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Ultrasound of The Pediatric Gastrointestinal Emergencies

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Abstract
Background: The use of ultrasound has gained significant significance as a diagnostic method for pediatric gastrointestinal emergencies. The primary goal of this research was to evaluate the role of ultrasound in diagnosing non-traumatic gastrointestinal emergencies in children. **Methods:** This observational study included 100 pediatric patients, both sexes, aged 0-16 years old, who presented at the emergency department at Benha University Hospital with acute abdominal pain and were directed to abdominal ultrasound in the Radiology Department between July 2022 and December 2022. All patients were subjected to detailed history taking, full clinical examinations, routine laboratory investigations and Radiological investigations including abdominal-pelvic ultrasound and CT abdomen if needed. **Results:** the age ranged from 3 to 16 years with a mean ± SD of 9.8 ± 4.34 years. 43 (43%) patients had Rt lower ¼ pain, 95 (95%) patients had abdominal pain, 37 (37%) patients had ileus, 41 (41%) patients had diarrhea, 17 (17%) patients had hematochezia, 63 (63%) patients had vomiting, 29 (29%) patients had fever and 44 (44%) patients had worse general conditions. Free intra-abdominal fluid represented 10 (10%) patients, portal vein gas represented 6 (6%) patients, loculated Rt lower ¼ mass represented 4 (4%) patients, abscess represented 2 (2%) patients, fluid-filled, uncompressible, blind-ending tubular structure represented 26 (26%) patients, distended, fluid-filled bowel loops represented 30 (30%) patients, pseudo kidney appearance represented 8 (8%) patients, doughnut sign represented 17 (17%) patients, target sign represented 40 (40%) patients, enlarged mesenteric lymph nodes represented 33 (33%) patients. **Conclusions:** Ultrasonography (US) is a key imaging tool for the evaluation of acute abdominal pain, especially in young patients, for whom a satisfactory examination is occasionally impossible.

Keywords: Ultrasound; Pediatric; Gastrointestinal; Emergencies.

1. Introduction

Ultrasound has become an increasingly important diagnostic tool in the evaluation of pediatric GI emergencies [1]. These emergencies can be broadly classified into nontraumatic and traumatic conditions. A variety of conditions fall under the category of nontraumatic gastrointestinal emergencies, which may include but are not limited to pyloric stenosis, appendicitis, intussusception, and bowel obstruction [2]. Early and precise identification of these ailments is crucial for proper treatment and to avoid possible complications [3].

Traditionally, radiographic imaging, such as plain radiographs and contrast studies, have been used to diagnose pediatric gastrointestinal emergencies. However, these imaging modalities have limitations, including radiation exposure and the need for contrast material, which can be problematic in certain patients. Ultrasound, on the other hand, is noninvasive, does not involve radiation exposure, and is readily available in most clinical settings [4].

The use of US in the diagnosis of pediatric nontraumatic GI emergencies has been shown to be highly accurate, with specificity and sensitivity approaching 100% in some cases. For example, ultrasound is considered the imaging modality of choice for the diagnosis of intussusception, with reported sensitivity and specificity of 98% and 100%, respectively. Similarly, US has been shown to be highly accurate in the diagnosis of pyloric stenosis, with reported sensitivity and specificity of 94% and 98%, respectively [5].

In addition to its high accuracy, US has other advantages over traditional radiographic imaging modalities. Ultrasound is a dynamic imaging modality, which allows for real-time assessment of the gastrointestinal tract and surrounding structures. This can be particularly useful in the assessment of conditions such as bowel obstruction, where the dynamic nature of ultrasound can provide valuable information regarding the location and cause of the obstruction [6].

This study aimed to assess the role of US in the assessment of pediatric nontraumatic GI emergencies.

2. Methods

From July 2022 to December 2022, a total of 100 children with acute abdomen were referred to the Radiology Department for abdominal ultrasound at Benha University Hospital's emergency department as part of this observational study.

This research study was done after being approved by the Research Ethics Committee, Faculty of Medicine, Benha University. Informed consent was obtained from the legal guardians of all pediatric patients included in this study prior to undergoing US evaluation for nontraumatic gastrointestinal emergencies.

Inclusion criteria were both sexes, age from birth 0-16 years old with acute abdominal pain.

Exclusion criteria were traumatic patients, age>16 years old.

All studied cases were subjected to 1. Detailed history taking, including Personal history; present

history, past history and Family history of similar condition. **2. Full clinical examination: A**-General examination including (General comment on patient conscious and mental state, Jaundice or pallor, Vital signs: pulse, blood pressure, capillary filling time, respiratory rate and temperature). **B**-Systemic examination including. **3. Routine laboratory investigations. 4. Radiological investigations:** Abdominal-pelvic ultrasound and CT abdomen if needed.

Abdominal ultrasound technique

Patients' preparation: There is no preparation necessary for the ultrasonography process. The study required the collection of demographic data, such as age and gender, as well as a comprehensive medical history, clinical symptoms, laboratory testing, and other diagnostic outcomes or surgical treatments. The Emergency Pediatric Unit conducts a clinical examination to establish an initial diagnosis. Before doing an ultrasound examination, radiologists must have a firm grasp of the clinical manifestations of gastrointestinal (GI) illnesses requiring emergency care. Vomiting, discomfort, hematochezia, and diarrhea, with or without fever, are the most prevalent symptoms. Although some illnesses have distinctive symptoms, many have symptoms and looks that are identical. The patient's medical history, age, and symptoms, as well as consultation with a pediatric emergency physician, are essential for making an appropriate diagnosis.

Grey-Scale Ultrasonography (U/S) and color Doppler Ultrasonography were utilized in a diagnostic method on the participants of the research (CDUS). Particularly in individuals with abdominal distension or guarding, the presence of intestinal gas might conceal abdominal organs on ultrasound studies. To circumvent this constraint, the approach of graduated compression was utilized. This technique successfully removes intestinal gas and shortens the distance between the transducer and the target organ. In addition, it can separate aberrant intestine segments (such as those with acute appendicitis or other intestinal inflammation) from normal bowel segments by pushing neighboring normal bowel segments away.

Technique of examination: During the ultrasound examination, the patients' abdomens were evaluated utilizing both 3.5 MHZ and 7.5 MHZ transducers in longitudinal and transverse orientations using Grey-Scale U/S. Additionally, color Doppler US was utilized to assess organ perfusion and inflammation. The patients were instructed to stretch their legs on the examination couch and to wear loose-fitting, comfortable attire. The transducer was positioned longitudinally and transversely until the maximal cross-sectional area was visible. At the start of the examination, the patient indicated the area of greatest soreness. The radiologist put a transparent, water-based gel to the belly and adjusted the transducer to sweep over the region of interest or angle the sound beam to see a specific spot.

Statistical analysis:

SPSS v26 was used to do statistical analysis (IBM Inc., Armonk, NY, USA). Using the Shapiro-Wilks test and histograms, the normality of the data distribution was determined. As mean and standard deviation, quantitative parametric data were given (SD). Non-parametric quantitative data are provided as the median and interquartile range (IQR). Using the Chi-square test, qualitative data were expressed as frequency and percentage (%) and examined. A two-tailed P value less than or equal to 0.05 was deemed statistically significant.

3. Results

Demographic data of the studied patients were shown in **Table 1**.

Table (1) Demographic data of the studied patients

		(n=100)
Age (Years)	**Mean ± SD**	9.8 ± 4.34
	Range	3 - 16
Sex	**Male**	63 (63%)
	Female	37 (37%)
Weight (Kg)	**Mean ± SD**	44.6 ± 10.56
	Range	25 - 60
Height (m)	**Mean ± SD**	1.4 ± 0.1
	Range	1.21 - 1.55
BMI (Kg/m^2)	**Mean ± SD**	24.2 ± 7.22
	Range	10.82 - 38.3

BMI: body mass index

43 (43%) patients had Rt lower ¼ pain, 95 (95%) patients had abdominal pain, 37 (37%) patients had ileus, 41 (41%) patients had diarrhea, 17 (17%) patients had hematochezia, 63 (63%) patients had vomiting, 29 (29%) patients had fever and 44 (44%) patients had worse general conditions. **Figure 1**

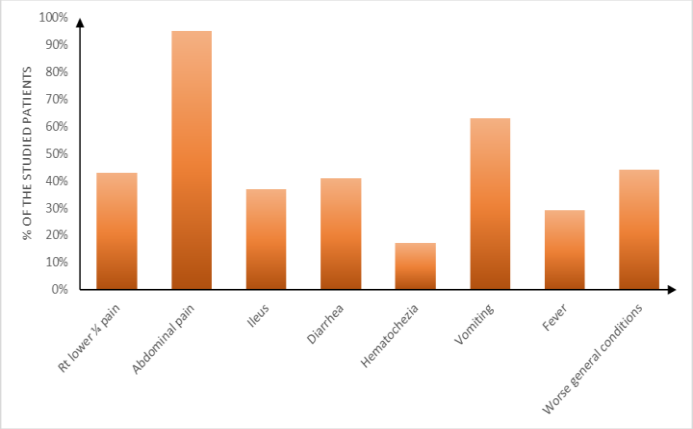

Fig. (1) Clinical presentation of the studied patients

HR ranged from 60 to 100 beats/min with a mean ± SD of 78.3 ± 12.51 beats/min. SBP ranged from 100 to 130 mmHg with a mean ± SD of 118.6 ± 10.15 mmHg. DBP ranged from 60 to 90 mmHg with a mean ± SD of 76.1 ± 10.14 mmHg. O_2 ranged from 97 to 99 % with a mean ± SD of 98 ± 0.82 %. Temperature ranged from 36.3 to 37.5 °C with a mean ± SD of 36.9 ± 0.38 °C. Hb ranged from 9.5 to 13 g/dL in with a mean ± SD of 11.2 ± 1.02 g/dL. WBCs ranged from 4.9 to 11 $x10^3$/L with a mean ± SD of 8.1 ± 1.85 $x10^3$/L. PLT ranged from 197 to 430 $x10^3$/L with a mean ± SD of 313.3 ± 65.47 $x10^3$/L. RBS ranged from 70 to 100 mg/dL with a mean ± SD of 83.6 ± 9.06 mg/dL. CRT ranged from 1.5 to 1.9 sec with a mean ± SD of 1.7 ± 0.13 sec. ALT ranged from 7 to 55 U/L with a mean ± SD of 29.7 ± 14.35 U/L. AST ranged from 8 to 40 U/L with a mean ± SD of 24.1 ± 9.95 U/L. **Table 2**

Table (2) Vital signs, Laboratory investigations of the studied patients

Vital signs		**(n=100)**
HR (Beats/min)	**Mean ± SD**	78.3 ± 12.51
	Range	60 - 100
SBP (mmHg)	**Mean ± SD**	118.6 ± 10.15
	Range	100 - 130
DBP (mmHg)	**Mean ± SD**	76.1 ± 10.14
	Range	60 - 90
O_2 (%)	**Mean ± SD**	98 ± 0.82
	Range	97 - 99
Temperature (°C)	**Mean ± SD**	36.9 ± 0.38
	Range	36.3 – 37.5
Laboratory investigations		(n=100)
Hb (g/dL)	**Mean ± SD**	11.2 ± 1.02
	Range	9.5 - 13
WBCs ($x10^3$/L)	**Mean ± SD**	8.1 ± 1.85
	Range	4.9 - 11
PLT ($x10^3$/L)	**Mean ± SD**	313.3 ± 65.47
	Range	197 - 430
RBS (mg/dL)	**Mean ± SD**	83.6 ± 9.06
	Range	70 - 100
CRT (sec)	**Mean ± SD**	1.7 ± 0.13
	Range	1.5 – 1.9
ALT (U/L)	**Mean ± SD**	29.7 ± 14.35
	Range	7 - 55
AST (U/L)	**Mean ± SD**	24.1 ± 9.95
	Range	8 - 40

HR: heart rate, DBP: diastolic blood pressure, WBCs: white blood cells, SBP: systolic blood pressure, O_2: oxygen saturation, Hb: hemoglobin, PLT: platelets, RBS: random blood sugar, CRT: capillary filling time, ALT: alanine transaminase, AST: aspartate aminotransferase

Free intra-abdominal fluid represented 10 (10%) patients, portal vein gas represented 6 (6%) patients, loculated Rt lower ¼ mass represented 4 (4%) patients, abscess represented 2 (2%) patients, fluid-filled, uncompressible, blind-ending tubular structure represented 26 (26%) patients, distended, fluid-filled bowel loops represented 30 (30%) patients, reversed SMA & SMV represented 1 (1%) patient, pseudo kidney appearance represented 8 (8%) patients, sandwich sign represented 0 (0%) patients, doughnut sign represented 17 (17%) patients, target sign represented 40 (40%) patients, double track sign represented 3 (3%) patients, enlarged mesenteric lymph nodes represented 33 (33%) patients and elongated pyloric canal represented 3 (3%) patients. Anechoic mesentery represented 6 (6%) patients, echogenic represented 17 (17%) patients, hyperechoic represented 58 (58%) patients and hypervascularization represented 19 (19%) patients. 6 (6%) patients had pyloric lesions, 10 (10%) patients had duodenum lesions, 9 (9%) patients had jejunum lesions, 17 (17%) patients had ileum lesions, 32 (32%) patients had ileocecal lesions, 6 (6%) patients had large intestine lesions and 20 (20%) patients had not determined/not GIT lesions. **Table 3**

Table (3) Abdominal ultrasonographic, Mesenteric ultrasonographic findings and Site of pathology of the studied cases

		(n=100)
Free intra-abdominal fluid		10 (10%)
Portal vein gas		6 (6%)
Loculated Rt lower ¼ mass		4 (4%)
Abscess		2 (2%)
Fluid-filled, uncompressible, blind-ending tubular structure		26 (26%)
Distended, fluid-filled bowel loops		30 (30%)
Reversed SMA & SMV		1 (1%)
Pseudo kidney appearance		8 (8%)
Sandwich sign		0 (0%)
Doughnut sign		17 (17%)
Target sign		40 (40%)
Double track sign		3 (3%)
Enlarged mesenteric lymph nodes		33 (33%)
Elongated pyloric canal		3 (3%)
Mesenteric ultrasonographic findings		
Mesentery	**Anechoic**	6 (6%)
	Echogenic	17 (17%)
	Hyperechoic	58 (58%)
	Hypervascularization	19 (19%)
Site of pathology		(n=100)
Pyloric		6 (6%)
Duodenum		10 (10%)
Jejunum		9 (9%)
Ileum		17 (17%)
Ileocecal		32 (32%)
Large intestine		6 (6%)
Not determined/Not GIT		20 (20%)

SMA: superior mesenteric artery, SMV: superior mesenteric vein

A strong correlation was observed between the cause of non-traumatic gastrointestinal emergencies in children and portal venous gas (P value <0.001). **Figure 2**

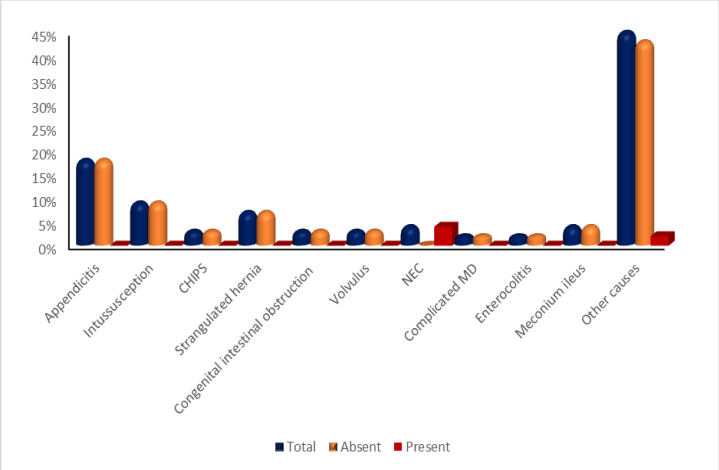

Fig.(2) Relationship between cause of pediatric non-traumatic GI emergencies and portal venous gas of the studied cases

The occurrence of the doughnut sign was significantly associated with the cause of non-traumatic gastrointestinal emergencies in pediatric patients (P value <0.001). **Figure 3**

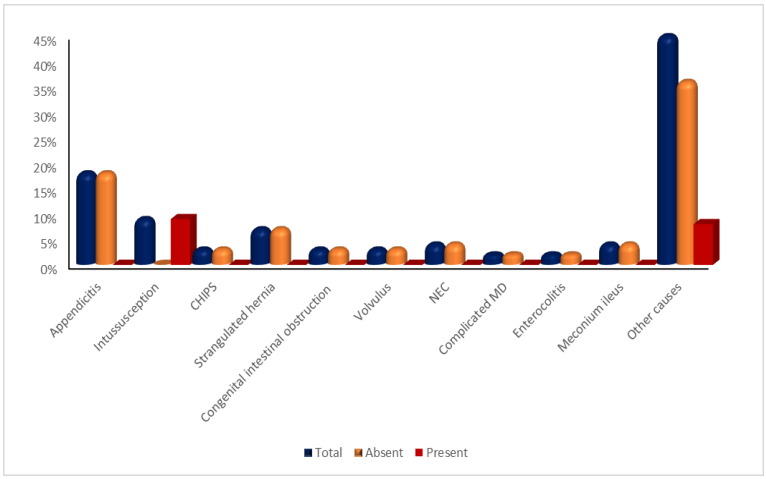

Fig.(3)Relationship between cause of pediatric non-traumatic GI emergencies and doughnut sign of the studied cases

There was a substantial correlation (P value < 0.001) between the etiology of pediatric non-traumatic GI emergencies and the target sign. **Table 4**

Table (4) Relationship between cause of pediatric non-traumatic GI emergencies and target sign of the studied patients

	Total	Absent	Present
Appendicitis	18 (18%)	1 (1%)	17 (17%)
Intussusception	9 (9%)	1 (1%)	8 (8%)
CHIPS	3 (3%)	0 (0%)	3 (3%)
Strangulated hernia	7 (7%)	0 (0%)	7 (7%)
Congenital intestinal obstruction	3 (3%)	3 (3%)	0 (0%)
Volvulus	3 (3%)	3 (3%)	0 (0%)
NEC	4 (4%)	4 (4%)	0 (0%)
Complicated MD	2 (2%)	2 (2%)	0 (0%)
Enterocolitis	2 (2%)	2 (2%)	0 (0%)
Meconium ileus	4 (4%)	4 (4%)	0 (0%)
Other causes	45 (45%)	40 (40%)	5 (5%)
P value		**<0.001***	

CHIPS: Congenital hypertrophic pyloric stenosis, NEC: necrotizing enterocolitis, MD: Meckel diverticulum, *: significant as P value ≤ 0.05.

4. Cases

Case 1: 5-year-old boy with RLQ pain. Longitudinal, color Doppler US image of the appendix in the RLQ. A blind-ending, tubular structure which is filled with fluid (asterisk) and measures 9 mm in diameter (dotted line) compatible with acute appendicitis. Also note hyperechoic surrounding inflamed fat (stars). Mild color Doppler flow is noted in the appendiceal wall. **Figure 4**

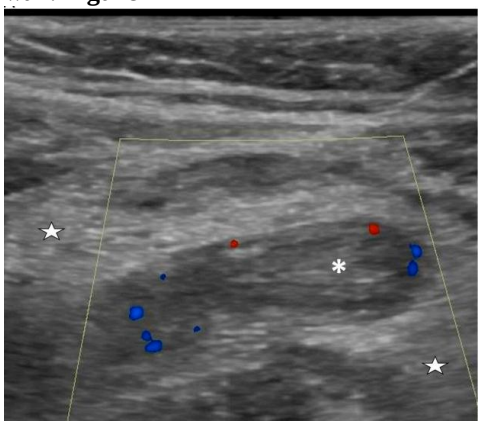

Fig.(4) A blind-ending, tubular structure which is filled with fluid (asterisk) and measures 9 mm in diameter (dotted line) compatible with acute appendicitis. Also note hyperechoic surrounding inflamed fat (stars). Mild color Doppler flow is noted in the appendiceal wall.

Case 2: 6-year-old girl with palpable left upper quadrant mass and intermittent abdominal pain. Grayscale US of the LUQ shows a large mass with only the superficial portion visible (white arrows) due to posterior acoustic shadowing (star). Note the multilayer gut wall signature (black arrows) of the anterior bowel wall proving the luminal location of the mass; the deep bowel wall is obscured by the mass. This mass is not stool in the colon as the colon is lateral to this location (not shown). After giving the patient water to drink, hypoechoic fluid is seen surrounding the mass (white arrowheads). **Figure 5**

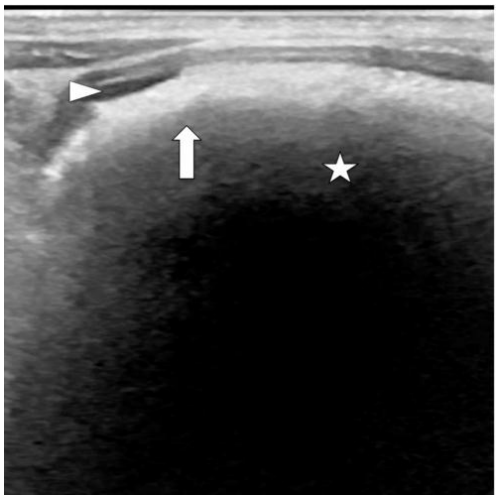

Fig.(5) Grayscale US of the LUQ shows a large mass with only the superficial portion visible (white arrows) due to posterior acoustic shadowing (star).

Case 3: 3-year-old boy with abdominal pain, who had an intussusception which was successfully reduced by air enema. The intussusception recurred four times over the next three days and was successfully reduced by air enema each time. Transverse grayscale US from the fourth recurrence shows the intussusception (calipers). Note the alternating hyper- and hypoechoic layers of the involved bowel segments. **Figure 6**

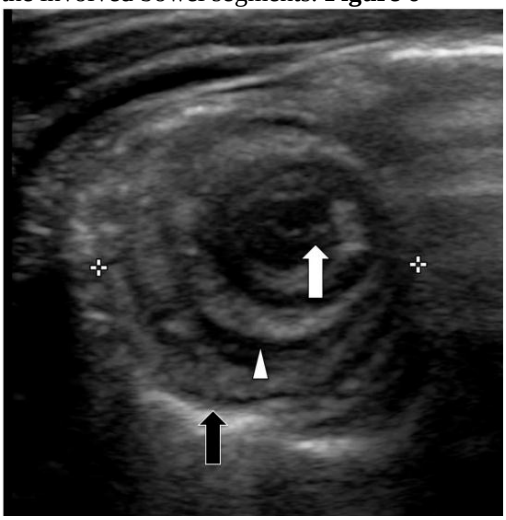

Fig.(6) Transverse grayscale US from the fourth recurrence shows the intussusception (calipers). Note the alternating hyper- and hypoechoic layers of the involved bowel segments.

5. Discussion

Cases of acute gastrointestinal (GI) disorders in children are often encountered in pediatric emergency departments, and these disorders

differ from those observed in adults due to the diverse range of possible diagnoses, which may include congenital and acquired lesions [7].

The demographic data of the patients studied showed similar results to those reported by Banoub et al. The majority of the patients were over 10 years old, accounting for around 38% of the study population. Males were slightly more represented than females, with 56.6% of the patients being male and 43.4% being female [8].

In terms of clinical presentation of the studied patients, our results are compatible with **Banoub et al.** who documented that 72 (35.1%) patients had Rt lower ¼ pain, 194 (94.6%) patients had abdominal pain, 33 (16.1%) patients had ileus, 65 (31.7%) patients had diarrhea, 28 (13.7%) patients had hematochezia, 143 (69.8%) patients had vomiting, 63 (30.7%) patients had fever and 102 (49.8%) patients had worse general conditions. Abdominal pain was the predominant clinical presentation among the group of patients under study, accounting for approximately 94.6% of cases [8].

According to Mwango et al., trans-abdominal sonography is an effective diagnostic tool for assessing upper gastrointestinal disease in children and should be prioritized over fluoroscopy as the initial imaging modality to minimize ionizing radiation exposure. Their study showed that ultrasound is a reliable and efficient screening method that accurately identifies the causes of upper gastrointestinal disease in children [9].

Our results agree with those documented by **Banoub et al.** who reported that free intra-abdominal fluid represented 5 (27.8%) patients, portal vein gas represented 4 (2%) patients, loculated Rt lower ¼ mass represented 6 (2.9%) patients, abscess represented 2 (1%) patients, fluid-filled, uncompressible, blind-ending tubular structure represented 51 (24.9%) patients, distended, fluid-filled bowel loops represented 56 (27.3%) patients, reversed SMA & SMV represented 2 (1%) patient, doughnut sign represented 21 (10.2%) patients, enlarged mesenteric lymph nodes represented 58 (28.3%) patients, pseudo kidney appearance represented 21 (10.2%) patients, target sign represented 74 (36.1%) patients, double track sign represented 5 (2.4%) patients, and elongated pyloric canal represented 5 (2.4%) patients. Target sign was the most prevalent finding in the cross-sectional study, accounting for around 36.1% of the examined individuals. Then free intraabdominal fluid, which accounted for 27.8% of the total [8].

In terms of Mesenteric ultrasonographic findings of the studied patients, parallel to our results, **Banoub et al.** showed that Anechoic mesentery represented 5 (2.4%) patients, echogenic represented 12.2% of the patients, hyperechoic represented 90 (43.9%) patients and hypervascularization represented 32 (15.6%) patients [8].

Regarding site of pathology of the studied patients, conforming our results, **Banoub et al.** showed that 5 (2.4%) patients had pyloric lesions, 7 (3.4%) patients had duodenum lesions, 5 (2.4%) patients had jejunum lesions, 22 (10.7%) patients had ileum lesions, 53 (25.9%) patients had ileocecal lesions, 9 (4.4%) patients had large intestine lesions and 104 (50.7%) patients had not determined/not GIT lesions.

The current study demonstrated a significant association (P value 0.001) between the etiology of non-traumatic gastrointestinal crises in pediatric patients and the presence of portal venous gas. This conclusion is consistent with the findings of Banoub et al., who also discovered a significant relationship between the etiology of non-traumatic gastrointestinal crises in pediatric patients and the presence of portal venous gas (P 0.001). In particular, all patients with necrotizing enterocolitis (NEC) contained portal venous gas, whereas none of the other cases had this characteristic [8].

There was a strong correlation between the etiology of non-traumatic gastrointestinal crises in pediatric patients and the appearance of the doughnut sign. Consistent with the findings of Banoub et al., who also showed a strong connection between the etiology of non-traumatic gastrointestinal crises in pediatric patients and the appearance of the doughnut sign ($P < 0.001$). Specifically, all instances of intussusception had the doughnut sign, but none of the other cases did. [8].

The current study revealed a noteworthy correlation between the cause of non-traumatic gastrointestinal emergencies in pediatric patients and the presence of the target sign (with a P value <0.001). These results are consistent with those of Banoub et al., who also found a significant association between the cause of non-traumatic gastrointestinal emergencies in pediatric patients and the presence of the target sign (with a P value <0.001). Specifically, all cases of colonic hematoma, ischemic bowel disease, and perforated peptic ulcer had the target sign on ultrasound, and 98% of

appendicitis cases had it. Additionally, 95.2% of intussusception cases had the target sign on X-ray, while no other cases exhibited this feature [8].

Sanchez et al. reviewed the sonographic characteristics of acute appendicitis, as well as the sonographic features of other conditions that can be mistaken for appendicitis, including mesenteric adenitis/gastroenteritis, intussusception, Meckel diverticulum, and ovarian torsion. The study concluded that sonography is a safe imaging technique that can effectively differentiate between the common causes of abdominal pain in children [10].

6. Conclusion

Ultrasound (US) is a valuable diagnostic tool for assessing acute abdominal pain, especially in children, where obtaining a thorough examination can be challenging for clinicians. With the ability to provide high-quality images along both the longitudinal and axial axes, ultrasound offers detailed anatomical information.

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