

## Research Article

# Reappraising Ultrasonography Role in Assessment of Surgical Causes of Acute Abdominal Pain in Pediatric Patients

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**Keywords**

• Ultrasound (US); Acute abdomen; Pediatrics; Surgical causes

**Abstract**

**Background:** Ultrasound (US) is considered the preferred imaging tool to evaluate the surgical causes of acute abdominal pain.

**Methods:** Our study aimed to reappraise the role of US in the evaluation of surgical causes of acute abdominal pain in pediatric patients by the identification and differentiation of its different pathologies.

**Results:** Our study included 120 pediatric patients who were presented to Elshatby University Hospital with acute abdominal pain due to a surgical cause from November 2019 to November 2020. The age of the studied patients ranged from five days to 18 years old. The study included 64 males (53.3%) and 56 females (46.6%). Appendicitis was the most common pathology among our studied patients being diagnosed in 40 patients (33.3%); it was correctly diagnosed by US in 36 patients and by Computerized Tomography (CT) in four patients. Other diagnosed pathologies included intussusception in 16 patients (13.3%), acute acalculous cholecystitis in eight patients (6.7%), midgut volvulus in eight patients (6.7%), renal stones in eight patients (6.7%), endometrioma in four patients (3.3%), pelvi-ureteric junction obstruction in four patients (3.3%), appendicular mass in four patients (3.3%), hemorrhagic cyst in eight patients (6.7%), ovarian torsion in eight patients (6.7%) and ureteric stones in 12 patients (10%). The overall sensitivity and specificity of US in the diagnosis of different pathologies in our study was 88.5% and 88.2% respectively with different percentage among different pathologies.

**Conclusions:** US is a reliable diagnostic imaging tool for the assessment of pediatric patients with acute abdomen due to surgical causes with high efficiency in differentiation between various pathological entities.

**Trial registration:** Our manuscript has been retrospectively registered.

**ABBREVIATIONS**

US: Ultrasound; CT: Computerized Tomography; MDCT: Multi-Detector Computerized Tomography; MIP: Maximum intensity projection; MPR: Multi-planner reformatted; CDUS: Color Doppler Ultrasonography; HRCT: High-resolution computed tomography; FOV: Field of view; KVP: The kilo voltage peak; mAs: Milliampere-seconds; KS: Kolmogorov-Smirnov; SMV: Superior mesenteric vein; SMA: Superior mesenteric artery

**INTRODUCTION**

Acute abdominal pain in the pediatric age group is defined as abdominal pain which lasts less than five days [1]. Early diagnosis of the cause of such condition leads to prompt management and better prognosis as well as lowering the morbidity incidence [2].

Abdominal Ultrasound (US) is considered the 1<sup>st</sup> recommended investigation in almost all cases of mild to severe abdominal pain in the pediatric age group whether procedural imaging is based on clinical manifestation or clinical suspicion of the etiology of acute abdomen [3].

In skilled hands, US is comparable to Computerized Tomography (CT), and due to the lack of ionizing radiation in US; it is considered the preferred imaging tool in the pediatric age group, especially if CT findings are ambiguous. Our work aimed to emphasize the role of US examination in the diagnostic work-up of pediatric patients presenting with acute abdominal pain caused by surgical causes [4].

**MATERIALS AND METHODS**

Our retrospective study was carried out on 120 pediatric patients who were presented to Elshatby University Hospital with abdominal pain suspected to be due to a surgical cause from November 2019 to November 2020 with the exclusion of all patients having a medical cause.

All of the studied patients were subjected to detailed history taking, careful clinical examination, and US examination (Color Doppler if needed) of the abdomen which was confirmed in some patients with Multi-Detector Computerized Tomography (MDCT). The radiological findings were correlated with the surgical findings if available.

## Data analysis and interpretation

Diagnostic analysis was used to assess the role of US in the evaluation of acute abdomen due to surgical causes in the pediatric age group. The MDCT images were interpreted using a dedicated workstation and post-processing software using multi-planner reconstruction (axial, sagittal, and coronal views), MIP (maximum intensity projection), and curved MPR (Multi-planner reformatted images). The US data and sensitivity were correlated with the MDCT and surgical data to reach the final diagnosis.

## Technical information

Grey-Scale Ultrasonography (U/S) 5-MHz linear transducer in both longitudinal and transverse orientation, combined with Color Doppler Ultrasonography (CDUS) when needed.

CT examination was carried out in selected patients for confirmation of the diagnosis in disputed cases. MDCT Scan parameters and technique: The axial section images (1 mm thickness) with a high spatial frequency reconstruction algorithm. On MDCT scanners volumetric acquisition of high-resolution CT datasets was acquired during inspiration in the supine position. The examinations were done on GE light speed 4 scanner, Siemens Emotion 64 MDCT, and Philips CT machines. Volumetric High -Spatial -Frequency Slice thickness: 0.5-1 mm. Tube rotation: 0.3-0.9 seconds. Detector Collimation 1-6 mm. Helical mode (volumetric HRCT). Reconstruction interval: 1mm Field of view (FOV) for small, medium, and large patients. KVP and mA per slice: lower doses (60-120 mAs) were used with pediatric patients receiving serial HRCT scans. For adequate multiplanar reconstruction, volumetric data acquisition was done commencing at the level of the diaphragm to the symphysis pubis with a breath-hold technique (as possible as the patient can) to avoid the motion artifacts. Reconstruction method: The thin slices were sent to the workstation, where they were available to view the data in MPR axial, sagittal, and coronal planes.

Pre and post-contrast CT examinations were done when needed, and contrast images were obtained in the arterial phase (30 seconds) and portal venous phases (70 seconds). Non-ionic iodinated contrast material was injected with a power injector at a rate of 3 mL/s through the antecubital vein. The total amount of injected contrast material was injected according to the body weight of the patient (1.5 mL/kg, 350 mg/mL).

## Statistics

Data were coded, reviewed, and analyzed using the SPSS version 25.0 (Armonk, NY: IBM Corp). The Kolmogorov-Smirnov (KS) test was used to test the normal distribution of the data. Quantitative data were expressed as median and range. Qualitative data were expressed as frequency and percentage. Kruskal-Wallis test was used to detect any statistically significant differences between three or more independent non-normally distributed groups. A pairwise comparison was conducted among significant groups. The Chi-square test was used to test the association between two categorical variables or to detect the difference between two or more proportions and whenever  $\chi^2$  was not valid, Monte Carlo exact probability was used for RxC tables.

## RESULTS

The current study included 120 patients; their age ranged between five days and 18 years old. There was slight male predominance (64 patients) in comparison to 56 female patients with a male: female ratio of 1.14:1.

The distribution of the studied patients according to their age group was shown in Table 1. Most of the studied patients were above 10 years with the least frequency below one-year-old. There were no patients between five and ten years old.

All of the studied patients presented with abdominal pain. Different presentations were found among our studied patients with different frequencies as seen in Table 2.

Appendicitis being the most frequent cause of acute surgical abdomen in the pediatric age group was the most common presentation in our study (40 patients, 33.3%) followed by intussusception (16 patients, 13.3%) with different frequencies among different pathologies as shown in Figure 1.

As the most common diagnosis was acute appendicitis; most of the studied patients presented with right iliac fossa pain (n=24, 20%). There were only four patients who presented with epigastric pain (3%). The remaining patients presented with variable sites of abdominal pain with different frequencies as seen in Figure 2.

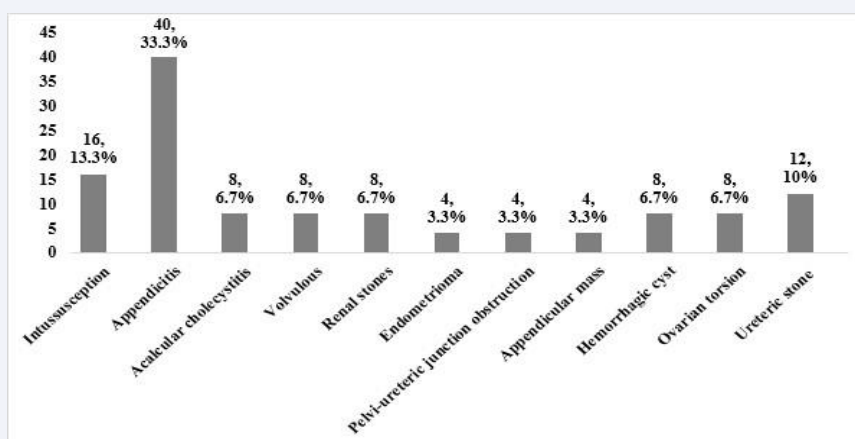
There were 40 patients having appendicitis in our study, it was correctly diagnosed by US in 36 patients and the remaining four patients who were not initially diagnosed by ultrasound were proved later on by CT as having appendicitis.

**Table 1:** Distribution of the studied cases according to their age (n=120).

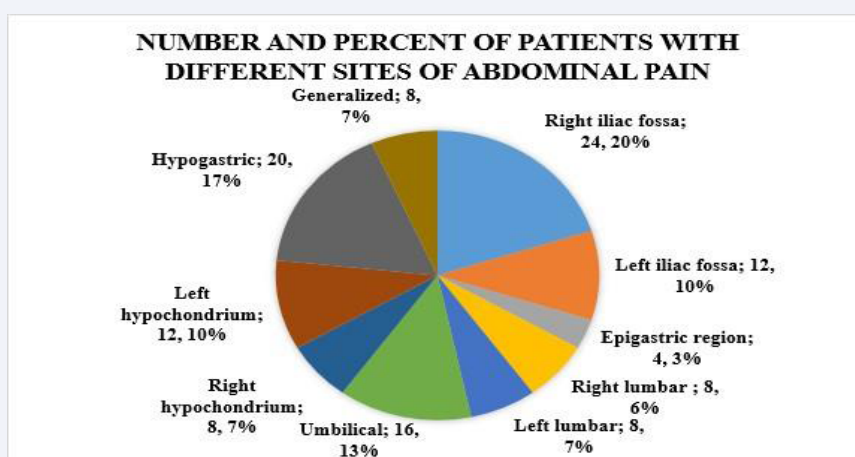
	Male (n=64)		Female (n=56)		Total (n=120)	
	No.	%	No.	%	No.	%
<b>Age (years)</b>						
0>1	0	0.0	8	100	8	6.7
1>5	16	57.1	12	42.9	28	23.3
5>10	0	0.0	0	0.0	0	0.0
10>18	48	57.1	36	42.9	84	70
<b>Total</b>	<b>64</b>	<b>53.3</b>	<b>56</b>	<b>46.6</b>	<b>120</b>	<b>100.0</b>

**Table 2:** Distribution of the studied patients according to the clinical presentation (n=120).

Presentation	Number	Percentage
<b>Abdominal pain</b>	120	100.0
<b>Nausea</b>	16	13.3
<b>Vomiting</b>	24	20.0
<b>Diarrhea</b>	12	10.0
<b>Distended abdomen</b>	8	6.7
<b>Rebound tenderness</b>	16	13.3
<b>Fever</b>	16	13.3



**Figure 1** Distribution of the studied patients according to the final diagnosis.



**Figure 2** Relation between cases distribution and location of abdominal pain.

The age of 28 patients was above ten years old; 24 males and four females, while the remaining 12 patients were females below the age of five years. Clinically, 80% of children had at least two of the following presentations: right iliac fossa pain, fever, nausea/vomiting, diarrhea, and rebound tenderness.

The US findings included appendicular distension with the outer diameter of the appendix measuring more than 6 mm in 32 patients, echogenic peri-appendicular fat along with fluid collection and abnormal vascularity in 36 patients, mesenteric edema in 24 patients, bowel dilatation and mesenteric lymph node enlargement in 20 patients and finally wall thickening in all patients (Figure 3).

Four male patients aged over ten years were diagnosed by US as having appendicular mass. All of them complained of severe abdominal pain, with signs of peritonitis and generalized sepsis.

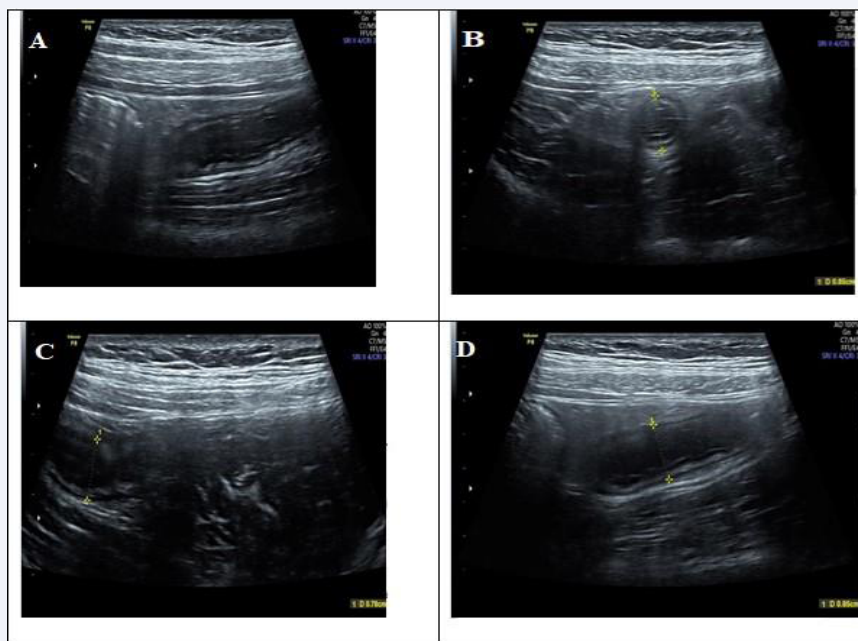
The US scan revealed dilated appendix more than six mm in its outer diameter, wall thickening, echogenic peri-appendicular fat, fluid collection, wall thickening, mesenteric edema, and lymph node enlargement, forming a mass-like structure measuring 6.4x3.9 cm. CT findings included appendicular dilatation more than six mm in diameter, along with wall thickening, mucosal

enhancement, perforation, a peri-appendicular fluid collection as well as fat stranding.

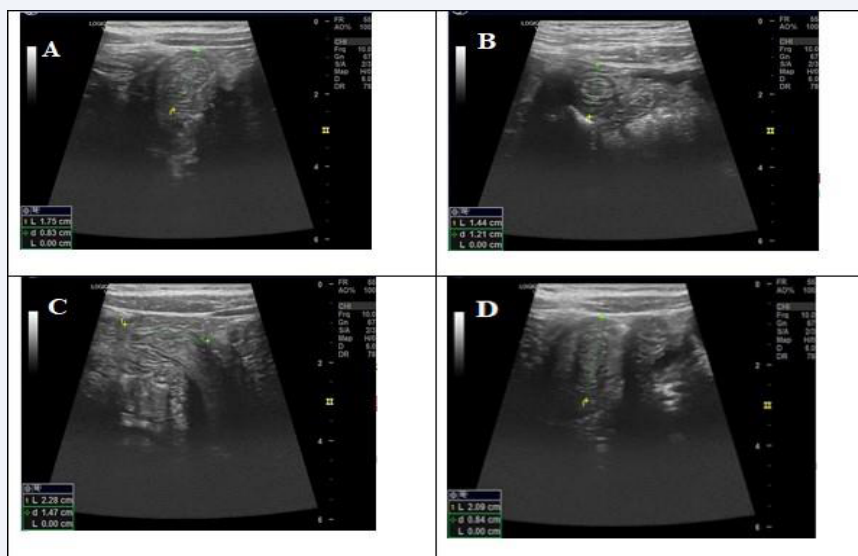
There were 16 male patients diagnosed as having intussusception in our study and all of them were under the age of two years. Clinically, they presented with varying combinations of vomiting, abdominal pain, red currant jelly stool, and excessive crying. US scans of all patients showed mesenteric edema; along with concentric alternating echogenic and hypoechoic layers representing the target sign; this was associated with enlarged mesenteric lymph nodes (Figure 4).

Eight male patients in our study were diagnosed as having acute acalcular cholecystitis by US; all of them were over 10 years old. Patients with this pathology complained of right upper quadrant abdominal pain, vomiting, and fever. The US findings showed gall bladder wall thickening of more than 3 mm, peri-cholecystic fluid collection, and abnormal vascularity denoting an inflammatory process

Eight female patients aged below 12 months old were diagnosed by US as having midgut volvulus. Clinically; those patients complained of a distended and tender abdomen, excessive crying, and bilious vomiting. The US scan in midgut



**Figure 3** Acute appendicitis in a 12 year old male patient complaining of abdominal pain in the right iliac fossa.. (A, B) transverse and longitudinal gray scale ultrasound views showing an acutely inflamed aperistaltic, non-compressible, dilated appendix with an 8.5-mm outer diameter. (C, D) Note the surrounding hyperechoic inflamed fatty tissue.



**Figure 4** Intussusception in a 11 months old female patient complaining of intermittent abdominal pain and vomiting. (A, B) transverse lower abdominal gray scale ultrasound views showing concentric alternating echogenic and hypoechoic bands representing Target sign. (C, D) transverse and longitudinal gray scale ultrasound views in which the length of the lesion is 2.2 cm in maximum dimension, preserved bowel wall motility was also noted during the scan.

volvulus revealed a clockwise whirlpool sign on color Doppler US in which the superior mesenteric vein (SMV) was seen swirling with the small bowel loops around centrally placed superior mesenteric artery (SMA) in all patients. This was associated with bowel dilatation, wall thickening in four patients, fluid collection, and abnormal vascularity in all patients.

Eight patients over the age of 10 years had renal stones in

our study; four males and four females. Clinically, those patients complained of loin pain. Half of those patients have been diagnosed by US initially and the other half were diagnosed later on by CT.

Twelve patients had been diagnosed as having ureteric stones, eight males and four females; all of them were over the age of ten years. Four patients were diagnosed by US while the other eight



patients were diagnosed by CT scans. The main complaint of all the patients was severe abdominal pain. The US scans of all of the patients revealed urinary system dilatation while only four patients had a urinary tract stone which was seen as echogenic foci with posterior acoustic shadowing.

There were four female patients over 10 years old who presented with left lion pain after ingestion of a large amount of oral fluids. The US examination of such patients revealed left hydronephrosis with dilatation of the left renal pelvis more than 16 mm and collapsed. There were no associated urinary stones in those patients.

Four patients were diagnosed by US as having endometrioma; all of those females were over 10 years old. Clinically, they complained of lower abdominal and pelvic pain.

Eight female patients over ten years old were diagnosed by US as having hemorrhagic cysts and complaining of severe pelvic pain. Concerning hemorrhagic cyst, the US scan of those patients revealed a cystic ovarian mass with mixed cystic and solid pattern measuring over 4 cm in diameter and exhibiting posterior acoustic enhancement, while only one patient had a pelvic fluid collection.

Eight female patients over ten years old were diagnosed by US as having ovarian torsion. Clinically, the patients complained of severe non-specific lower abdominal and pelvic pain sustained nausea and vomiting. The US scan of those patients showed an enlarged adnexal lesion with peripheral cysts confirming the mass to be ovarian in origin, a small amount of free pelvic fluid collection was also noted. Color Doppler US showed a complete absence of blood flow in the ovary.

The overall sensitivity of US in our study was about 88.5%, with variable percentage among different pathologies as seen in Figure 5. Also, the overall specificity of US in the diagnosis of different pathologies in our study was about 88.2% with different percentages among different diseases as seen in Figure 6.

## DISCUSSION

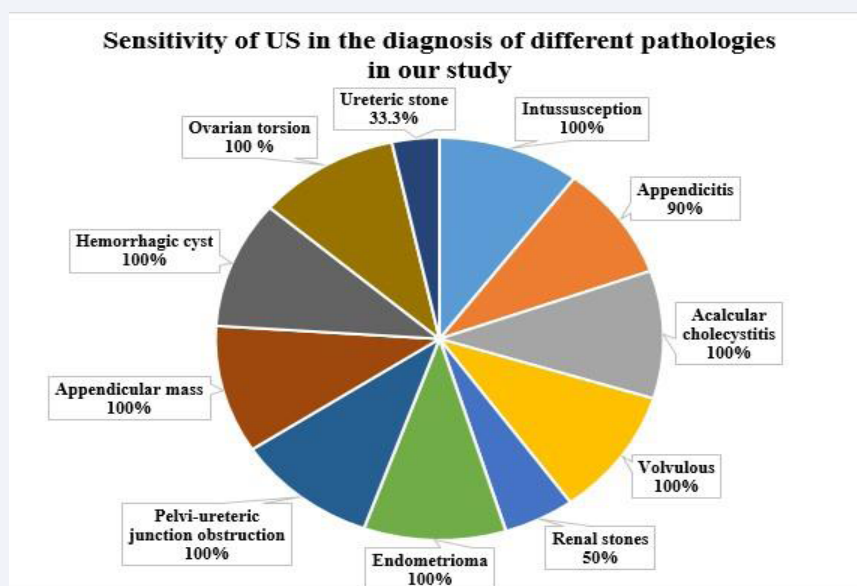
Appendicitis was the most common diagnosis in our study as it is the most common pediatric surgical emergency according to **St Peter et al. [5,]** findings. There were variable presentations of such condition among our studied patients. All patients showed thickened appendicular wall with variable other findings in US examination; these observations were similar to that of **Janitz et al. [6]**, in their study.

Our study revealed that the sensitivity and specificity of diagnosing appendicitis by US were 90% and 95% -as confirmed by the operative findings- respectively. These findings were similar to that of **Carrico et al [7]**, who concluded in their study that US could be considered reliable in the diagnosis of appendicitis.

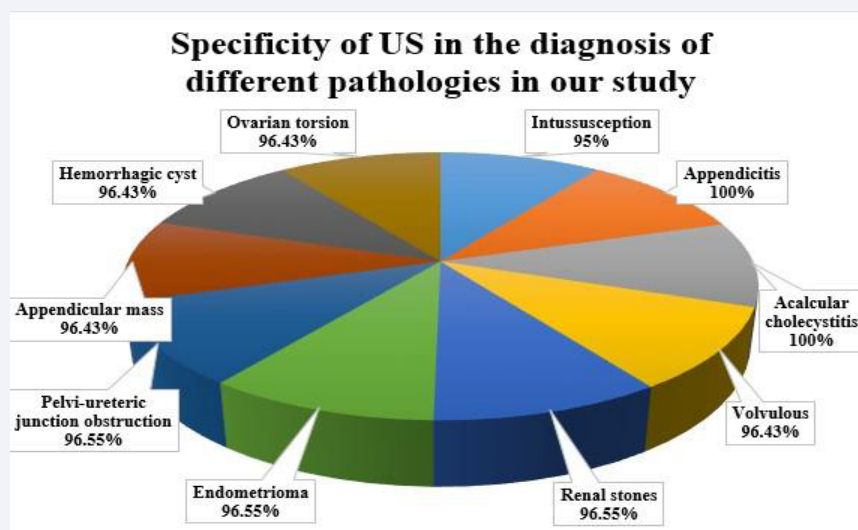
The findings of our study in the diagnosis of appendicular mass were similar to that detected by **Borushok et al. [8]**, who found that the presence of peri-cecal fluid collection, phlegmon or abscess, and echogenic peri-appendicular fat were diagnostic of such condition. **Bhandari et al [9]**, stated that the CT features used to diagnose inflammatory appendicular mass were similar to our research. **Rajput et al. [10]**, stated that US in the diagnosis of cases presented with appendicular lesions has sensitivity and specificity of 96% and 93% respectively which were almost similar to the findings in our study where the sensitivity and specificity were 100 % and 96.55% respectively.

The age of patients having intussusception in our study was under two years old similar to the findings of **Riera et al. [11]**, in their study. According to **Harrington et al. [12]**, study; the classic manifestation of intussusception including colicky abdominal pain, bloody stool (commonly characterized as “red currant jelly stools”), and vomiting develops in only about 25% of patients.

**Gale et al. [13]**, described the imaging features of intussusception as the “target” or “donut sign” with alternating hyperechoic and hypoechoic concentric layers. Also, they



**Figure 5** The sensitivity of US in the diagnosis of different pathologies in our study.



**Figure 6** The specificity of US in the diagnosis of different pathologies in our study.

concluded that the presence of fluid film between the concentric layers of intussusception and a lack of color flow could indicate a lower risk of reduction and bowel ischemia. In our study; the US findings of patients with intussusception included mesenteric edema along with the presence of concentric alternating echogenic and hypoechoic layers representing the target sign. In the current research, the sensitivity and accuracy for diagnosing intussusception by US were 100%; this is similar to the findings of Hryhorczuk et al. [14].

This finding proves that US is a reliable diagnostic method of intussusception in the pediatric age group. Another important role of US in the prediction of the success of hydrostatic reduction of intussusception was declared by Elrouby et al. [15], in their study as they found that a higher success rate was found in those patients with their abdominal mass in the upper right quadrant.

All of the eight patients who were presented with cholecystitis had the acute acalculous type and all of them were above ten years old. Thus agreeing with Tsakayannis et al. [16], opinion that acalculous cholecystitis is the most common type of cholecystitis in the pediatric age group.

Huffman et al. [17], believed that the diagnosis of acute acalculous cholecystitis could be confirmed reliably with the use of abdominal ultrasonography, which has an accuracy of 98.5 % and a sensitivity of 100 % using the 3 mm wall thickness as a cut-off point. The sensitivity and specificity in our sample in such cases were 100%. The criteria of sonographic diagnosis of cholecystitis in the pediatric age group include the following criteria; gall bladder wall thickness greater than 3 mm, peri-cholecystic fluid collection, presence of biliary sludge and gall bladder distension; the presence of two findings are usually diagnostic as concluded by Poddighe et al. [18], who found also that US finding of a thickened gall bladder wall in acute acalculous cholecystitis is the most accurate single criterion.

All of the eight female patients who were diagnosed as having mid gut volvulus were under one year old; this age incidence is similar to the findings of Aboagye et al. [19], who concluded in

their study that mid gut volvulus most commonly presents in the first year after birth.

The whirlpool sign was found by color Doppler US in all of those patients; this sign according to Rokade et al. [20], directly shows the anatomic modification caused by midgut volvulus, in which the bowel and the mesenteric vessels are twisted, resulting in the wrapping of the SMV around the SMA.

Shimanuki et al. [21], used color Doppler US to test the clockwise “whirlpool sign” in diagnosing midgut volvulus, with sensitivity and specificity of 92 % and 100 %, respectively. The sensitivity and specificity in our sample were both 100 %.

The accuracy of US in the diagnosis of pediatric renal stones is not constant. Stones of the urinary tract could be detected in over 30% of cases; this is much better in kidneys as compared to the ureter. Vijayakumar et al. [22], mentioned that sensitivity and specificity of US in the diagnosis of renal stones are 45% and the 88% which is approximately similar to the findings in our study in which the sensitivity and specificity were 50% & 96.43% respectively. MDCT has a higher sensitivity in the diagnosis of ureteric stones as declared by Yilmaz et al. [23], who detected in his study that the sensitivity of MDCT was 94% while that of US was 19%. Another study conducted by Vijayakumar et al. [22], declared that the sensitivity and specificity of US in the diagnosis of ureteric calculi are 45% and 94% respectively. In our study the sensitivity and specificity were 33.3% & 96.43% respectively.

Patel et al. [24], declared that some patients with pelvi-ureteric junction obstruction do not show symptoms until adulthood when loin pain could be precipitated by diuresis-causing drinks such as coffee; this is similar to the finding in our study. The diagnostic findings detected by US in diagnosis of such patients was similar to the findings of Siegel et al. [25], in their study. Benacerraf BR et al. [26], declared that US scans provides pivotal information concerning the necessary renal assessment. CT scans in our study of such conditions demonstrated urinary system dilatation in the form of moderate calyceal dilatation and markedly dilated extra-renal pelvis while the ureter was not

dilated. **Dias et al. [27]**, stated that the sensitivity of US was 91%. In our study the sensitivity and specificity of US were 100 % and 96.55% respectively.

Lower abdominal and pelvic pain was the main complaint in all of the studied patients diagnosed with endometrioma. This finding agrees with **Sinaii et al. [28]**, who declared that almost 75% of symptomatic patients having such condition report pelvic pain.. The sensitivity and specificity of US diagnosis of endometrioma in our study was 100 % and 96.55% respectively. A study conducted by **Holland et al. [29]**, revealed a sensitivity and specificity of 84% and 95.6 % respectively of sonographic diagnosis of such patients.

The mixed cystic and solid pattern of the hemorrhagic ovarian cyst diagnosed in our patients with the posterior acoustic enhancement were the diagnostic sonographic signs of such patients in our study which was similar to the findings of **Baltarowich et al. [30]**, in his study who declared that hemorrhagic cyst has a variable sonographic appearance which may present with echogenic content, **Patel et al. [24]**, declared that the sensitivity and specificity of US in diagnosing hemorrhagic cyst is 80-83% & 100% respectively, in our study the sensitivity and specificity were 100% and 96.43 % respectively; this was due to the sample size of our study.

Regarding ovarian torsion, **Hiller et al. [31]**, stated that US is considered the best imaging scan for diagnosing ovarian torsion. **Swenson et al. [32]**, declared that US was 80% sensitive, and 95% specific. The sensitivity and specificity for diagnosing ovarian torsion by US in our study is 100 % and 96.43%, respectively. **Naffaa et al. [33]**, declared that ovarian torsion is common in children owing to the increased mobility of the fallopian tube. The US finding of an enlarged adnexal lesion with peripheral cysts confirmed that the mass was ovarian in origin; this agreed with **Chang et al. [34]**, who stated that the finding of an enlarged ovary with peripheral follicles can be seen in up to 72% of cases of ovarian torsion.

US in case of acute abdominal pain is considered reliable diagnostic tool as discovered in our study which revealed that the overall sensitivity of US in such condition was about 88.5%. Despite the great advances in radiological diagnostic tools, US is still a rapid, reliable, safe one with no radiation exposure. CT abdomen exposes the child to a radiation dose equal to 100 chest X-ray which raises the risk of a radiation-induced solid cancer to be one per 300 to 390 CT scans of the abdomen and pelvis for females, and one per 670 to 760 scans for males [35].

**Güliz Yılmaz et al. [36]**, concluded in their study that CT should be used only in undiagnosed patients presented with acute abdominal pathologies as most cases can be reliably and safely diagnosed by US and simple plain X-ray abdomen. This is similarly recommended by our study which revealed 88.2% sensitivity of US in the diagnosis of acute abdominal emergencies.

## LIMITATIONS

Some Limitations were encountered in our study including the wide variations of the included pathologies which affected the sample size in each pathological entity. Another entity was

that a larger number of patients may be of value in achieving better statistical analysis.

## CONCLUSION

This study stated that US is a very efficient imaging technique in the diagnosis and differentiation between different surgical causes of acute abdominal pain. US can be done in any imaging plane; this is beneficial in describing the anatomy of different abdominal organs. Thus abdominal US could be considered as a perfect and reliable imaging scan for initial examination in pediatric patients with acute abdominal pain. MDCT should be performed if the sonogram is non-conclusive or negative despite the presence of abdominal signs.

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