Singapore Med J 2003 Vol 44(6) : 312-322

# Imaging and the Child with Abdominal Pain

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## ABSTRACT

**Abdominal pain is a common presenting symptom in children. A substantial percent of unscheduled paediatric office visits and paediatric emergency room visits are due to abdominal pain. Children may present with an acute episode of pain or with chronic, recurrent pain. Only a small fraction of children presenting with abdominal pain will prove to have an organic cause necessitating interventional management. In this essay, a discussion of abdominal pain is presented, with particular emphasis on the role of radiologic imaging tests to investigate potential causes of abdominal pain. The more common and clinically significant causes of abdominal pain in a child will be discussed in greater detail.**


**Keywords: children, abdomen, pain, imaging**

*Singapore Med J 2003 Vol 44(6):312-322*

## INTRODUCTION

Abdominal pain is a common presenting symptom in children. A substantial percent of unscheduled paediatric office visits and paediatric emergency room visits are due to abdominal pain[1-6]. Children may present with an acute episode of pain or with chronic, recurrent pain[6-8]. Only a small fraction of children presenting with abdominal pain will prove to have an organic cause necessitating interventional management[1-8]. In this essay, a discussion of abdominal pain is presented, with particular emphasis on the role of radiologic imaging tests to investigate potential causes of abdominal pain. The more common and clinically significant causes of abdominal pain in a child will be discussed in greater detail.

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## DISCUSSION

Abdominal pain in children is common. Virtually any parent will attest that their child will occasionally complain of a "tummy ache." Most episodes are insignificant. Different children will have different thresholds for pain tolerance. Similarly, parents will vary in their threshold of when to bring the child to medical attention. Paediatricians and paediatric emergency room physicians must decide which patients warrant further work-up with imaging and which patients warrant referral to the paediatric surgeon. Paediatric surgeons must decide which patients warrant surgical intervention and which patients should be observed or managed medically[9]. Although the presentation of a child with abdominal pain is common, each individual child provides a unique challenge to the physicians involved.

The pathophysiology of abdominal pain is complex[10,11]. Stimuli from the abdominal organs, including the gastrointestinal tract, course through sympathetic nerves to thoracic ganglia and to the spinal cord. These stimuli are poorly localised. Pain originating from visceral organs is thus poorly localised, often perceived as midline and often associated with secondary autonomic effects such as nausea, vomiting or pallor. The general location of pain may infer the affected organ[10,11]. Epigastric pain originates from stomach, duodenum, pancreas, liver or biliary system (foregut derivatives). Periumbilical pain originates from small intestine or cecum (midgut derivatives). Infraumbilical pain originates from colon and rectum (hindgut derivatives), uterus and ovaries, bladder or the kidneys. Renal and ovarian pain is laterally located to the affected side. When intense, visceral pain may occasionally be referred to a dermatomal distribution[11]. Stimuli from the parietal peritoneum, the diaphragm and the abdominal wall course through somatic nerves. Pain originating from these parietal structures is thus usually well localised and often dermatomal in distribution.

Stimuli for pain vary in their effect[11]. Stretching, tension, traction and rapid distention of an organ cause pain. Crushing, shearing or slow gradual distension is less painful. Inflammation and ischemia also cause pain. Psychologic stimuli, including that initiated by pain itself, cause stress. Stress may induce pylorospasm, air swallowing with resultant gut distention and altered intestinal tone, all of which may cause abdominal pain and potentially obscure the inciting symptoms.

Approximately 25% of all children will be brought to medical attention for abdominal pain by the age of 15 years; however, only 5% of the patients will likely require hospitalisation, and fewer yet, surgical intervention[5]. As many as 10% of children may experience recurrent abdominal pain[5]. Scholer et al investigated the prevalence of children presenting with non-traumatic abdominal pain for an unscheduled paediatric office or paediatric emergency room visit[6]. Out of 22,546 patients seen between two and 12 years of age, 1,141 (5.1%) presented with acute abdominal pain of three or less days duration[6]. An additional 3% had pain of longer duration[6]. The six most prevalent diagnoses in children presenting with acute abdominal pain were upper respiratory infection and/or otitis (18.6%), pharyngitis (16.6%), viral syndrome (16.0%), "abdominal pain of uncertain etiology" (15.6%), gastroenteritis (10.9%), and acute febrile illness (7.8%)[6]. Ten children (0.8%) had appendicitis and 2 (0.2%) had other surgical diagnoses[6].

Other studies have also investigated the eventual diagnosis given to children presenting with acute abdominal pain. In a series of 588 paediatric admissions for acute abdominal pain for less than one week by O'Donnell et al, 57% of patients were eventually diagnosed with "acute non-specific abdominal pain," 31% with appendicitis and 12% with other diagnoses[1]. In a similar series by Jones, a surgeon, of 364 paediatric patients admitted with acute abdominal pain, 30% received a diagnosis of "non-specific abdominal pain," 67% had a non-surgical diagnosis, 28% had appendicitis and only 3% had other surgical diagnoses[3]. In a series of 377 patients under 16 years old presenting to an emergency room with abdominal pain by Reynolds and Jaffe, 36% left with a diagnosis of "abdominal pain" and 16% with gastroenteritis, while 8% had appendicitis[2]. Eighty-nine percent of children in this series had a non-surgical diagnosis[2]. In a recent series of 1,017 children presenting to an large inner city paediatric emergency room with acute abdominal pain, Klein et al identified the final diagnosis as "abdominal pain" in 48% of patients[4]. In this series, "abdominal pain" was the most common diagnosis in all subsets of age (<2 years old, 2-5 years old, 5-12 years old, and >12 years old) for both sexes[4]. Six percent of patients in the series had appendicitis and other surgical diagnoses were uncommon[4].

From this review of the literature, the following conclusions can be reached: (1) abdominal pain is a common presenting symptom in children; (2) the overwhelming majority of children presenting with abdominal pain do not have a surgical condition; (3) many children presenting with abdominal pain do not ever receive a specific diagnosis; (4) appendicitis accounts for only a small fraction of children presenting with abdominal pain; and (5) other surgical conditions presenting with abdominal pain in a child are infrequent.

The challenge to the clinician caring for a child with abdominal pain comes in determining which child warrants further work-up. The i mportance of a good history and physical examination cannot be overstated. The choice of whether to obtain laboratory examinations and which ones to obtain depends on the initial evaluation of the patient and may help guide subsequent investigation, including imaging. There are three questions that the clinician must address in regards to imaging: Does this child require imaging for diagnosis? Does this child require imaging to exclude a diagnosis? Which imaging technique is most likely to give the information needed to direct clinical care?

Accompanying signs and symptoms to abdominal pain are often a clue as to the presence of an organic or treatable etiology for the pain. Other symptoms may be dominant and suggest a specific disease process. Clinical findings in a child with abdominal pain that may suggest the need for further investigation include pain which is not periumbilical or pain which migrates from a periumbilical location, fever, leukocytosis, abnormal urinalysis, blood in the stool, or a palpable mass.

The choice of an imaging modality in a child with abdominal pain will be heavily dependent on the results of a well-performed history and physical examination and initial laboratory evaluation. Selection of imaging methods may vary somewhat based on personal and institutional preference and experience. Radiography, ultrasound and computed tomography (CT) are the main imaging tools used in evaluating the child presenting with acute abdominal pain.

Radiographs are inexpensive, readily available and easy to obtain. Unfortunately, radiographs are relatively insensitive and non-specific, particularly in regards to the diagnosis of appendicitis. The radiation dose incurred, albeit very small, is also a disadvantage. Nevertheless, radiographs are often a good first imaging tool, particularly when gastrointestinal tract pathology is suspected. Occasionally, radiographs may verify a suspected diagnosis of appendicitis by identifying an appendicolith. Radiographs serve to exclude the presence of some non-surgical conditions including lower lobe pneumonia and constipation. Radiographs also serve to help identify other surgical conditions which may mimic appendicitis including bowel obstruction, bowel perforation and intussusception.

Sonography is often selected as the initial imaging modality in the child with abdominal pain[12]. This is usually appropriate, but at times sonography is utilised inappropriately as it is perceived as the least harmful

test for the child. The chief advantage of sonography is that no ionising radiation is involved. Although still images are obtained, sonography is performed in real-time allowing for discourse between the sonographer or radiologist and the patient and parent. This allows for correlation of sonographic findings with physical examination findings and directed scanning based on information provided by the patient or his or her parent. Sonography can also be performed portably, if patient condition necessitates. The chief disadvantage of sonography is that it is very operator dependent. Adequate training, knowledge of the expected pathologies and anatomy, and skill and patience in scanning technique are all paramount. Although the entire abdomen can be scanned, sonography does not provide the same global evaluation that CT does. Gas containing structures and bones obscure underlying structures. Guarding by the patient or excessive motion may make sonographic evaluation and interpretation difficult. Sonography is best utilised when properly selected and guided by the clinical presentation of the patient. Abnormalities of the parenchymal organs and gallbladder are well seen on ultrasound. An exception is the pancreas, which is often obscured by overlying bowel gas. Sonography can be used to look for abnormalities of the gastrointestinal tract including appendicitis and intussusception.

CT is a powerful and versatile imaging tool for disorders of the abdomen. With proper technique there is excellent spatial resolution and good contrast resolution. With CT, as opposed to sonography, coverage between the uppermost slice and lowermost slice is global. All structures between are included, and none are obscured by overlying gas or bone or reliant on the ability of the imager to demonstrate them. For this reason many radiologists place greater confidence diagnoses made with CT than sonography. There are several disadvantages of CT that preclude greater utilisation. CT is more expensive than sonography. CT is less readily available. Patients needing emergency scanning must be "squeezed in" between scheduled patients, displace scheduled patients or be placed in a figurative queue with other patients to be done emergently. Intravenous contrast is needed for most abdominal applications, necessitating intravenous access. Intravenous contrast may be contraindicated in some patients due to a history of anaphylactoid contrast reaction or renal failure. Oral contrast is also helpful, particularly for gastrointestinal tract pathology, but requires time for transit through the bowel. When pain is associated with nausea and vomiting, the patient may not tolerate drinking the oral contrast. The greatest disadvantage of CT, however, is the radiation dose. Although small, the radiation dose is not without long-term deleterious effects and should not be ignored[13]. Nevertheless, when firmly indicated and with technique properly tailored to the individual patient, the benefits of CT are substantial and counterbalance the small risk incurred[14].

Gastrointestinal contrast studies may occasionally be performed in children presenting with acute abdominal pain. Usually, these children have other clinical signs or symptoms indicating a specific diagnosis such as malrotation with volvulus or intussusception. Excretory urography (intravenous pyelography) is now rarely performed in the emergency setting, having been largely replaced by sonography and non-contrast thin-section CT. Other imaging studies, including magnetic resonance imaging, nuclear medicine studies and angiography are rarely, if ever, indicated for imaging of the child presenting with acute abdominal pain. Occasionally, initial clinical evaluation and earlier imaging studies may guide subsequent use of one of these modalities.

The differential diagnosis for abdominal pain in a child is extensive[5]. Table I. lists potential causes for abdominal pain children, divided into medical and surgical entities. As previously discussed, it is important to remember that many children in all age groups will not receive a specific diagnosis for their symptom of abdominal pain. There are specific diagnoses for abdominal pain in a child that clinical physicians and radiologists should be very familiar with. Appendicitis is, by far, the most common surgical condition presenting with acute abdominal pain in children. Children with malrotation with volvulus and intussusception usually have other symptoms, which may be dominant; however, pain is often a prominent symptom. These are conditions which should not be missed because of the potential for substantial morbidity. Pyelonephritis and renal calculi are important renal causes of abdominal pain, which in children may indicate the possibility of an underlying abnormality predisposing the child to infection or calculus formation. Inflammatory bowel disease, particularly Crohn's disease, is not infrequently diagnosed in childhood. Although symptoms are usually chronic, these children may present initially with acute symptoms, mimicking appendicitis. Each of these processes will be discussed with emphasis on the role of imaging in diagnosis.

**Appendicitis**

The classic presentation of appendicitis is periumbilical pain which, with time, migrates to the right lower quadrant. Early distention of the appendiceal lumen results in autonomic pain reflexes. Pain is thus poorly localised and periumbilical in location reflecting the midgut location of the appendix. As the disease process

**Table 1. Causes for abdominal pain in a child.**

| **Medical Causes** |
|---|
| Aerophagia |
| Cholelithiasis |
| Cholangitis |
| Colic |
| Constipation |
| Crohn's disease |
| Diabetes mellitus |
| Epididymitis |
| Food poisoning |
| Gallbladder hydrops |
| Gastroenteritis |
| Glomerulonephritis |
| Gynaecologic |
| Endometriosis |
| Hemorrhagic Cyst |
| Mittelschmerz |
| Pelvic inflammatory disease |
| Pregnancy |
| Heavy metal poisoning |
| Hemolytic uremic syndrome |
| Henoch-Schölein purpura |
| Hepatitis |
| Hirschsprung's disease with colitis |
| Infectious mononucleosis |
| Ingestion |
| Intestinal pseudo-obstruction |
| Irritable bowel |
| Lead or heavy metal poisoning |
| Malabsorption including lactose intolerance |
| Medicine reaction |
| Mesenteric adenitis |
| Milk allergy |
| "Non-specific abdominal pain" |
| Omental torsion |
| Pancreatitis |
| Parasites (ascariasis) |
| Peptic ulcer disease |
| Pharyngitis |
| Pleural effusion |
| Pneumonia |
| Porphyria |
| Primary peritonitis |
| Pyelonephritis |
| Reye's syndrome |
| Sepsis |
| Sickle cell anemia crisis |
| Spine - discitis, infection, tumor |
| Typhlitis |
| Urinary calcui |
| Urinary tract infection |
| Varicella |
| Viral syndrome |
| Yersinia infection |
| **Surgical Causes** |
| Abscess |
| Appendicitis |
| Bezoar |
| Bowel obstruction |
| Cholecystitis |
| Choledochal cyst |
| Duplication cyst |
| Foreign body |
| Gastric volvulus |
| Gynaecologic |
| Ectopic pregnancy |
| Endometriosis |
| Hydrometros, Hydrometrocolpos |
| Ovarian torsion |
| Hernia |
| Intussusception |
| Malrotation and malrotation with volvulus |
| Mass/tumour |
| Meckel's diverticulum |
| Mesenteric ischemia |
| Testicular torsion |
| Trauma, including child abuse |
| Urachal cyst (infected) |
| Ureteropelvic junction obstruction |

Note: Processes with a high likelihood to require surgical or imaging guided intervention are listed as "surgical causes." Processes usually treated medically without the need for surgery are listed as "medical causes." This list is, by no means, complete.

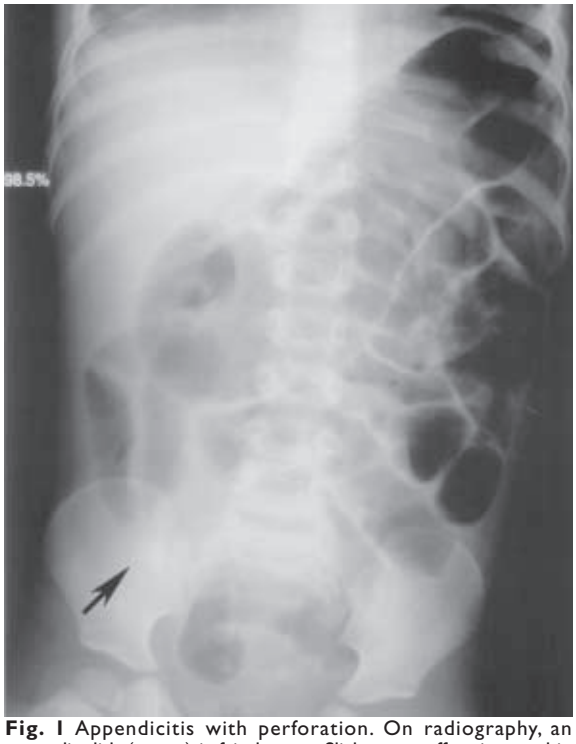

**Fig. 1** Appendicitis with perforation. On radiography, an appendicolith (arrow) is faintly seen. Slight mass effect is noted in the right hemipelvis. Gaseous distension of bowel is due to ileus.

progresses, the inflamed appendix causes inflammation of the adjacent parietal peritoneum. Somatic reflexes now produce pain, which is localised to the right lower quadrant. In patients with this classic presentation, accompanied by fever and an elevated white blood cell count, a clinical diagnosis is often made without the need for imaging. Although presentation is frequently classic, atypical presentations are common. Imaging is thus often performed for diagnosis. Imaging also serves to identify complications, namely perforation and/or abscess, which may alter therapeutic approach.

A number of radiographic findings may be seen in the child with appendicitis. The presence of an appendicolith in a patient with right lower quadrant pain and fever is diagnostic. Appendicoliths are frequently oval and lamellated, but are often subtle or obscured by bone or bowel gas on radiography. Dilated small bowel loops (focal ileus) or a paucity of right lower quadrant bowel gas are not uncommon findings (Fig. 1). Frank small bowel obstruction is uncommon, but when seen usually indicative of perforation. Free intraperitoneal air is rarely seen in the setting of perforation. Plain films are often normal, particularly if the appendix is not perforated.

The sensitivity and specificity of sonography for appendicitis will vary considerably from institution to institution depending on many factors including the skill of the sonographers, the machines available, and most importantly, the population of patients referred for sonography. It is unlikely that the high sensitivity

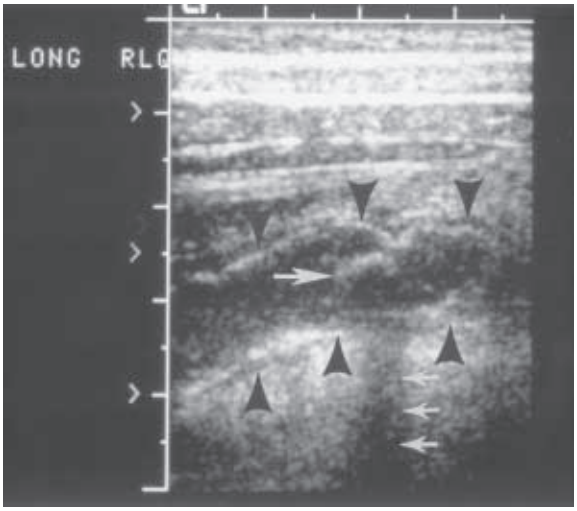


**Fig. 2** Appendicitis without perforation. On sonography, the appendix (arrowheads) is seen as a blind-ending tubular structure, approximately 1 cm in diameter. Note appendicolith (large arrow) with posterior acoustic shadowing (small arrows).

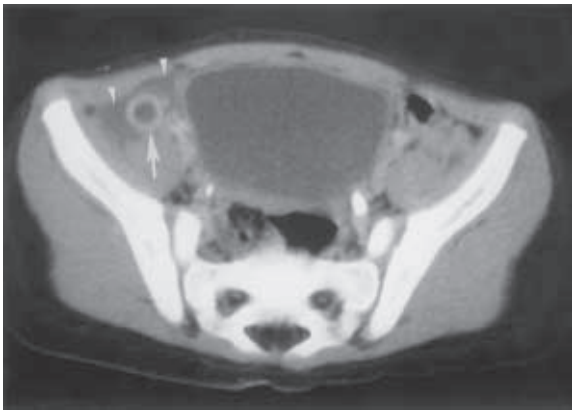

**Fig. 3** Appendicitis without perforation. On CT, the appendix (arrow) is enlarged with marked enhancement of its wall. Adjacent fluid is seen (arrowheads).

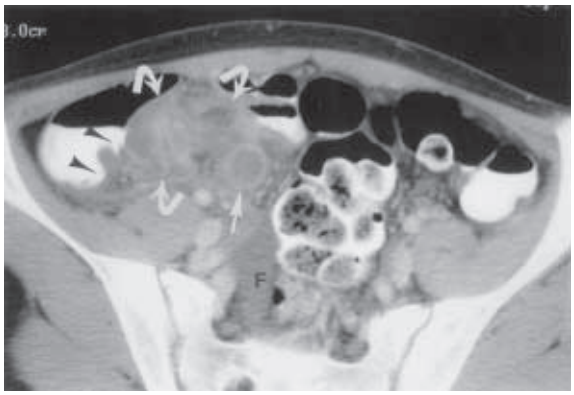


**Fig. 4** Appendicitis with perforation. Although this CT does not show specific findings for perforation, the degree of inflammatory changes (phlegmon, curved arrows) are substantial and suggest perforation. Arrow = enlarged appendix. Arrowheads = medial cecal wall thickening. F = fluid.

reported in the literature will be achieved at most institutions. The graded compression examination for appendicitis is a difficult examination to perform and can be time intensive. Technologists may be reluctant to compress adequately due to the discomfort it produces. Nevertheless, in experienced hands, sonography is an excellent test for appendicitis with a relatively high sensitivity and specificity[15]. In the ideal setting, all paediatric patients with suspected appendicitis would undergo sonography prior to CT[16,17]. Those with a positive sonogram would proceed to surgery and those with an equivocal sonogram or a continued high index of suspicion would proceed to CT. False positive ultrasound examinations are uncommon. Sonography is particularly helpful in the adolescent female patient, where pelvic pathology and appendicitis may present similarly.

The normal appendix is rarely seen on sonography. The abnormal appendix is a non-compressible tubular structure in the right lower quadrant, typically measuring 7-12 mm in diameter[15]. A non-compressible structure larger than this may represent inflamed bowel. An appendicolith is not uncommonly seen within the appendix (Fig. 2). Typically, the patient is point tender immediately over the appendix, aiding in localisation; however, when the appendix is not immediately found a systematic search of the right lower abdomen is warranted. A small amount of free fluid near the appendix is typically sympathetic and not necessarily indicative of perforation. With perforation, the appendix may become ill-defined and difficult to identify. A mass may represent abscess or phlegmon from perforation.

A variety of CT techniques are used to evaluate for appendicitis with varying methods of contrast administration. We believe that intravenous contrast and oral contrast preparation (ideally a full two to four hours) offer the best possible study in our particular patient population of children. Intravenous contrast is very helpful in children to identify the inflamed appendix, particularly with the normal paucity of intra-abdominal fat in children. Some centres perform CT for appendicitis with rectal contrast only[18,19]. There have been no published studies in children directly establishing the rectal contrast only CT technique to be as accurate as CT with oral and IV contrast. Moreover, accuracy for perforation has not been proven with the rectal contrast only CT technique. Identification of perforation is important as this often warrants a change in patient management from immediate surgery to conservative management with later surgery.

Regardless of CT technique, when appendicitis is suspected thinner sections (5 mm or thinner) should be obtained in the lower abdomen and upper pelvis. On CT, the inflamed appendix is identified as an enhancing tubular structure of approximately 1 cm diameter in the right lower quadrant (Fig. 3)[18,20]. Adjacent fluid, inflammatory edema of fat, fluid and bowel wall thickening are frequently present[18,20]. CT is more sensitive that plain films in identifying


**Fig. 5** Malrotation with volvulus. Upper GI shows a "corkscrew" course of the distal duodenum and proximal jejunum (arrows). Proximal jejunum (j) lies in the lower mid-abdomen rather than left upper quadrant, as is normal.

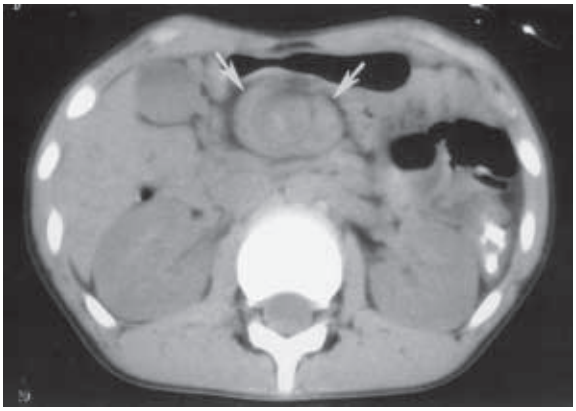

**Fig. 6** Malrotation with volvulus. Non-contrast CT shows a mass (arrows) in the mid-abdomen with whorled appearance due to volvulus.


**Fig. 7** Intussusception. On radiography, the intussusceptum (arrowheads) is outlined by gas within mid-transverse colon (the intussuscipiens). A paucity of bowel gas is seen in the right abdomen.

appendicoliths. Free fluid does not equate to perforation. Extraluminal gas, phlegmon and abscess suggest perforation (Fig. 4)[21]. Abscesses, if accessible, can be drained under CT or sonographic guidance[22].

**Malrotation with volvulus**

Children with malrotation and volvulus most commonly present in the first month of life with bilious vomiting; however, children may present throughout childhood. Although vomiting is always a prominent symptom with volvulus, the children also have abdominal pain which may be severe. In fact, abdominal pain is the major presenting symptom in children over one year of age with malrotation. With acute volvulus, pain is due to ischemia due to vascular compromise and bowel obstruction. Patients with malrotation may have intermittent volvulus or chronic partial obstruction due to Ladd's bands. Malrotation therefore is a diagnostic consideration in the child with chronic, recurrent abdominal pain.

If malrotation is suspected, an upper GI examination is the study of choice[23,24]. Normally, the duodenum takes a C-shaped course with the fourth portion extending leftward. In malrotation, the duodenal course is anomalous. With volvulus a corkscrew course of the distal duodenum and proximal jejunum is seen revolving around the mesenteric axis (Fig. 5) or an abrupt obstruction of the distal duodenum may be seen, often with a beaked appearance[23,24]. Patients with chronic malrotation may show less severe abnormality. Although cross-sectional imaging is not the preferred method of diagnosing malrotation, if children with abdominal pain are imaged the diagnosis will occasionally made. In the setting of volvulus a whorled mass of bowel loops and mesenteric vessels may be seen centrally in the abdomen (Fig. 6). Other signs of malrotation include inversion of the normal relationship of the superior mesenteric artery and vein (normally the vein is rightward, but with malrotation it is often leftward), malposition of bowel (i.e. all of the colon one side) and lack of identification of the duodenum crossing the midline[25].

**Intussusception**

In intussusception, proximal bowel (intussusceptum) telescopes within distal bowel (intussuscipiens). Pain is produced due to stretching of the bowel wall and due to ischemia. Most intussusceptions are ileocolic. Over 90% of childhood intussusceptions are idiopathic, perhaps related to relative hyperplasia of lymphoid follicles in the distal ileum. Underlying pathologic lead points are uncommon. Lymphoma, polyps, Meckel's diverticulum and hematoma are most common identified lead points in children. Most patients are

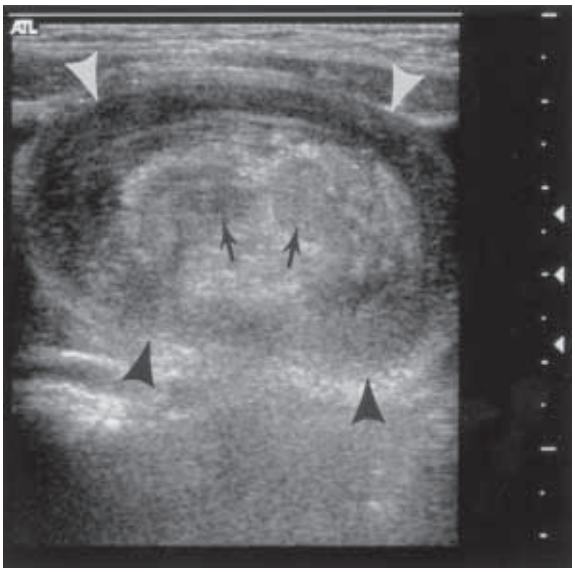

**Fig. 8** Intussusception. Sonography shows a large mass (arrowheads) with a thick hypoechoic periphery. The hyperechoic centre represents mesenteric fat with the intussusception, in this case including small lymph nodes (arrows).

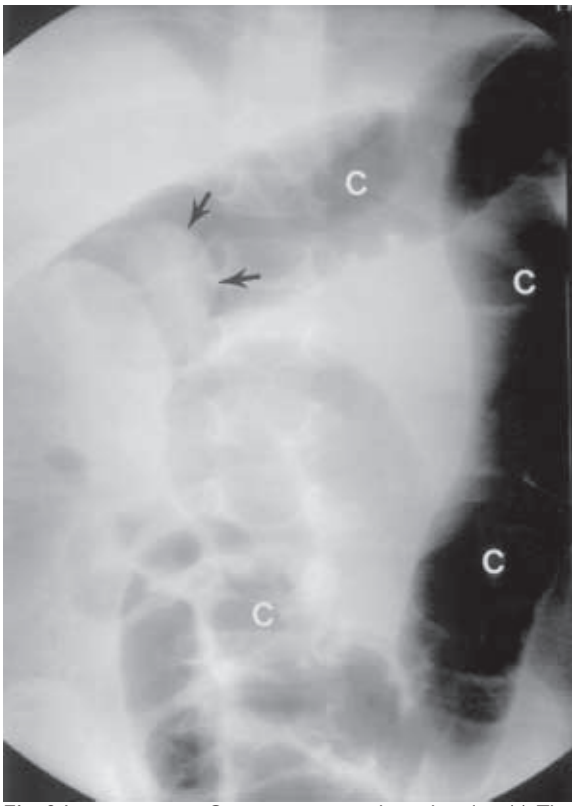


**Fig. 9** Intussusception. On air enema, gas distends colon (c). The intussusception is seen in the proximal transverse colon (arrows).

six months to four years of age; however, idiopathic intussusceptions can occur outside of the normal range. Patients with Henoch-Schönlein purpura (intramural hematoma) and cystic fibrosis (inspissated secretions, enlarged mucous glands) are at increased risk and can present outside of the normal age range. Common presenting signs and symptoms of intussusception include abdominal pain, vomiting, palpable mass and blood in stool. The pain may be intermittent. Some children present with lethargy. Intussusception is a radiologic/surgical emergency. If not treated expediently, there may be infarction of bowel, perforation, sepsis and even death.

Radiographs may be diagnostic of intussusception by showing a crescent of air around the intussusceptum in the colon (Fig. 7)[26]. More commonly, there may be a paucity of bowel gas in the right abdomen or a subhepatic mass effect. Frank evidence of small bowel obstruction may be seen, but is less common. Free air from perforation is extremely uncommon, but should be excluded with a positional view (upright or decubitus) as it is a contraindication to enema. A normal plain film makes the diagnosis of intussusception less likely, but does not exclude it, short of a complete gas filled cecum and terminal ileum.

Intussusception can be readily diagnosed by sonography in the hands of skilled sonographers familiar with the diagnosis and its findings[27,28]. On sonography, intussusception is seen as a large mass with a thick outer hyperechoic layer and a hyperechoic centre (Fig. 8). At our institution, sonography is used to identify patients with intussusception and has considerably decreased the number of negative enemas performed. At some institutions, intussusceptions are reduced by saline under sonographic guidance[29]. The advantage of this technique is the avoidance of ionising radiation.

The only absolute contraindications to enema are free intraperitoneal air or evidence of peritonitis or sepsis. Diagnostic and therapeutic enemas may be performed with air, water-soluble contrast material or barium[27,30,31]. With each medium, the incidence of perforation with enema is approximately 1% and the occurrence is more a manifestation of the underlying disease process rather than a failure of technique[32]. A potential complication of perforation with air enema is tension pneumoperitoneum. This may cause respiratory compromise and must be treated emergently with needle decompression. The therapeutic efficacy of air or liquid contrast is approximately equal at approximately 75%. Benefits of air are less peritoneal contamination in the unlikely event of perforation and cleanliness of the procedure[27,30,31]. Benefits of liquid contrast are improved diagnosis of alternative diagnoses (i.e. appendicitis, haematoma from Henoch-Schönlein purpura) and underlying lead points[27]. Barium is somewhat preferable to water soluble contrast material in this regard. I will tend to use air when the patient is in the typical age range and suspicion for intussusception is high. I will tend to use barium in patients outside of the typical age range in whom alternative diagnoses or lead points are more likely. Per protocol, we notify our paediatric surgeons prior to any enema performed for

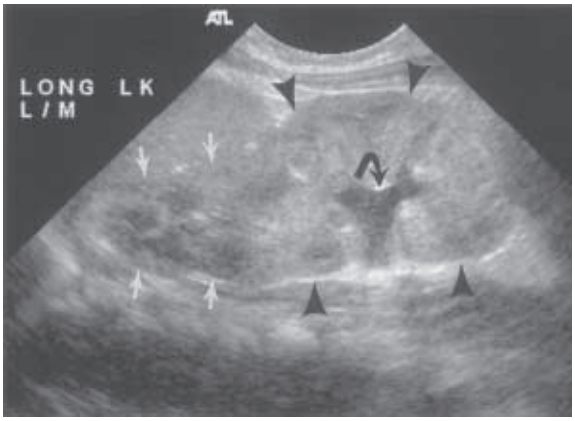


**Fig. 10** Pyelonephritis. The sonographic findings suggest an etiology. The upper pole of the kidney (arrows) appears normal. Parenchyma of the lower pole (arrowheads) is enlarged with slight dilatation of the collecting system (curved arrow). Findings are consistent with duplication with lower pole pyelonephritis, likely secondary to reflux.

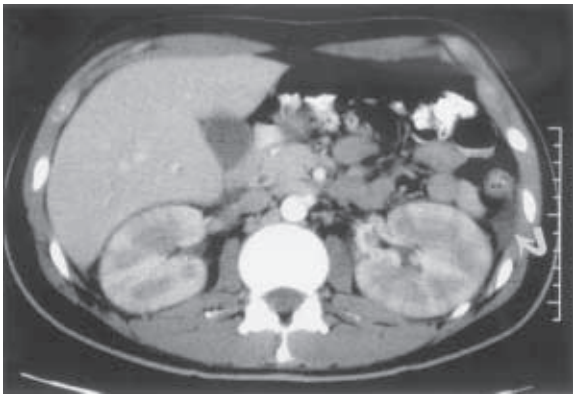

**Fig. 11** Pyelonephritis. CT shows streaky and wedge-like areas of decreased parenchyma enhancement. Some adjacent inflammatory oedema of fat is best seen anterolateral to left kidney (curved arrow).

possible intussusception, such that a patient can be treated expediently in the unlikely event of a perforation.

Air is insufflated such that a pressure of 100-120 mmHg is not exceeded during administration. Pressures may reach the 200-250 mm Hg with Valsalva. Liquid contrast is administered by gravity. With either contrast medium the intussusception is identified as an intraluminal mass within the colon (Fig. 9). This may be encountered as far distally as the rectum. Contrast is instilled to push the intussusception retrograde in the colon to ileum. A variable degree of resistance will be met. Some intussusceptions reduce immediately. Some reduce slowly, but eventually. Some partially reduce. Some do not reduce at all. If no reduction occurs, usually the colon is decompressed and one or two more attempts made. If some reduction occurs, but stops without incomplete reduction, the colon is allowed to decompress and is refilled in 10-15 minutes. Partial reduction will reduce venous obstruction and oedema and additional attempts may yield further or full reduction. In approximately 25% of patients, the intussusception cannot be fully reduced with an enema and requires an operative reduction.

**Pyelonephritis**

Pyelonephritis is usually a clinical diagnosis. Children present with fever and flank pain. There may be other symptoms of a urinary tract infection, including frequency, increased wetting or dysuria. The white blood cell count is usually elevated. A urinalysis usually confirms the diagnosis. Sonography is often performed in the setting of acute pyelonephritis[33,34]. Sonography serves both to look for an underlying anatomical anomaly predisposing the child to pyelonephritis and to look for complications such as pyonephrosis or renal abscess[35]. If the clinical diagnosis is clear, imaging may not be needed. Depending on the child's age and sex, work-up for reflux disease may be performed after treatment of the acute infection. The most common sonographic appearance of pyelonephritis is a normal study. The most common sonographic abnormality is renal enlargement, which may be difficult to appreciate without follow-up studies. Pyelonephritis may cause increased echogenicity of the parenchyma, which may be inhomogeneous and occasional produce mass-like enlargement of a portion of the kidney (Fig. 10). Frank abscesses developing from pyelonephritis are rarely seen. Although CT is not the preferred method of imaging childhood pyelonephritis, some patients will be diagnosed by CT. We have seen several children with pyelonephritis present with urinalysis and culture that were initially non-diagnostic. Such cases may represent pyelonephritis arising from haematogenous sources rather than ascending infections. Because of the unclear diagnosis and the presence of pain, fever and an elevated white blood cell count, CT was performed. On CT, pyelonephritis is seen as streaky inhomogeneity or wedges of decreased enhancement within the renal parenchyma (Fig. 11)[36,37]. Inflammatory oedema may be seen in the adjacent fat. In children, this appearance is relatively specific for pyelonephritis. Repeat urinalysis and culture may prove diagnostic.

**Renal calculi**

Although much less common than in adults, renal calculi do occur in children[38,39]. Particularly in young children, presentation with renal calculi may suggest the possibility of an underlying disorder in calcium metabolism or an anatomic abnormality[39]. Calculi in the kidneys themselves are asymptomatic; however, calculi passing through the ureter or impacting within the ureter may produce symptoms. The classic presentation of a ureteral calculus is acute flank pain and hematuria. Even in children, most patients present

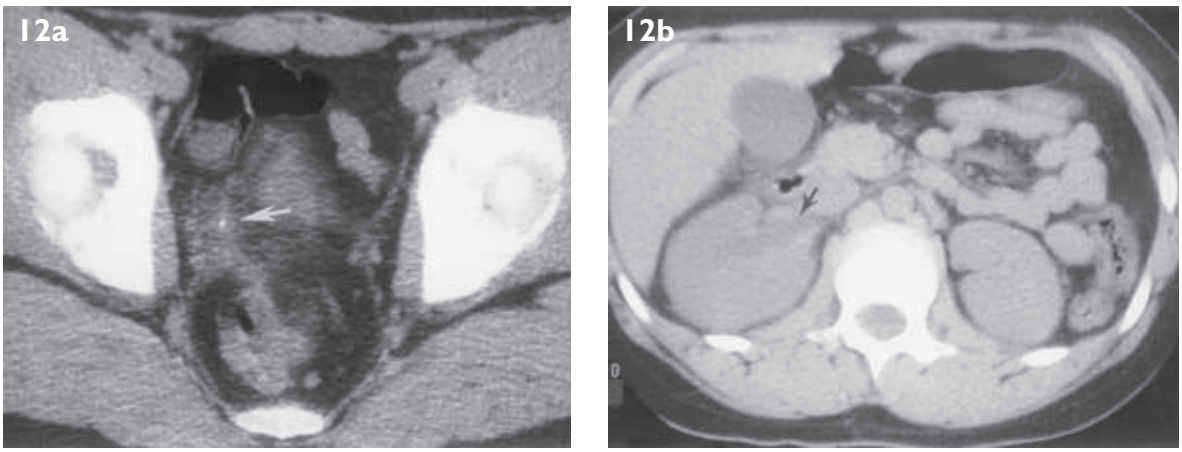


**Fig. 12** Ureteral calculus. A) CT shows a calculus in the distal right ureter (arrow). The ureteral wall appears swollen. B) A CT image at the level of the kidneys shows increased size, decreased attenuation and slight collecting system fullness (arrow) of the right kidney, indicative of obstruction. Slight edema is noted in fat adjacent to the renal hilus and margins of the right kidney are slightly indistinct.

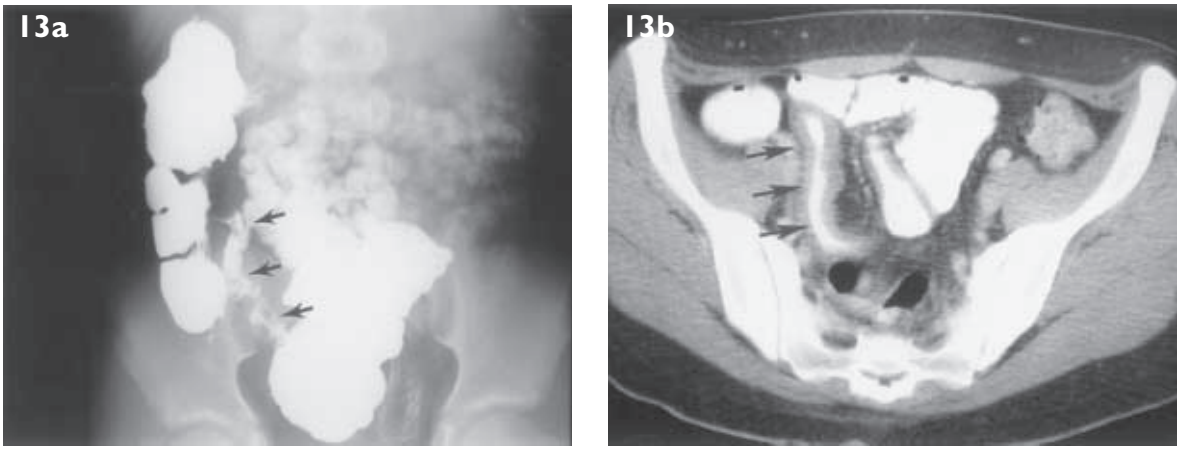


**Fig. 13** Crohn's disease. A) Small bowel follow-through with barium shows irregularity and nodularity of the terminal ileum (arrows). B) On CT, bowel wall thickening of the terminal ileum (arrows) is seen.

with these symptoms. Imaging may not be necessary. Unfortunately, flank pain and haematuria is not entirely specific for ureteral calculus and some children with calculus may not present in a classic manner[38]. Imaging may therefore be performed. In past times, radiographs, conventional tomography and intravenous pyelography (IVP, excretory urography) were used to delineate renal and ureteral calculi. Disadvantages of IVP are the need to administer intravenous contrast and the delay in opacification of an obstructed system. Sonography is often performed in patients with calculus disease. Calculi within the kidneys are readily seen and mild collecting system dilatation may be noted with acute obstruction; however, ureteral calculi are rarely delineated except for an occasional calculus at the uretero-vesicular junction. More recently, non-contrast thin section CT has been introduced as a means to assess for urinary tract calculi[38,40,41]. The examination is performed without contrast. Calculi are identified as opaque foci in the kidneys or ureter. Secondary signs, including periureteric and perinephric stranding, collecting system dilatation and decreased attenuation of the kidney, vary depending on the degree and chronicity of the obstruction (Fig. 12)[38,41]. CT is an effective modality for confirming a ureteral calculus in a child; however, it is best utilised in conjunction with careful clinical examination which selects patients in whom a calculus is suspected but unproven by other means[38]. If other pathology besides a ureteral calculus is suspected, the non-contrast thin section CT is not likely the optimal imaging modality.

**Chronic, recurrent abdominal pain**

Chronic, recurrent abdominal pain is also a common paediatric diagnostic dilemma. In a study of 1,000 school children, Apley found that 11% had complaints of some form of recurrent or chronic abdominal pain[7]. Fleisher and Hyman note that "about 25% of children referred to paediatric gastroenterologists come with a chief complaint of recurrent abdominal pain of obscure origin[8]". The great majority of paediatric patients with chronic, recurrent abdominal pain do not have an identifiable organic etiology for their pain[7,8,42]. A variety of labels have been used to name or

describe the pain incurred by these children including functional abdominal pain, irritable bowel syndrome, recurrent abdominal pain syndrome and abdominal migraine. Psychological factors probably play a role in many children; however, the exact role of environmental stresses and the reality of the pain are often difficult to firmly grasp. It must be remembered that patients with the symptom of recurrent abdominal pain may present with acute disorders. Pain which differs significantly from the chronic or recurrent pain in degree, quality or location should not be discounted and may herald an unrelated acute disease process or perhaps represent a new manifestation of the yet unidentified process causing chronic symptoms.

As with the patient with acute pain, a careful history and physical examination is paramount in guiding the work-up of a child with chronic or recurrent abdominal pain. Clinical features suggestive of an organic disease include onset of pain before four years of age or after 13 years of age, a positive family history of gastrointestinal disease, weight loss, growth failure, fever, anaemia, genitourinary symptoms, abnormal urinalysis or blood chemistries and pain localised away from the midline[43]. Conversely, features suggestive of non-organic etiology include onset of pain between the ages of four and 13 years, normal appetite, normal weight, normal growth and development, normal urinalysis and blood chemistries, periumbilical or epigastric location of pain and pain awakening the child at night[43]. A number of intra-abdominal disorders may present with chronic or recurrent abdominal pain. Inflammatory bowel disease is perhaps the most common organic process diagnosed in these children and will be briefly discussed. Malrotation may occasionally present with chronic, recurrent abdominal pain. In less well-developed portions of the world, parasitic diseases account for a substantial portion of children presenting the chronic, recurrent abdominal pain.

**Inflammatory bowel disease (Crohn's disease)**

Crohn's disease is probably the most common identified organic cause of chronic, recurrent abdominal pain in older children. As many as 25% of patients with Crohn's disease develop symptoms beginning in childhood. Crohn's disease can present at any age, but is rare under six years of age and increases in incidence throughout childhood. Although the presentation may be with an acute episode, chronic, recurrent pain is a frequent complaint at the time of initial diagnosis. Other presenting symptoms include diarrhoea, bloody stools, fever, weight loss and failure to thrive. Patients may present with small bowel obstruction or perianal disease (fistulae, abscesses). If presenting acutely, Crohn's disease may be confused for appendicitis. In fact, Crohn's disease may cause appendicitis.

As sonography and CT are commonly performed to evaluate children with acute abdominal pain, patients are often first diagnosed with Crohn's disease with these modalities. On sonography, marked bowel wall thickening is seen[44]. Doppler interrogation shows hyperaemia. CT is an excellent modality for the evaluation and follow-up of patients with Crohn's disease[45]. Bowel wall thickening is well seen and the extent of involved bowel is delineated (Fig. 13). Abscesses are well seen. Fistulae are less well seen, but may occasionally be identified or at least suggested. The most definitive radiologic examination for Crohn's disease of the small bowel is a barium study, usually in the form of a small-bowel follow through[46,47]. Findings of active Crohn's disease are nodularity, ulceration and narrowing of the terminal ileum (Fig. 13). Skip lesions may be seen more proximally in the small bowel. Fistulae are better delineated by barium studies than CT. Often, small bowel follow-through is performed in conjunction with upper and lower endoscopy for evaluation of the entire gastrointestinal tract.

## CONCLUSION

Acute and chronic, recurrent abdominal pain are common symptoms in children presenting for medical evaluation. A substantial portion of children with acute abdominal pain and a great majority of those with chronic, recurrent abdominal pain will not have an identifiable organic cause for the pain, even on extensive work-up. A careful history and physical examination is extremely valuable in guiding further work-up of a child with pain, particularly in selecting which patients warrant imaging and which imaging test to utilise. Imaging plays an important role both by making diagnoses in patients with an organic etiology for pain and by excluding potential diagnoses in patients without organic disease. Although imaging protocols are often designed to address a specific potential diagnosis, attention to the individual patient assures the most efficient utilisation of radiologic resources. Good communication between the clinical physician and the radiologist is very helpful in deciding how to image and tailoring the selected studies to best address the clinical differential diagnoses.

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