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Role of Ultrasound in the Assessment of Pediatric Non-Traumatic Gastrointestinal Emergencies

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ABSTRACT

Background: Non-traumatic gastrointestinal emergencies in the children and neonatal patients and the presenting characteristics ultrasound features on the longitudinal and axial axes are a dilemma for the radiologist in the emergency room. The most frequent emergencies are appendicitis, intussusceptions, hypertrophic pyloric stenosis, and volvulus due to intestinal malrotation.

Objectives: this work aimed to assess the role of ultrasound in the assessment of pediatric non-traumatic gastrointestinal emergencies.

Patients and Methods: A retrospective analysis of 205 ultrasound examinations performed for neonatal and children patients with fever, abdominal pain, vomiting and diarrhea were evaluated. **Results:** Of 205 cases, 19 cases of intussusceptions, 49 cases of appendicitis, 2 cases associated with abscess, 1 gangrenous appendicitis with absence a color Doppler, 30 cases of perforated appendicitis and 3 cases of volvulus were found.

Conclusions: Acute abdominal pain is one of the most common complaints in childhood, and one that frequently requires rapid diagnosis and treatment in the emergency department. Although acute abdominal pain is typically self-limiting and benign, there are potentially life-threatening conditions that require urgent management, such as appendicitis, intussusception, or bowel obstruction. Meticulous history taking and repeated physical examinations are essential to determine the cause of acute abdominal pain and to identify children with surgical conditions.

Keywords: Gastrointestinal pediatric emergencies, Intussusceptions, Appendicitis, Hypertrophic pyloric stenosis, Volvulus.

INTRODUCTION

Non-traumatic gastrointestinal emergencies in the children and neonatal patients and the presenting characteristics ultrasound features on the longitudinal and axial axes are a dilemma for the radiologist in the emergency room. Presentation with acute abdominal pain or abdominal symptom pathology is a very common cause of presentation of children to hospital. The causes are dependent in part on the age of child and in part on the presence of previous surgery [(1)].

The diverse etiologies include acute surgical disease, intra-abdominal medical disorders, extra-abdominal conditions, systemic illness and commonly functional abdominal pain. The most frequent emergencies are appendicitis, intussusceptions, hypertrophic pyloric stenosis, strangulated hernia, congenital intestinal obstruction and volvulus due to intestinal malrotation [(2)].

Necrotizing enterocolitis is a serious abdominal disorder of premature neonates, which most often affects the terminal ilium and ascending colon. Clinical symptoms include abdominal distention and hematochezia as well as apnea, acidosis, temperature instability, and lethargy. Sonography may be useful when perforation and abscess formation are suspected. The examination can be performed portably in the neonatal intensive care unit with excellent resolution of bowel anatomic characteristics when high frequency (7- to 10-MHz) transducers are used [(3)].

Malrotation can be suggested when the positions of the superior mesenteric artery and vein are reversed. A different set of diseases produce the acute abdomen. Intussusception is particularly common in the 1-month to 2-year age group. A strangulated inguinal hernia, complicated Meckel diverticulum, and malrotation with volvulus are surgically treated causes. Appendicitis is less common in this age group than in the older child but can occur. Non–surgically treated causes including primary peritonitis, colic, and gastroenteritis, are more common and must be differentiated. Ileo-colic intussusception with invagination of the ileum through the ileocecal valve into the colon occurs predominately in the first 2 years of life [(4)].

The aim of this work was to assess the role of ultrasound in the assessment of pediatric non-traumatic gastrointestinal emergencies.

PATIENTS AND METHOD

This study was carried out during the period from December 2018 to June 2019 in radio-diagnosis Department, Zagazig University Hospitals and included 205 patients, ranging in age from 1 day to 18 years. Male and female children presented with acute abdominal pain at the Emergency Department (ED), Zagazig University Hospitals were directed to abdominal ultrasound in Radiology Department

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during the mentioned period and underwent surgical interference as a line of management or subjected to medical treatment.

All Patients were subjected to the following:

1. Full clinical history: Personal history (name, age, sex, past history and family history).
2. Present history: course of the disease and duration.
3. Clinical examination.
4. Abdominal ultrasound.

Patients' preparation: No specific preparation is needed. Demographic data including age, sex, detailed history, clinical presentation, laboratory tests, and data of any other investigations or operation were obtained. Clinical examination was done in Emergency Pediatric Unit for provisional diagnosis. Patients were examined by Grey-Scale Ultrasonography (U/S) combined with color Doppler Ultrasonography (CDUS).

Technique of examination:

Patient First examination of whole abdomen was done by Grey-Scale U/S using both 3.5 MHZ and 7.5 MHZ transducers. It was done in both longitudinal (parallel to long axis of the patient) and transverse (perpendicular to long axis of the patient) orientation. Finally, examination by color Doppler US for assessment of organ perfusion and diagnosing inflammation. Ultrasound is safe and painless, and produces pictures of the inside of the body using sound waves. Ultrasound imaging, also called ultrasound scanning or sonography, involves the use of a small transducer (probe) and ultrasound gel placed directly on the skin. High-frequency sound waves are transmitted from the probe through the gel into the body. The transducer collects the sounds that bounce back and the computer then uses those sound waves to create an image.

Ultrasound examinations do not use ionizing radiation (as used in x-rays), thus there is no radiation exposure to the patient. Because ultrasound images are captured in real-time, they can show the structure and movement of the body's internal organs, as well as blood flowing through blood vessels was performed using Logic p6 with 3.5 to 7.5 MHZ transducer and 7 to 10 MHZ transducer. Patients lay supine on the examination couch with extended legs. Child should be dressed in comfortable, loose-fitting clothing for an ultrasound exam. Scans were obtained with the transducer placed transversely and longitudinally until the plane showed the maximum cross-sectional area of examination. For most ultrasound exams, doctor was positioned lying face-up on an examination table that can be tilted or moved. Patients may be turned to either side to improve the quality of the images.

A clear water-based gel is applied to the area of the body being studied to help the transducer make secure contact with the body and eliminate air pockets between the transducer and the skin that can block the sound waves from passing into your body. The sonographer (ultrasound technologist) or radiologist then places the transducer on the skin in various locations, sweeping over the area of interest or angling the sound beam from a different location to see an area of concern. Doppler sonography is performed using the same transducer.

Ethical approval and written informed consent:

An approval of the study was obtained from Zagazig University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of the operation.

Statistical analysis: All data were collected, tabulated and statistically analyzed using SPSS 22.0 for windows (SPSS Inc., Chicago, IL, USA). Continuous Quantitative variables were expressed as the mean ± SD & median (range), and categorical qualitative variables were expressed as absolute frequencies (number) & relative frequencies (percentage). Categorical data were compared using Chi-square test or Fisher's exact test when appropriate. All tests were two sided. P-value ≤ 0.05 was considered statistically significant (S), p-value < 0.001 was considered highly statistically significant (HS), and p-value > 0.05 was considered statistically insignificant (NS).

RESULTS

Table (1) showed demographic data of the studied cross-section. The most common age group among the studied cross-section was older than 10 years; they represented about 38% of the studied patients. Regarding sex distribution, male was a bit more frequent than female (56.6% versus 43.4% respectively)

Table (2) showed clinical presentation of the studied cross-section. The most common clinical presentation among the studied cross-section was abdominal pain; they represented about 94.6% of the studied patients.

Table (3) showed the cause of pediatric non-traumatic gastrointestinal emergencies among the studied cross-section. The most common cause among the urgent cases was appendicitis (23.9%), then intussusception (10.2%). Regarding the other causes such as gastroenteritis or renal disease represented 46.3% of all studied patients.

Table (4) showed abdominal ultrasonographic. The most common finding among the studied cross-section was target sign; they represented about 36.1% of the studied patients. Then free intraabdominal fluid, which represented 27.8%.

Table (5) showed relationship between cause of pediatric non-traumatic gastrointestinal emergencies

and portal venous gas among the studied cross-section. There was a significant association between cause of pediatric non-traumatic gastrointestinal emergencies and portal venous gas (P-value < 0.001), where 100% of necrotizing enterocolitis (NEC) cases had portal venous gas versus 0% of other cases.

Table (6) showed the relationship between cause of pediatric non-traumatic gastrointestinal emergencies and doughnut sign among the studied cross-section. There was a significant association between cause of pediatric non-traumatic gastrointestinal emergencies and doughnut sign (p-value < 0.001), where 100% of intussusception cases had doughnut sign versus 0% of other cases.

Table (7) showed relationship between cause of pediatric non-traumatic gastrointestinal emergencies and target sign among the studied cross-section. There was a significant association between cause of pediatric non-traumatic gastrointestinal emergencies and target sign (p-value < 0.001), where 100% of CHIPS and 98% of appendicitis cases had target sign by ultrasound and 95.2% of intussusception cases had target sign by X-RAY versus 0% of other cases.

Table (1): Demographic data of the studied cross-section (N=69)

Demographic data	The studied cross-section (N=205)	
	No.	%
Age		
<1 years	32	15.6%
1-5 years	41	20%
5-10 years	53	25.9%
>10 years	79	38.5%
Sex		
Male	116	56.6%
Female	89	43.4%

Table (2): Clinical presentation of the studied cross-section (N=205).

Clinical presentation	The studied cross-section (N=205)	
	No.	%
Abdominal pain	194	94.6%
Rt lower ¼ pain	72	35.1%
Ileus	33	16.1%
Diarrhea	65	31.7%
Hematochezia	28	13.7%
Vomiting	143	69.8%
Fever	63	30.7%
Worse general condition	102	49.8%

Table (3): Cause of pediatric non-traumatic gastrointestinal emergencies among the studied cross-section (N=205).

Cause	The studied cross-section (N=205)	
	No.	%
Appendicitis	49	23.9%
Intussusception	21	10.2%
CHIPS	5	2.4%
Strangulated hernia	10	4.9%
Congenital intestinal obstruction	5	2.4%
Volvulus	3	1.5%
NEC	4	2%
Complicated Meckel diverticulum	2	1%
Enterocolitis	9	4.4%
Meconium ileus	2	1%
Other causes	95	46.3%

Table (4): Abdominal ultrasonographic findings among the studied cross-section (N=205).

Abdominal Ultrasonographic findings	The studied cross-section (N=205)	
	No.	%
Free intra-abdominal fluid	5	27.8%
Loculated Rt lower ¼ mass	6	2.9%
Abscess	2	1%
Portal vein gas	4	2%
Fluid-filled, uncompressible, blind-ending tubular structure	51	24.9%
Distended, fluid-filled bowel loops	56	27.3%
Reversed SMA & SMV	2	1%
Pseudo kidney appearance	21	10.2%
Sandwich sign	0	0%
Doughnut sign	21	10.2%
Target sign	74	36.1%
Double track sign	5	2.4%
Enlarged mesenteric lymph nodes	58	28.3%
Elongated pyloric canal	5	2.4%
Mesentery		
Anechoic	5	2.4%
Echogenic	2	12.2%
Hyperechoic	90	43.9%
Not checked	85	41.5%
Hypervascularisation	32	15.6%
Site of pathology		
Pyloric	5	2.4%
Duodenum	7	3.4%
Jejunum	5	2.4%
Ileum	22	10.7%
Ileocaecal	53	25.9%
Large intestine	9	4.4%
Not determined/Not GIT	104	50.7%

Table (5): Relationship between cause of pediatric non-traumatic gastrointestinal emergencies and portal venous gas among the studied cross-section (N=205).

Cause	Total (N=205)	Portal venous gas				
		Absent (N=201)			Present (N=4)	
		No.	%		No.	%
Appendicitis	49	49	100%		0	0%
Intussusception	21	21	100%		0	0%
CHIPS	5	5	100%		0	0%
Strangulated hernia	10	10	100%		0	0%
Congenital intestinal obstruction	5	5	100%		0	0%
Volvulus	3	3	100%		0	0%
NEC	4	0	0%		4	100%
Complicated Meckel diverticulum	2	2	100%		0	0%
Enterocolitis	9	9	100%		0	0%
Meconium ileus	2	2	100%		0	0%
Other causes	95	95	100%		0	0%
Test‡	205.000					
p-value (Sig.)	<0.001 (HS)					

‡ Chi-square test. P < 0.05 is significant. Sig.: significance.

Table (6): Relationship between cause of pediatric non-traumatic gastrointestinal emergencies and doughnut sign among the studied cross-section (N=205)

Cause	Total (N=205)	Doughnut sign				
		Absent (N=184)			Present (N=21)	
		No.	%		No.	%
Appendicitis	49	49	100%		0	0%
Intussusception	21	0	0%		21	100%
CHIPS	5	5	100%		0	0%
Strangulated hernia	10	10	100%		0	0%
Congenital intestinal obstruction	5	5	100%		0	0%
Volvulus	3	3	100%		0	0%
NEC	4	4	100%		0	0%
Complicated Meckel diverticulum	2	2	100%		0	0%
Enterocolitis	9	9	100%		0	0%
Meconium ileus	2	2	100%		0	0%
Other causes	95	95	100%		0	0%
Test‡	205.000					
p-value (Sig.)	<0.001 (HS)					

Table (7): Relationship between cause of pediatric non-traumatic gastrointestinal emergencies and target sign among the studied cross-section (N=205)

Cause	Total (N=205)	Target sign				
		Absent (N=131)			Present (N=74)	
		No.	%		No.	%
Appendicitis	49	1	2%		48	98%
Intussusception	21	1	4.8%		20	95.2%
CHIPS	5	0	0%		5	100%
Strangulated hernia	10	10	100%		0	0%
Congenital intestinal obstruction	5	5	100%		0	0%
Volvulus	3	3	100%		0	0%
NEC	4	4	100%		0	0%
Complicated Meckel diverticulum	2	2	100%		0	0%
Enterocolitis	9	9	100%		0	0%
Meconium ileus	2	2	100%		0	0%
Other causes	95	94	98.9%		1	1.1%
Test‡	192.335					
p-value (Sig.)	<0.001 (HS)					

DISCUSSION

The most frequent final diagnosis was acute appendicitis and its complications, which showed the highest percentage (23.9%) and other causes, which was 46.3%.

Kim *et al.* [5] showed that the negative appendectomy rates were similar among imaging modalities and age groups, and between genders. Most negative appendicitis cases on US examinations were related to sonographic tenderness or sonographic noncompressibility. The diagnosis of appendicitis needs to be critically queried when the appendiceal diameter is equivocal and there is no periappendiceal fat inflammation.

In children, the localization of abdominal pain is not indicative of a specific pathology as in the adults; inability to give reliable history, atypical clinical presentations and many extra-abdominal causes and the painful abdomen in children often causes difficulties in arriving at the correct diagnosis. The causes of the acute abdomen in children vary depending on the ages of the children. The role of diagnostic imaging, in particular of ultrasound (US), is to determine whether the acute abdominal pain is due to a surgically or medically treatable disease and, when possible, to diagnose the exact nature of the pathology **[6].**

Ultrasonography (US) is therefore rapidly becoming an important imaging modality for the evaluation of acute abdominal pain, particularly in pediatric patients, where satisfactory examination is often not achievable for the attending clinicians. US provides excellent anatomic details on the longitudinally and axial axes [7]. B -mode and color Doppler ultrasonography has become the imaging modality of choice for evaluating non-traumatic gastrointestinal emergencies. Ultrasound, through the research for these characteristic signs, is a valid method for the study and for the immediate diagnosis in the emergency room of these pathologies **[8].**

The main advantages of using ultrasound as the first diagnostic imaging modality in abdominal disorders may be the shortening of time needed for achieving an accurate diagnosis, avoiding unnecessary, costly or even risky procedures with a positive fall-out in terms of saving of financial resources. Ultrasound is a dynamic and repeatable tool, which experienced sonographers usually employs using variable technical approaches to overcome the main limitations due to gas and patient constitution. Progressive bowel compression of the air-containing organ, changing the patients' position, water administration, or oral luminal contrast agents can be used to assess or to improve the visualization of all parts of the gastrointestinal tract **(9).**

Regarding NEC, plain abdominal radiography remains the current modality of choice for evaluation and follow-up of neonates with NEC, but this modality is not without its limitations. The major advantages of abdominal US over plain abdominal radiography are that abdominal US can depict intraabdominal fluid, bowel wall thickness, and bowel wall perfusion. However, further large prospective studies are required to better define the role that abdominal US should play and to establish whether abdominal US should be used routinely in all neonates with NEC or in selected patients at the time of diagnosis or follow-up **[10].**

We found 4 cases diagnosed as NEC. Two of them were premature, came with vomiting, blood in stool and abdominal distention. Plain x-ray revealed thick bowel wall, focal fluid collection and free fluid. Ultrasound revealed dilated bowel loops, intramural gas, portal venous gas and abdominal free fluid. Hyperemia by color Doppler also detected.

Regarding congenital bowel obstruction, Joseph *et al.* [11] stated that more than one third of congenital bowel obstructions result from intestinal atresia. Although the duodenum is the most common site, the jejunum and ileum account for 39% of intestinal atresia. Affecting 1 per 3000 to 5000 births, jejunal and ileal atresia may result from incomplete embryonic recanalization. However, most cases are thought to result from intestinal vascular impairment.

We found 5 cases of congenital intestinal obstruction, 3 of them were jejunal atresia. Plain x-ray revealed triple bubble sign. Ultrasound revealed to and fro movement with abdominal free fluid. Another cause of intestinal obstruction in children is strangulated inguinal hernia. It occur due to weakness of abdominal muscles at the groin region at the first few months of life. We found 10 patients came with abdominal pain, vomiting and swelling at inguinal region. Ultrasonography in the inguinal region was performed preoperatively in all children using a 10-MHz transducer, revealed a defect in inguinal canal with intestinal loop bulging through it in strangulated hernia and signs of intestinal obstruction were found.

Regarding intussusception, Lagalla *et al.* [12] stated that the typical sonographic signs of intussusception were visible in all patients. Lesions appeared as heterogeneous masses with a "pseudokidney" structural pattern in all cases COU allowed demonstration of small vessels within these masses in nine out of 11 patients. Vascular images were visible both in their center and at their periphery and were interpreted as arising, respectively, from the walls of the intussusceptum and from mesenteric vessels accompanying its course within the intussuscipiens. Barium enema reduction was attempted in these patients. It proved possible in eight of them but failed in the remaining

one. The patient had to be submitted to surgery for operative reduction. However, marked parietal edema did not allow operative reduction, and bowel resection was required. Pathologic examination of the specimen did not demonstrate necrosis of the bowel wall [(12)].

We found 19 cases of intussusception. On the axial scans, we evaluated "crescent in doughnut sign" and "concentric ring sign", a sign of the donut. On the longitudinal scan, there were the "sandwich sign", and "hairfork sign". Plain x-ray revealed the "target sign ". On the US image, the intussusceptions is a complex structure. The intussusceptions (the receiving loop) contains the folded intussuscepted (the donor loop), which has two components: the entering limb and returning limbs. Axial intussusception has a variable appearance, which is primarily due to the amount of mesentery. US obtained at the apex showed a hyperechoic outer ring separated from a hypoechoic center by a thin hyperechoic ring, which likely represents the opposed serous surface of the intussuscepted. US obtained near the apex showed multiple concentric rings with a hypo-echoic ring surrounding a hyper-echoic ring, which surrounds another hypoechoic ring. US scan obtained at the base showed the central limb of the intussusception eccentrically surround by the hyper-echoic mesentery that show the crescent in doughnut sign.. Ultrasound is a highly accurate in the diagnosis with a sensitivity of 98%-100% and a specificity of 88%-100%. In US modality, the intussusceptions had a large mass, usually greater than 5 x 2.5 cm that often displaces adjacent bowel loops. In our study, this mass is palpable in 35 patients and is localized on the sub-hepatic region. In our experience, the mean age is 1 year, and the tract of the intussusception are ileum-colic in all patient. 15 patients had a classic clinical triad: currant-jelly stools, hematochezia and a palpable mass, and 4 patients had vomiting.

Regarding appendicitis, in a study carried out by **Birnbaum and Wilson [(5)],** they stated that an important limitation of US is that the sensitivity and specificity for perforated appendicitis are lower than those typically seen for nonperforated appendicitis are. A non-compressible appendix may be identified in only 2.9% of patients with perforation. The US aided diagnosis of perforated appendicitis depends on the identification of the secondary findings [(5)]. So, in acutely inflamed appendix, examination by conventional abdominal US can be satisfactory. We found 49 cases of appendicitis, 10 gangrenous appendicitis with absence of color Doppler, and 39 cases of perforated appendicitis. The ultrasonographic sign in axial scans is "target sign", in longitudinal scans is a fluid-filled uncompressible, blind-ending tubular structure with parietal diameter > or = 6 mm. Color Doppler in axial scan reveals the fire ring.

Regarding CHIPS, Hernanz-schulman *et al.* [(13)] stated that the hypertrophied muscle is hypoechoic, and the central mucosa is hyperechoic. Diagnostic measurements include pyloric muscle thickness, i.e. diameter of a single muscular wall (hypoechoic component) on a transverse image is > 3 mm (most accurate 3) length, i.e. longitudinal measurement is > 15-17 mm, pyloric volume is >1.5 cm^3 and pyloric transverse diameter is >13 mm. With the patient right side down, the pylorus should be watched and should not be seen to open. We found 2 cases of hypertrophic pyloric stenosis. The sonographic features on the axial scans is "donut sign". On the longitudinal scans is "double track sign".

CONCLUSION

Acute abdominal pain is one of the most common complaints in childhood, and one that frequently requires rapid diagnosis and treatment in the emergency department. Although acute abdominal pain is typically self-limiting and benign, there are potentially life-threatening conditions that require urgent management, such as appendicitis, intussusception, or bowel obstruction. Meticulous history taking and repeated physical examinations are essential to determine the cause of acute abdominal pain and to identify children with surgical conditions. When acute appendicitis is suspected, the possibility of complicated appendicitis as in appendicular mass or abscess, or a perforated appendix should be excluded during the sonographic examination. Otherwise, US was proved to be quiet satisfactory as the first imaging modality of acute abdomen, regarding the cost, ionizing radiation hazards, and time consumption.

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