Research article

The radiological characteristics of childhood intussusception including unusual features and rare pathological lead points

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ABSTRACT

Purpose: To describe the radiological characteristics for childhood intussusceptions including unusual radiological features and rare pathological lead points (PLP).

Material and methods: The medical records of all childhood intussusceptions between 1/1/2010 -1/10/2020 were retrospectively reviewed. 95 cases were identified in 82 patients. The demographic data, presenting symptoms, diagnostic and treatment methods, radiological features, and PLPs among the different types of intussusception were analyzed.

Results: Ileocolic intussusception (ICI) represented 53.7% (51/95). The average age for ICI was 1.87 years. Males constituted 72.1% (31/43). 29.4% (15/51) were treated primarily surgically due to peritonitis. Small bowel intussusception (SBI) represented 40% (38/95) in which females constituted 51.5% (17/33). Ileo-ileal represented 63.2% (24/38). 81.8% (27/33) were transient. On ultrasound; There was a statistically significant difference in the size of the outer diameter of ICI compared to SBI (P-value 0.00012). Ileo-ileocolic and colo-colic intussusceptions constituted 3.2% (3/95); each and were more common in females. Vomiting was the most common symptom for intussusception and ultrasound was diagnostic in the majority of cases. PLPs were seen in 36.6% (30/82) of the patients of which the average age was 7 years. PLPs/risk factors were benign in 80% (24/30). A case of colo-colic intussusception was seen in a 16-year-old female due to clear cell sarcoma which was not reported before. 12.2% patients (10/82) had recurrent intussusception.

Conclusion: Our study showed that ICI is the most commonly encountered type. SBIs are mostly transient. It is important to radiologically determine the type of intussusception and to identify PLPs or unusual radiological features to avoid unnecessary intervention and significant patient morbidity.

1. Introduction

Intussusception remains one of the commonest causes of acute abdomen in children [1]. Its peak age of incidence is 3–18months [2]. Different types of intussusception can be encountered in clinical practice involving both the small and large bowel loops [3]. Most cases of childhood intussusceptions are of the ileocolic type and idiopathic in nature [4]. Small bowel intussusceptions are less commonly encountered than the ileocolic type and are mostly transient [5]. Lead points as a cause of childhood intussusceptions are seen in 5% of cases [4], with Meckel's diverticulum and Henoch-Schönlein purpura being the most frequently encountered ones [2]. A recent case series had reported colo-colic intussusception in 8 children [6]; which is rare in the pediatric population and is mostly secondary to pathological lead points [7].

The clinical diagnosis of intussusception is challenging as the classic clinical triad of intermittent abdominal pain, currant red jelly stools, and abdominal mass at the time of presentation is only seen in 7.5–40% of cases [1]. Adding to this challenge is that the different types of intussusception present clinically in a similar manner [8]. Therefore; imaging plays an essential role in the diagnosis or exclusion of intussusception.

Table 1. Comparison between the different types of intussusception.

Type of intussusception	Ileocolic	Small bowel	Ileoileocolic	Colo-colic	Total/%
Cases # (% from total)	51 (53.7)	38 (40)	3 (3.2)	3 (3.2)	95 (100)
Average Age *	1.87	6.02	6.3	6.3	
Sex					
• Male (#)	31	16	1	1	49
• Female (#)	12	17	2	2	33
Duration of symptoms (days)					
• Mean (median)	2.5 (2)	13.9 (2)	2 (2)	20.8 (2)	
Presenting symptoms:					
• Vomiting (%)	68.60%	56.70%	100%	100%	65.3%
• Abdominal Pain (%)	27.40%	47.40%	33.30%	66.70%	36.8%
• Currant Jelly stool (%)	47.10%	28.90%	33.30%	33.30%	38.9%
• Clinical triad (#)	4	0	0	1	5 (5.3)
Diagnostic method:					
• US (#)	49	15	3	2	69
• CT (#)	1	21	-	1	23
• BOTH (#)	1	2	-	-	3
Radiographic features					
• Location	RUQ	Variable	RUQ	Left Abdomen	
• U/S (AP x length))cm)					
• Average	2.9 × 4.4	2 × 3.3		-	-
• Median	2.6 × 3.9	1.8 × 3		-	-
• IQR	(2.4–3.6) x (3.1–5.3)	(1.5–2.4) x (1.9–3.9)		-	-
• CT (AP x length) (cm)					
• Average	-	2.4 × 3.6		-	-
• Median	-	2.2 × 2.2		-	-
• IQR	-	(2.1–4.7) x (1.8–2.9)		-	-
• Entrapped fluid (#)	16	1	-	-	
• LNS within (#)	17	0	-	-	
• Mesenteric LNs (#)	12	9	-	-	
• Free Fluid (#)	19	16	-	-	
• US intact Vascularity (#)	44	17	-	-	
• Bowel obstruction (#)	4	3	1	1	9
• Pathological lead point (# of patients)	6	21	1	2	30
Treatment method					
Nonsurgical	23	31	-	2	56 (59)
Surgical	28	7	3	1	39 (41)

#: number, *: years, %: percentage, RUQ: right upper quadrant, cm: centimeter, US: ultrasound, CT: Computed tomography AP: Anteroposterior, LNs: Lymph nodes.

The US is the modality of choice for the diagnosis of intussusception [1, 8, 9, 10]. US can differentiate between the different types of intussusception and can suggest alternative diagnoses. CT scan has a reported sensitivity of 100% in diagnosing intussusceptions [11]. A recent study has shown that performing CT scan early on in children with suspected intussusception secondary to pathological lead points, especially cases of persistent small bowel intussusceptions, could be beneficial; contributing to a decrease in the rate of unnecessary enema reduction, the waiting time for surgery and hence overall bowel complications [11].

Imaging also plays an important role in the management of intussusception. Non-operative reduction of intussusception by air or liquid enema is still the mainstay first-line option in the management of intussusception. Many studies had investigated the different methods of non-surgical reduction of intussusception [9, 12]. The possible sonographic parameters differentiating surgical from non-surgical cases of intussusception had also been studied [5, 13]. Those included the length of intussusception, the presence of PLP, free intra-abdominal fluid, trapped fluid sign, and the vascularity of the intussusception; all of which provide important information to patient care and prognosis.

Scarce previous reports had evaluated the different types of pediatric intussusceptions in the developing countries and the Middle east. The unusual radiological features of intussusception and the rare pathological

lead points are mostly limited to case reports in the literature. In this article, we will comprehensively discuss the usual and the unusual radiological features for the different types of childhood intussusceptions; some of which present a unique diagnostic challenge.

2. Materials and methods

The medical records of pediatric patients with a discharge diagnosis of intussusception between 1/1/2010 and 1/1/2021 were retrospectively reviewed. Patients were classified according to the type of intussusception into 4 groups which are ileocolic, ileo-ileocolic, small bowel, and colo-colic intussusceptions. The simultaneous identification of more than one segment of intussusception in the same child was considered as multiple intussusceptions. The age, gender, presenting symptoms, diagnostic methods, treatment methods, and recurrence rate in each group were recorded. The ages included in this study were from 0-18years of age. Diagnostic methods that were reviewed included ultrasound and CT scan. The radiological features of the intussusceptions were assessed by referring to the archived images and radiological reports. The presence of pathological lead point/predisposing risk factor and its nature were also assessed. SPSS version 22.0 was used to manage the research data.
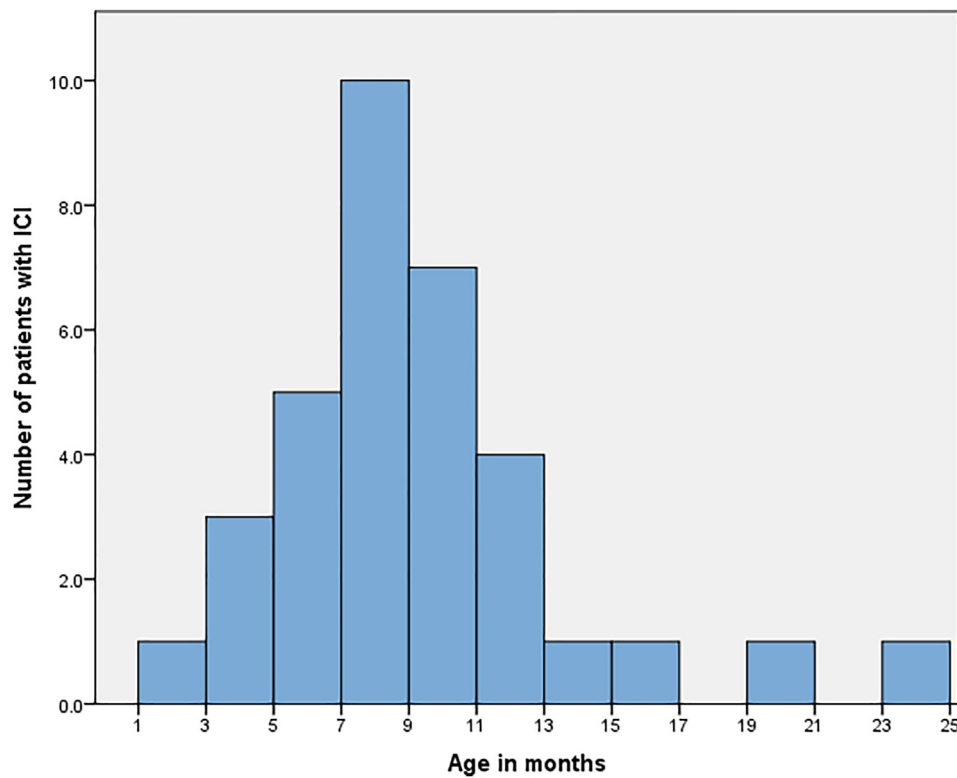
Figure 1. Histogram showing the age distribution (in months) for ileocolic intussusception.

The study was approved by the institutional review board and research committee at Jordan University of Science and Technology, which waived the need for informed consent due to the retrospective nature of this study. All methods were performed in accordance with their relevant guidelines and regulations.

3. Results

There were 95 cases of intussusception in the 11-year study period which were documented in 82 patients. One episode of intussusception was seen in 72 patients while recurrent intussusception was seen in 10 patients (12.2% (10/82)). ICI was the most common type and was mostly seen in males 72.1% (31/43) (Table 1). The majority of ICI cases (79.1% (34/43)) presented before 2 years of age and most of them were diagnosed between 5-10 months of age(Figure 1).

Patients with intussusception presented with a spectrum of variable symptoms among which vomiting was the most common (Table 1). The time interval between the onset of symptoms to the diagnosis of the intussusception was variable among the different types of intussusception as shown in Table 1. SBI was asymptomatic in 9 patients and was incidentally detected on imaging performed for irrelevant presentation.

Intussusceptions were diagnosed with ultrasound in 72.6% (69/95) (Table 1). SBIs showed no predilection for a certain location in the abdomen. They constituted mainly of ileo-ileal intussusceptions which represented 63.2 % of SBIs (24/38). Jejune-jejunal SBIs represented

Table 2. The treatment methods for the different types of intussusception.

	Type of intussusception			
	ICI n (%)	SBI n (%)	ileoileocolic n (%)	Colocolic n (%)
Treatment Modality				
Successful Pneumatic reduction	13 (25.5%)			1 (33.3%)
Surgical Reduction	10 (19.6%)	4 (10.5%)	1 (33.3%)	
Surgical Resection	5 (9.8%)	3 (7.9%)	2 (66.7%)	1 (33.3%)
Trial of more than one treatment				
● Pneumatic and Surgical reduction	5 (9.8%)			
● Pneumatic reduction and surgical resection	4 (7.8%)			
● Pneumatic reduction and negative intraoperative	2 (3.9%)			
Hydrostatic reduction				
● Barium reduction	2 (3.9%)			
● Saline Reduction	1 (2.0%)			
Spontaneous resolution	7 (13.7%)	31 (81.6)		1 (33.3%)
intraoperative spontaneous resolution	1 (2.0%)			
Negative intraoperative	1 (2.0%)			

ICI: ileocolic intussusception, SBI: small bowel intussusception, n: number, %: percentage.

Table 3. The pathological lead points encountered in the different types of intussusception.

Case	Sex	Age	Type	Pathological lead point/Risk factor	Diagnostic Method	Outcome
1	M*	5.5,7	SBI	Previous ileoileal intussusception reduction surgery	U/S	Spontaneous resolution
2	F	1.25	SBI	Celiac disease	U/S, CT	Spontaneous resolution
3	M	2.5	SBI	HSP[1]	U/S	Spontaneous resolution
4	M	17	SBI	Mediastinal lymphoma on chemotherapy	CT	Spontaneous resolution
5	M	0.5	SBI	HSP[1]	U/S	Spontaneous resolution
6	F*	1.25	SBI	History of liver transplantation	U/S	Spontaneous resolution
7	M	4	SBI	Large chest wall Rhabdomyosarcoma	CT	Spontaneous resolution
8	F	17	SBI	Liver and spleen hydatid cysts compressing the bowel	CT	Spontaneous resolution
9	F	1	SBI	History of nephrectomy	U/S	Spontaneous resolution
10	M	4	SBI	Meconium peritonitis	CT	Spontaneous resolution
11	M	3	SBI	ALL on chemotherapy[2]	CT, MRI	Spontaneous resolution
12	M	3	SBI	Abdominal surgeries twice for recurrent ICI	CT	Spontaneous resolution
13	M	5	SBI	ALL on chemotherapy[2]	CT	Spontaneous resolution
14	F	5	SBI	Waugh's syndrome	U/S, Fluoro.	Resection and anastomosis
15	F	0.16	SBI	Meckel's diverticulum that mimicked duplication cyst	U/S	Surgical Red.
16	F	16	SBI	Hamartomatous polyp in Peutz-Jeghers Syndrome	CT	Surgical Red.
17	M	17	SBI	Hamartomatous polyp in Peutz-Jeghers Syndrome	CT	Resection and anastomosis
18	F	7	SBI	Gastric trichobezoar	U/S, CT	Gastrotomy
19	M	1.5	SBI	HLH (hemophagocytic lymphocytosis)	CT	Spontaneous resolution
20	M	16	SBI	Crohn's disease	CT	Spontaneous resolution
21	F	17	SBI	Recent Cesarian section	CT	Spontaneous resolution
22	F	0.67	Ileocolic	Acute appendicitis	U/S	Surgical Red. & appendectomy
23	F	3	Ileocolic	Lymphoma	U/S	Surgical reduction
24	M	11	Ileocolic	Acute appendicitis	U/S	Resection and anastomosis
25	M	0.42	Ileocolic	Meckel's diverticulum	U/S	Resection and anastomosis
26	M	0.67	Ileocolic	Multiple abdominal surgeries for VUR[3]	U/S	Surgical Red.
27	M	11	Ileocolic	Lymphoma	U/S, CT	Surgical Red.
28	F	17	Ileo-ileocolic	Ovarian cyst and Meckel's diverticulum	U/S	Resection and anastomosis
29	F	16	Coli-colic	Clear cell sarcoma of the descending colon	CT	Resection and anastomosis
30	F	2.5	Coli-colic	MMC[4]	U/S	Spontaneous resolution

M: male, F:female, Age in years,*: Indicates recurrence, [1]: Henoch Schonlein Purpura, [2]:Acute lymphocytic Leukemia, [3]:Vesicoureteric reflux,[4]: Myelomeningocele, U/S: ultrasound, CT: computed tomography, MRI: magnetic resonance imaging, Fluoro.: fluoroscopy, Red.: reduction.

28.9% (11/38). The rest of the SBIs were a combination of other small bowel loops. Multiple SBIs were identified in 18.2 % of the patients (6/33). Those constituted of 4 multiple ileo-ileal intussusceptions, one a combination of jejunal and gastroduodenal intussusceptions and another one was multiple ileal and jejunal intussusceptions. There was one patient who presented with concomitant ileocolic and ileo-ileal intussusceptions.

On a transverse US image; intussusception appeared as concentric rings of altered echogenicity giving the classic target sign. The outer diameter of ICI (anteroposterior diameter) was measured on a transverse US image. The mean of the outer diameter of the ICI was larger as compared to SBI (p-value = 0.00012) (Table 1). The mean length of the ICI was measured through the greatest longitudinal axis of the telescoped bowel segments. The entrapped interloop fluid was documented in 31.4% (16/51) of ICI; where the average of its maximum dimension as measured on a transverse US image was 10.8mm (median 9.5mm, IQR 7.8–13mm). The entrapped interloop fluid was echogenic in only 1 case of ICI.

On CT scan; SBIs appeared as a multilayered intraluminal mass containing fat that is continuous with the mesenteric fat. The mean for the outer diameter of SBI was measured on an axial CT image while the mean of its maximum length was measured on the coronal CT image (Table 1). The entrapped interloop fluid was documented only in 1 case (2.6%) of SBI on a CT scan; where its maximum dimension measured on the axial CT image 23.5mm. Intraperitoneal free fluid was noted in 42.1% of SBIs(CT = 9, US = 7). Mesenteric lymph nodes were seen in 23.7% (CT = 6, US = 3).

Bowel obstruction with either sonographic or CT evidence of dilated small and/or large bowel loops proximal to the level of intussusception was documented in 9.5% (9/95) of the cases (Table 1).

ICIs were treated primarily surgically in 29.4% (15/51) (Table 2) of the cases due to signs of peritonitis. Most of the ICIs with entrapped fluid (62.5% (10/16)) were treated surgically. The pneumatic reduction was attempted in 47.1% (24/51) of cases with a success rate of 54.2% (13/24). One of the ICI which presented with bowel obstruction was reduced successfully with pneumatic reduction. No complications related to the pneumatic reduction procedure were seen during the study period. There was no statistical significance (all p-value > than 0.05) in the presenting symptoms, gender, mean age, duration of symptoms, mean radiological dimensions of the intussusception, the presence of entrapped fluid or free fluid as well as pathological lead points between the cases that were treated successfully with pneumatic reduction compared to the cases which failed the reduction. As for SBIs; they were transient in 81.8% of the patients (27/33), and resolved spontaneously without any intervention. The remaining patients had persistent SBIs that required surgical intervention.

Pathological lead points/predisposing risk factors for intussusception in this series were documented in 36.6% (30/82) of the patients (Table 1 and Table 3). An associated predisposing risk factor was seen in more than half (59.3%) of the patients (16/27) with transient SBIs (Tables 1 and 3). In the remaining patients with persistent SBI, an associated PLP was identified in 5/6 (Table 3). A predisposing risk factor/pathological lead point was documented in 3 patients with multiple SBIs (Table 3). The average age for the patients with pathological lead points (PLP) was

Figure 2. Pathological intussusception secondary to Meckel's diverticulum in a 2 month old boy. Transverse ultrasound image demonstrating ileocolic intussuscepiton in the right upper quadrant (thin arrows) and a cystic pathological lead point (thick arrow) which proved to be Meckel's diverticulum intraoperatively. The lesion was radiologically interpreted as a Duplication cyst.

almost 7 years with 70% (21/30) of those patients being older than 2 years. Intussusceptions associated with PLP were identified on ultrasound in 68.8% (22/32) (Table 3). The encountered lead points were benign in nature in 80% (24/30) of the cases (Table 3). Prior history of abdominal surgery was the most commonly encountered risk factor representing 29.2 % (7/24). Among the benign pathologies is a case of Waugh's syndrome and a case of Meckel's diverticulum that mimicked the duplication cyst on imaging (Figure 2). A case of gastric trichobezoar causing multiple gastroduodenal and jejunal SBIs was also seen in a 7-year-old female patient who presented with chronic abdominal pain for 6 months (Figure 3). An 18-year-old female patient who presented with ileo-ileocolic intussusception had 2 pathological lead points (Table 3). There were 7 malignant lead points/malignancy-related risk factors identified during the study period (23.3%) (Table 3). Those included a previously unreported case of clear cell sarcoma causing colo-colic intussusception in a 16-year-old female patient (Figure 4).

Among the 10 patients with recurrence, 8 were males. Recurrent ICI was seen in 14% (6/43) of the patients whose first episode was ICI. ICI recurred twice within 4 days in one patient (1/6 (16.7%)) while the time to recurrence was variable in the rest of the patients ranging from 2 weeks to 1 year. One of these patients had two recurrent episodes of ICI that were treated with surgical reduction, followed by a third recurrence 3 years later as an ileo-ileal intussusception. Also, recurrent ICI was diagnosed in one patient two weeks after his first ileo-ileocolic intussusception. The initial episode was treated with surgical resection while the postoperative recurrence was treated with surgical reduction. Recurrent ileo-ileal intussusception was diagnosed in 2 patients with previous ileo-ileal intussusceptions; both of which were associated with a predisposing risk factor (Table 3). Another recurrent ileo-ileal intussusception was documented in a patient who had his first episode as ICI.

4. Discussion

This study was conducted in a tertiary care center and is comprehensively evaluating the radiological features of the different types of childhood intussusception; which remains an important cause of acute abdomen in children.

ICI was the most common type of intussusception encountered in this series constituting about 53.7% of the total. This rate is lower than the 76- >80% rate reported by other series [2, 14]. This might be related to the selective referral of complicated or clinically missed cases to our tertiary center. The high male predominance of ICI was close to that reported by Sonmez et al [2].

Imaging plays an important role in both diagnosing and treating intussusception. Plain radiographs might provide prognostic information regarding the non-surgical enema reducibility of ICI, and to the potential outcomes for patients needing surgical intervention [15]. US was diagnostic in the vast majority of cases. This reflects the high specificity and sensitivity of the US in diagnosing intussusception [9, 12, 16]. It also supports the recent clinical recommendations and practice of performing ultrasound as a primary investigation tool in cases with high clinical suspicion [16, 17]. The interloop fluid was noted in 31.4% of ICIs on sonography which is higher than the 22% reported before [18]. Most ICIs were seen in the right upper quadrant as reported by Ayaz [16].

Surgical intervention for ICIs was high in this series representing 29.4% of the primarily treated cases compared to the 19% reported rate by Ein et al [19] and the only 0.6% reported in a large cohort series from South Korea [20]. The overall surgical intervention rate in this study including cases of failed pneumatic reduction was 47.1 % (24/51) (Table 2). This rate was also higher than what is reported by Das et al in his study involving 19 tertiary care centers in India [14]. The delayed presentation/referral of patients, with an average of about 2.5 days, to our center (Table 1) can be a contributing factor for this high surgical intervention; in concordance with a previous report [21]. The pediatric radiologists' experience and availability in addition to the variation of the preferred treatment method among different institutions can be other influential factors. However; the type of surgical intervention was close to other series with surgical resection and anastomosis documented in 37.5% (9/24) [22]. Similar to what is reported; the majority of cases with entrapped fluid as documented on sonography were treated surgically. This supports that this sonographic parameter might help the physician in selecting the treatment option for the patient as it is reported to be associated with a higher rate of bowel necrosis, and a lower success rate of pneumatic reduction [9, 23]. In 11.1% of the cases

Figure 3. Multiple pathological intussusceptions in a 7 year old female secondary to gastric trichobezoar. (a) Coronal CT scan reconstruction of the abdomen and pelvis with oral and IV contrast showing a heterogenous mass like lesion in the stomach interspersed with gas foci and calcifications (thin arrows) consistent with trichobezoar. There is a jejuno-jejunal intussusception (thick arrow). (b) Notice another jejuno-jejunal intussusception (thin arrow) and a concurrent gastroduodenal intussusception (thick arrow).

(3/27), there was no evidence of intussusception intraoperatively as shown in Table 2. This is close to what was previously reported and we do agree that approaching the patient initially laparoscopically when surgery is needed might contribute to a decrease in the patient's morbidity [24].

The recurrence rate of ICI was higher from the 5–10% known recurrence rate [4]. The time to recurrence was more delayed than what is reported with only 16.7 % of cases seen within few days from the first episode [4]. In the current series, 3 patients developed a different type of intussusception in the recurrent episode. This is an unusual presentation of intussusception that can add to the challenges in the diagnosis and management of recurrent intussusception. Although many studies had investigated the patterns and risk factors associated with recurrent intussusception [25, 26]; to date and up to the authors' knowledge there is still lacking data focusing on how to approach and manage a different type of intussusception in the recurrent episode. Large-scale research is needed to further address this.

Similar to other series; the majority of SBI were of no clinical significance and had resolved spontaneously without intervention [8, 27]. Ileoileal intussusception was the most commonly encountered type; contrary to Strouse et al where jejunum was the most common type [28]. The average reported age for small bowel intussusception and the sex predilection are variable among different series. In this series, the average age was younger than what is reported by Strouse [28], and older than other series [5, 8]. There was a slight female predominance in this series which is similar to what is reported [5]. The clinical presentation was indistinguishable from ileocolic intussusception. 24.2% of patients were asymptomatic as opposed to 65% from another report [29]; although we included all cases of SBI in this series including the transient type.

It is of utmost importance to differentiate ICI from SBI or colo-colic intussusception to avoid unnecessary interventions. In this series; SBIs had a similar sonographic appearance to ileocolic intussusception. However; our measurements of the mean outer diameter of ICI (2.9cm)
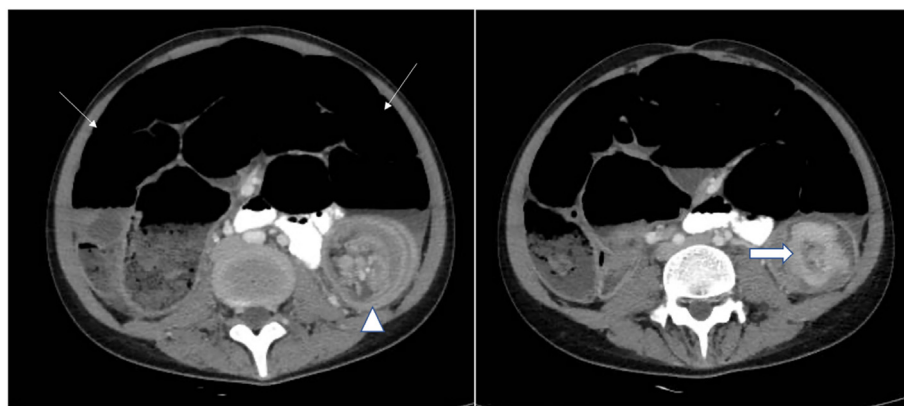
Figure 4. Colocolic intussusception in a 17-year old female secondary to malignancy. (a) Axial CT of the abdomen and pelvis with oral and IV contrast demonstrating colo-colic intussusception (arrow head) causing proximal large bowel obstruction (thin arrows). (b) Notice the enhancing polypoidal mass lesion within the intussusception (thick arrow). The lesion proved to be a clear cell sarcoma.
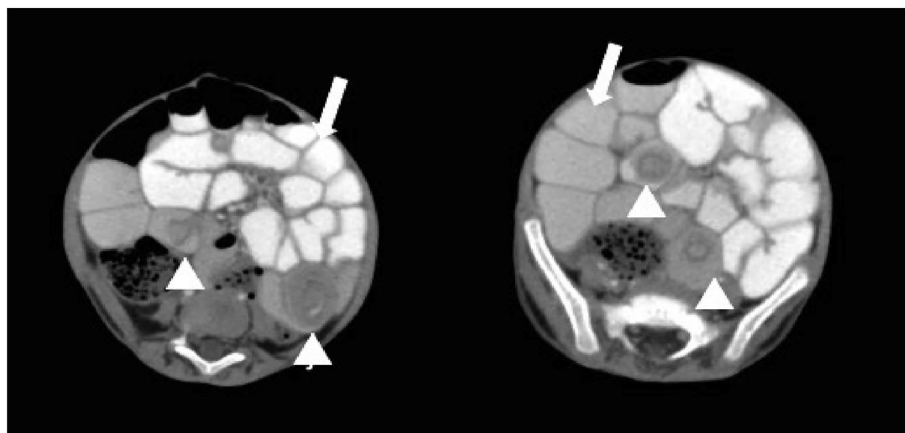
Figure 5. Axial CT scan of the abdomen and pelvis with oral and IV contrast for a 1.25 year female patient at two different levels. Notice the multiple small bowel intussusceptions (arrow heads) and the dilated bowel loops (thick arrows). The patient was diagnosed with celiac disease.

Figure 6. 17 year old male with Peutz –Jegher's syndrome. CT scan of the abdomen and pelvis with oral and IV contrast demonstrating multiple jejunal (arrow head) and ileal intussusceptions (white arrow).

were significantly larger compared to that of SBI (2cm). This is close to other reports in which the mean of the outer diameter for the ICI ranged from 2.53-3.7cm and that of the SBI ranged from 1.38-1.68cm [8, 30, 31, 32]. In a previous report [8], the location of the intussusception was one of the important factors differentiating ICI from SBI as most SBIs are seen in the paraumbilical region compared to the right side of the abdomen in ICI [8]. In this series; the location of the SBI was variable with no predominant predilection for a certain location, adding to the diagnostic challenge.

The incidence of bowel obstruction among the different types of intussusception is inadequately represented in the literature, although intussusception is considered the most common cause of intestinal obstruction in children [1]. In this series; an associated bowel obstruction was almost equally distributed in the cases of SBI and ICI (about 7.8%). A recent study has shown that the presence of bowel obstruction in radiographs was associated with a higher rate of enema reduction failure and a higher rate of surgical bowel resection [15]. The authors; however, did not specify the incidence of bowel obstruction among the different types of intussusception.

The coincidence of double-site intussusceptions without PLP represents a relatively uncommon entity with few reported cases in the literature [33]. Such a presentation will contribute to challenges in deciding the best treatment method for the patient. In our series; there was a case of concurrent ileocolic and ileoileal intussusception in a 10-month old male. The ileocolic intussusception was reduced successfully with pneumatic reduction and the ileoileal intussusception reduced spontaneously without complications or recurrence.

In this series, a pathological lead point or a predisposing risk factor including previous surgeries that might have contributed to bowel instability were observed in 36.6% of the patients (Table 3). This is higher than the 0.3–20% range reported in the literature [17, 34]. Most (70%) of patients with pathological lead points or predisposing factors were older than 2 years with an average age of 7 years (Table 3). This is slightly higher than what is reported by Navaro [27]. The occurrence of intussusception after the age of 5 years is considered an unusual feature of intussusception [35]. There was wide variability in the detected PLPs in this series and their diagnostic modality adding to the diagnostic challenge (Table 3). Some of the identified PLPs presented with simultaneous multiple SBIs which is an unusual variety of SBI [36]. In the present study; 6 patients had multiple SBIs. One of which was in a 1.25-year-old female who was diagnosed with celiac disease (Table 3, Figure 5). This association is rarely reported in the radiology literature [37, 38]and at this young age. In one patient, multiple ileal and jejunal SBIs were identified which is an extremely rare incidence [36]. Peutz-Jegher's syndrome was the underlying pathology in this patient (Figure 6). There was a case of trichobezoar seen in a 7-year-old female who presented with multiple SBIs one of which was gastroduodenal (Figure 3). Trichobezoar is a rare cause of atypical intussusception in children with a few reported cases in the literature [39, 40]. Up to the authors' knowledge, no previous reports had reported the occurrence of concurrent gastroduodenal intussusception in association with trichobezoar.

Only one case of confirmed Waugh's syndrome was noted during our study period representing about 1% of the total. This contradicts the 40% incidence of Waugh's syndrome from a previous report [41]. The SBI in this patient was of the jejunoileal type which is among the rarest types of SBI [42]. The reported incidence of postoperative intussusception in the literature is 0.01–0.25% [43]. Postoperative intussusception is hard to recognize and requires a high index of suspicion for diagnosis. In this series 2.4% of the patients (2/82) had postoperative intussusception; one of which was in the second postoperative day following the cesarian section (Table 3). This type of operation was not reported as a cause of postoperative intussusception in the pediatric radiology literature. The other patient was a 5-month-old male who developed ileocolic intussusception 2 weeks after surgical resection of ileo-ileocolic intussusception. This represents an extremely rare variant of postoperative intussusception [44]. 6.1% of the patients with transient SBIs had a prior history of variable types of abdominal surgeries of more than 30 days from their presentation (Table 3). Whether this represents a temporal coincidence or is related to the surgical manipulation/adhesions remains unclear.

Malignant lead points are rarely reported as pathological lead points in colocolic intussusception [45, 46]. The largest series [6] of pediatric

colocolic intussusceptions included 8 cases in which 7 were secondary to benign juvenile polyp which is the most commonly reported PLP for colocolic intussusception [46]. The rarity of reported colocolic intussusceptions can add to the therapeutic and diagnostic challenges. Similarly, In this series, only 3 patients are reported with colocolic intussusception, among which one patient had a malignant lesion as the pathological lead point. This PLP was proved to be clear cell-like sarcoma in a 16-year-old female. No similar cases of this rare clinical entity have been reported in pediatric patients.

Most of the patients with SBI were treated conservatively; even in the presence of predisposing risk factors (Table 3). This supports what was suggested in an earlier study that conservative management of SBI with close monitoring if the clinical situation allows can be performed safely in those patients instead of rushing into emergent laparotomy [47]. This will reduce patient morbidity and mortality in the proper clinical settings. There is an emerging role for magnetic resonance enterography (MRE) in characterizing the different PLPs associated with intussusception which can reflect on the overall management of intussusception [48].

The study is limited by the relatively small number of the studied cases as well as its retrospective design. Adding to this; the ultrasound exams were performed by two different pediatric radiologists as well as different radiology residents contributing to the lack of standardized images.

In conclusion, our study showed that ICI is the most common type and is idiopathic in most cases. ICI is more common in males compared to slight female predominance in other types of intussusception. Vomiting was the most common presenting symptom of all types. US proved to be a reliable tool for diagnosing intussusception of any type. Most cases of SBI were transient. A variety of pathological lead points/risk factors were encountered in this study; some of which represented rare incidences and imposed a diagnostic challenge. It is important to differentiate radiologically ileocolic intussusception from other types and to look for pathological lead points to avoid unnecessary intervention and avoidable increase in overall patient mortality and morbidity.

Declarations

Author contribution statement

Ruba Khasawneh: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Mwaffaq El-Heis, Mamoon Al-Omari and Samah Awad:Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Mohammed A. Al-Qaralleh, Abdel Rahman Al-Manasra and Abdallah A. Alqudah: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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