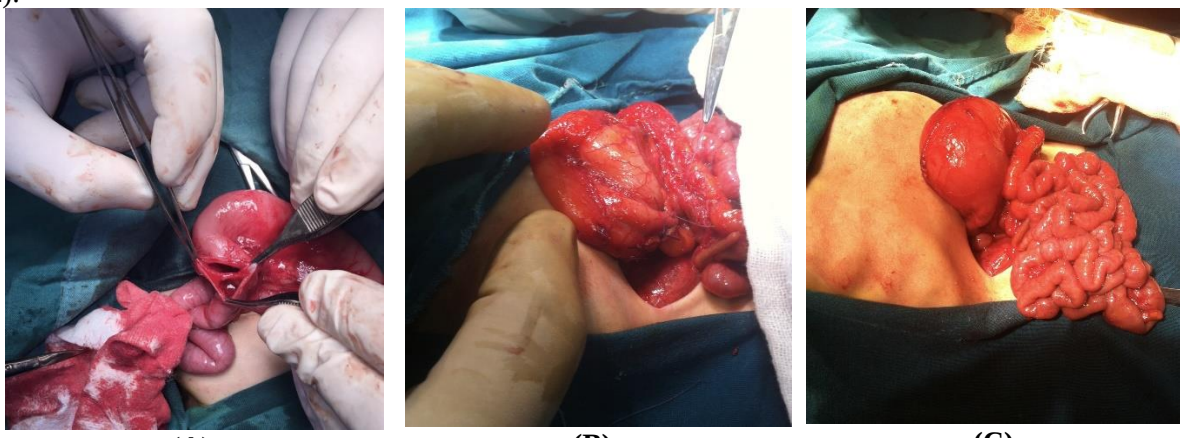


Figure (1): Ultrasonic images of the GI tract after saline intake in neonates with AP showing dilated stomach and dilated proximal duodenum with collapsed distal part (A) on serial scanning after 5, 10, and 15 minutes (B, C and D) persistent dilatation is noted suspecting obstruction.

A follow-up ultrasound was conducted 10 minutes after the initial assessment to confirm the persistence of the duodenal obstruction. The stomach and duodenum remained distended, and no fluid or contrast passed beyond the duodenum, further supporting the diagnosis of obstruction. Following the US examination, the saline was extracted from the stomach utilizing the Ryle tube.

To confirm the ultrasound findings, an abdominal X-ray was performed on all neonates. The X-ray looked for the characteristic "double bubble" sign, which is defined as a dilated stomach and proximal duodenum, with no air or contrast seen distally. This radiographic sign is a key indicator of duodenal obstruction.
Neonates with positive findings on both ultrasound and X-ray underwent exploratory surgery for definitive diagnosis and treatment. During the surgery, the obstruction was confirmed, and appropriate surgical correction was performed (Figure 2).



(A) **(B)** **(C)**

Figure (2): showing (A) duodenal web, (B, and C) duodenal atresia.

The surgical findings were recorded and correlated with the imaging results to validate the accuracy of the saline-aided ultrasound technique.

Standard of reference:
• In our investigation, intraoperative findings served as the standard of reference.
• We evaluated the sensitivity, specificity, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and area under the receiver operating characteristic (ROC) curve (AUC) and accuracy for saline-aided ultrasound for cause of duodenal obstruction.

Ethical approval:
Menoufia University Hospitals Ethics Committee (REC) gave its approval for this work (RAD 7-2024). Informed consent was acquired from parents in writing for participation in the study, following a comprehensive explanation of the study's aims, process, and relevant objectives. The study adhered to the Helsinki Declaration throughout its execution.

Statistical analysis

Version 27.0 of SPSS was used for the statistical analysis. The quantitative data were displayed as mean ± standard deviation (SD). Frequency and percentage (%) were used to represent the qualitative variables. The study evaluated the diagnostic performance of ultrasound (US) features against intraoperative findings (the gold standard), calculating sensitivity, specificity, PPV, NPV, accuracy, and area under the ROC curve (AUC). Agreement between two sonographers was assessed using Kappa statistics [10]. P value less than 0.05 with two tails was deemed statistically significant.

RESULTS

50 preterm neonates at the incubation diagnosed with duodenal obstruction were included in this study; their ages ranged from 30 to 34 day. There were 26 (52%) males. All neonates were premature birth. The birth weight ranged from 1100 -1800 g. According to clinical examination, vomiting was the most common findings in the 34 (68%) neonates (Table-1).

Table (1): Demographic data and clinical examination of the studied patients

		(n=50)
Age (days)		32.1 ± 1.3
Sex	**Male**	26 (52%)
	Female	24 (48%)
Premature birth		50 (100%)
Birth weight (g)		1328 ± 193.3
Clinical examination	**Vomiting**	34 (68%)
	Feeding intolerance	3 (6%)
	Recurrent chest infection	5 (10%)
	Bilious vomiting	2 (4%)
	Aspiration	2 (4%)
	Distension	4 (8%)

Data are presented mean ± standard deviation (SD) or as frequency (%).

The most common cause of duodenal obstruction was AP in 17 (34%) neonates (Table-2).

Table (2): Causes of duodenal obstruction of the studied patients

		(n=50)
Causes of duodenal obstruction	**Annular pancreas**	17 (34%)
	Duodenal atresia	4 (8%)
	Duodenal web	15 (30%)
	Duodenal malrotation	14 (28%)

Data are presented as frequency (%).

X-ray finding was double bubble sign in 41 (82%) neonates, these 41 (82%) neonates were positive in ultrasound aided saline injection findings. The amount of saline was 5 ml each time till 20 ml in all patients. Time for decision was 10 minutes in all patients (Table-3).

Table (3): X-ray, ultrasound aided saline injection findings, amount of saline and time for decision of the studied patients

		(n=50)
X-ray finding	**Double bubble sign**	41 (82%)
	Free	9 (18%)
US aided saline injection findings	**Positive**	41 (82%)
	negative	9 (18%)
Amount of saline	**5 ml each time till 20 ml**	50 (100%)
Time for decision	**10 minutes**	50 (100%)

Data are presented as frequency (%).

The 41 (82%) neonates who had double bubble sign on X-ray findings and were positive on ultrasound findings underwent surgery and had confirmed diagnosis; the other 9 (18%) neonates were managed by clinical follow-up and were improved (Table-4).

Table (4): Management and result of management of the studied patients

		(n=50)
Management	**Surgery**	41(82%)
	Follow up	9 (18%)
Result of management	**Confirm diagnosis**	41 82%)
	Improved	9 (18%)

Data are presented as frequency (%).

The sensitivity, specificity, PPV, NPV, and accuracy of the hyperechogenic band for the detection of AP were 76.5%, 100%, 100%, 89.2%, and 92% respectively with an AUC of 0.882.

The presence of hyperechogenic band had almost perfect agreement (P <0.001, kappa=0.811) between the two sonographers. There was a moderate agreement between surgery and ultrasound (P <0.001, Kappa= 0.520) for the detection of duodenal atresia with sensitivity, specificity, NPV, and accuracy of 0%, 100%, 92% and 92% respectively. There was almost perfect agreement between surgery and ultrasound (P <0.001, Kappa=1.00) for the detection of both duodenal web and duodenal malrotation with sensitivity, specificity, PPV, NPV, and accuracy of 100%, 100%, 100%, 100% and 100% respectively (Table-5, Figure 3).

Table (5): Diagnostic Accuracy of Saline-Aided Ultrasound for Cause of duodenal Obstruction

Ultrasound		**Surgery**			**Kappa**	**P**
		Positive	**Negative**	**Total**		
Annular pancreas	**Positive**	13(76.47%)	0(0%)	13	0.811	**<0.001***
	Negative	4(23.53%)	33(100%)	37		
		17	33	50		
		Sensitivity	Specificity	PPV	NPV	Accuracy
		76.5%	100%	100%	89.2%	92%
		Positive	**Negative**	**Total**		
Duodenal atresia	**Positive**	0(0%)	0(0%)	0	0.520	**<0.001***
	Negative	4(100%)	46(100%)	50		
	Total	4	46	50		
		Sensitivity	Specificity	PPV	NPV	Accuracy
		0%	100%	-	92%	92%
		Positive	**Negative**	**Total**		
Duodenal web	**Positive**	15(100%)	0(0%)	15	1.00	**<0.001***
	Negative	0(0%)	35(100%)	35		
	Total	15	35	50		
		Sensitivity	**Specificity**	**PPV**	**NPV**	**Accuracy**
		100%	100%	100%	100%	100%
Duodenal malrotation	**Positive**	14(100%)	0(0%)	14	1.00	**<0.001***
	Negative	0(0%)	36(100%)	36		
	Total	14	36	50		
		Sensitivity	**Specificity**	**PPV**	**NPV**	**Accuracy**
		100%	100%	100%	100%	100%

*Significant

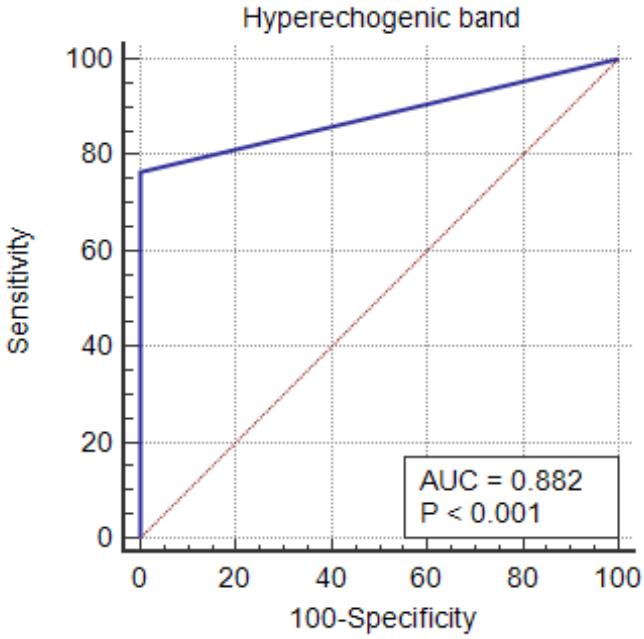


Figure (3): ROC curve of the hyperechogenic band for the diagnosis of AP.

DISCUSSION

Despite the established role of US in diagnosing various neonatal gastrointestinal conditions, studies explicitly assessing the application of saline-assisted US for the detection of duodenal blockage in preterm neonates are conspicuously lacking. This study is among the first to explore the use of saline-enhanced US for detecting duodenal obstruction in preterm infants.

Saline-aided US offers significant advantages for imaging neonates and infants due to its lack of radiation exposure and broad accessibility. The introduction of contemporary high-frequency probes, which offer detailed vision of GI structures, is one of the technological advancements in US that has contributed to the great diagnostic accuracy shown with saline-assisted US [11]. Saline-aided US allows for dynamic visualization of the UGI tract, enabling real-time assessment of fluid flow and bowel dilatation [12]. This dynamic aspect is particularly valuable in diagnosing partial obstructions or intermittent blockages like annular pancreas, that might be missed on static imaging [13].

In this study, the sensitivity, specificity, and accuracy of the hyperechogenic band for the detection of AP were 76.5%, 100%, and 92% respectively with an AUC of 0.882. There was nearly perfect agreement (κ= 0.811) between the two sonographers regarding the presence of the hyperechogenic band.

Our findings came in line with **Yang *et al.*** [11] who reported that the hyperechogenic band detected AP with 78.8% sensitivity, 90.3% specificity, and 86.3% accuracy. Also, **Chen *et al.*** [14] noted that saline-aided US exhibited good interobserver agreement for the existence (κ= 0.87) and level (κ= 0.85) of blockage.

In the present study, there was a moderate agreement between surgery and ultrasound (Kappa= 0.520) for the detection of duodenal atresia with sensitivity, specificity, and accuracy of 0%,100%, and 92% respectively. This moderate agreement may be attributed to the technical challenges associated with visualizing the atretic segment, which can be obscured by the dilated proximal duodenum. Lower sensitivity for duodenal atresia compared to other causes of obstruction in our study might be due to the small sample size of atresia cases in our cohort or the challenge of differentiating complete atresia from severe stenosis on ultrasound [15].

Yang *et al.* [11] agreed with our results and demonstrated that the sensitivity, specificity, and accuracy for detecting duodenal atresia were 0%, 100%, and 93.6%, respectively..

Our results showed that there was almost perfect agreement between surgery and US (κ= 1.00) for the detection of both duodenal web and duodenal malrotation with sensitivity, specificity, and accuracy of 100%, 100% and 100% respectively.

Yang *et al.* [11] reported the same of our findings as they found that the sensitivity, specificity, and accuracy for the detection of duodenum web were 100%, 100%, 100%, and 100%, respectively and for the detection of malrotation were 100%, 100%, and 100%, respectively.

While X-rays have been the traditional imaging modality for diagnosis, our findings support the idea that saline-aided ultrasound could potentially replace it as the primary investigation in preterm infants with suspected duodenal obstruction. As US significantly reduces the radiation exposure, it aligns with the ALARA (As Low As Reasonably Achievable) principle in pediatric imaging [16].

One limitation of the study was that it was performed at a single institution, which may affect the generalizability of the results. Another limitation is the relatively small sample size, which might not represent the diverse presentation of duodenal obstruction.

Additionally, the study only evaluated preterm neonates, which may not be applicable to neonates of different ages or full-term neonates. Future multicentric studies with larger sample sizes evaluating different age groups, including both preterm and full-term neonates, are needed to confirm the results and investigate the applicability of saline-aided US in a broader population. It is also recommended to evaluate the cost-effectiveness of saline-aided ultrasound compared to other imaging modalities and whether it can effectively reduce the need for invasive investigations.

CONCLUSIONS

Saline-aided US is an effective, radiation-free primary diagnostic tool for detecting duodenal obstruction in preterm infants, offering high diagnostic accuracy and excellent agreement with surgical findings.

- **No funding.**
- **No conflict of interest.**

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