

**The use of abdominal imaging studies in children visiting emergency department was variable and unsystematic**

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Abbreviations: CRP, C-reactive protein; CT, computed tomography; ED, emergency department; MRI, magnetic resonance imaging; ultrasound

## **Abstract**

**Aim:** As imaging is used for various reasons in children with acute gastrointestinal complaints, we evaluated the indications and diagnostic yield of abdominal imaging, particularly ultrasound at emergency department (ED).

**Methods:** Indications and imaging reports of consecutive children who had undergone abdominal imaging in general, surgical and paediatric EDs in the Tampere University Hospital, Finland in 2015 were collected. Symptoms, clinical findings, imaging indications and findings were categorised and further analysed.

**Results:** Altogether 394 imaging studies, 310 ultrasounds, 72 X-rays and 12 computed tomographies (CT), for 348 children (55% boys) aged 0-16.9 years, median 7.1 years, were performed. The most common indications for ultrasound were suspected appendicitis or infection (36%) and explanation for symptoms (32%), for X-ray suspected foreign body (39%) and obstruction (39%) and for CT trauma (50%). The cause of the symptoms or a clinically significant finding was established in 23% of ultrasounds, varying from 0% to 50% depending on the indication, symptoms and age.

**Conclusions:** There was wide variation in the indications and yield of abdominal imaging. The clinical benefits, particularly those of US, were often questionable, even leading to delayed diagnosis and complications. More uniform imaging guidelines are needed in the paediatric ED.

**Keywords:** Abdominal pain; Children; Emergency department; Ultrasound

**Key Notes:** Imaging at emergency department in paediatric abdominal complaints is used for various, sometimes even questionable indications. Therefore, we evaluated the imaging studies performed during a one year time period and found the diagnostic yield, particularly that of ultrasound to be often debatable, even leading to diagnostic delay. Creating uniform guidelines for paediatric abdominal imaging may sharpen diagnostics, reduce patients' anxiety and save resources.

## INTRODUCTION

Abdominal complaints are a common reason for paediatric emergency department (ED) visits, and various imaging modalities are often used to supplement clinical and laboratory investigations. The decision on the use and the choice of a suitable modality are made by a physician in collaboration with a radiologist. A variety of aetiologies, such as infections, surgical conditions and malignancies, can cause acute abdominal pain in children and the diagnostic performance of the various imaging modalities in these may vary. Ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) have gradually, but not completely, replaced abdominal X-ray as a first-line modality (1,2). A major disadvantage of plain X-ray and especially CT is exposure to ionizing radiation, which has led to increasing use of non-radiating ultrasound and MRI as primary paediatric imaging modalities (3,4).

The drawbacks of MRI include costs, limited availability and the requirement for general anaesthesia in toddlers (4,5). By contrast, ultrasound is a widely available and cheaper means of investigation that can also give dynamic information about bowel motility and blood flow (3,5,6). These advantages may tempt the treating physician to use ultrasound with a low threshold. However, the diagnostic performance of ultrasound is variable and affected by the expertise of the radiologist and patient-related factors such as restlessness, obesity and bowel gas (3,4,7). Although it is fairly painless, having an ultrasound may cause infants anxiety and it can also be very time consuming. Moreover, a radiologist performs the study hands-on and retrospective evaluation of the findings is difficult. The inferior accuracy and subjectivity of ultrasound predispose to false positive or negative findings that could actually be misleading (8).

In view of this the optimal selection of abdominal imaging examinations in paediatric ED settings is essential. Research so far has focused mainly on specific disease entities and there is a lack of systematic studies. We therefore aimed to further ascertain the indications and diagnostic yield of acute abdominal imaging, particularly ultrasound, in children.

## **MATERIALS AND METHODS**

### **Patients and study design**

The study was conducted at Tampere University Hospital. The hospital is both a tertiary referral centre and a local emergency care unit with a catchment area of approximately one million inhabitants, including 120,000 children.

Consecutive children aged 0 – 16.9 years who underwent ultrasound examination, plain X-ray or CT of the abdomen on their general, paediatric and surgical ED visits in 2015 were identified and included in the present study. No MRIs were performed in the ED during the study period. The electronic medical records of these children were reviewed and data recorded as described in detail below. Testicular and gynaecological imaging studies were not included.

### **Study data**

The medical data collected included demographics, clinical and laboratory findings, indications for and possible findings of the radiological investigations and possible final diagnoses and treatments. Presenting gastrointestinal symptoms were categorised as follows: nausea or vomiting, anorexia, diarrhoea, constipation, dysphagia, bloating and bloody diarrhoea. Possible elevated body temperature measured at the ED or reported by the parents were recorded, likewise additional extraintestinal symptoms. The laboratory findings collected were C-reactive protein (CRP) (Reference value <10 g/l) and white blood cell count ( $4.5\text{--}21.0 \times 10^9$  cells/L depending on age) (9).

The main information on indication for and modality of the abdominal imaging was gathered from the imaging referrals and their findings from the radiology reports. The cases were divided into three groups based on the use of ultrasound, CT or X-ray imaging. Each group was then reviewed separately, and the ultrasound studies were then analysed in more detail.

The findings of the imaging studies were determined to be clinically significant if they had an impact on the final diagnosis or treatment. The significance was evaluated by the authors (K.K, S.P) based on all medical information available.

### **Statistics**

The results are shown as number of patients or percentages in tables and figures. The results were analysed both for the entire group and separately for boys and girls and for children under the age of three years and the age of three years and over. If several imaging examinations had been done for the same child those done during the study period, these were considered as separate cases. The possible effect of the imaging unit, general, paediatric and surgical ED, was also assessed. No statistical analyses were performed in this descriptive study.

### **Ethical considerations**

The study was approved by the Tampere University Science Centre (approval code R16579). Approval of the Ethics Committee or participants' informed consent was not required since this was a registry-based study and the patients were not contacted. All identifiable individual information was coded and data were analysed anonymously.

## **RESULTS**

Altogether 394 imaging examinations were performed for 348 children (median age 7.1 years, range 12 days to 16.9 years; 55% boys), including 310 (79%) abdominal ultrasounds, 72 (18%) plain X-rays and 12 (3%) CTs (Figure 1). Of these, 108 (27%) were performed for children under the age of three years, only one of which was CT (Table 1). There were no major gender differences in those under the age of three years, while in older children age all imaging and particularly CT studies were more common in boys (Table 1).

### **Abdominal X-rays and CT**

The most common indications for X-rays were suspected foreign body ingestion (39%) and coprostasis or obstruction (39%), the other reasons each representing  $\leq 5\%$  of the studies. Of all X-

ray studies, the imaging revealed the cause of symptoms in 50% of cases, the percentage being highest (68%) when a foreign body was suspected. Abdominal trauma was the indication for CT in six (50%) out of the 12 cases, while the remaining six examinations were all done for separate indications. CT scans were only done with serious indications and the findings of all 12 cases, both positive and negative, were considered clinically significant.

### **Abdominal ultrasound**

Abdominal ultrasound was performed on 84 (27%) children under the age of three years and 226 (73%) children aged three years and over. The most common indication for US in the whole cohort was suspected appendicitis or intra-abdominal abscess, followed by a general question “any explanation for symptoms?”, infection focus, assessment of abdominal organs and trauma. However, in children aged under three years the most frequent indication was suspicion of pyloric stenosis which were all carried out on subjects under 0.9 years of age, suspected appendicitis being the indication in only three cases. All but one assessment of abdominal organs and all examinations due to suspected malignancy and pyloric stenosis were done in the paediatric ED, whereas the vast majority involving suspected appendicitis and trauma were performed in the general or surgical ED. Other indications were more evenly distributed (data not shown).

Clinically significant findings were detected in 74 (24%) ultrasound examinations. This percentage varied substantially depending on the age of the patients and on the condition suspected (Figure 2). In children aged under three years, suspicion of malignancy, assessment of abdominal organs and other indication resulted in the highest diagnostic yield of 32-50% (Figure 2a). No ultrasound abnormalities were reported in children with trauma, unclear infection focus and suspicion of appendicitis (Figure 2a). In children aged three years and over, the percentage of significant ultrasound findings varied from 11% (explanation for symptoms) to 33% (suspicion of appendicitis or abscess), excluding cases with coprostasis, none of which had ultrasound abnormalities (Figure 2b). When a benign or malignant solid tumour was suspected, it was confirmed in 67% of the patients also by imaging.

In the detailed analysis of the association between gastrointestinal or other symptoms and clinical signs and ultrasound findings, the percentage of significant findings varied from 0% to 50% in the whole group (Table 2). These figures were mostly comparable between children under and over the age of three years, excluding the rare cases of constipation, bloating and anorexia. Signs suggestive of infection, including elevated body temperature, leucocytosis and increased CRP had fairly high predictive value for abnormal ultrasound findings in both age groups (Table 2).

In total, 71 of the study children underwent surgical or endoscopic procedures during the same hospital visit as the imaging study was performed. Appendectomy was by far the most common surgical procedure, performed on 43 study children, of whom 34 (79%) had confirmed appendicitis. In altogether 80 subjects the main indication for ultrasound study was suspicion of appendicitis. Of these, positive ultrasound findings were reported in 22 children before the emergency appendectomy, and 19 of these were operated on and appendicitis found in 18. Negative or inconclusive finding in ultrasound was reported for 58 children, but 14 of these were operated on for clinical reasons and appendicitis was found in eight. Of those children undergoing ultrasound examinations with other indications a further 12 were given appendicitis as their final diagnosis. Of these, one appendicitis was confirmed with ultrasound, four had a suspected abscess and seven had negative or inconclusive ultrasound examination. Altogether four children had a negative or inconclusive ultrasound and ended up having a perforated appendix.

## **DISCUSSION**

The main finding of this study was that there is wide variation in the indications and diagnostic yield of paediatric abdominal imaging studies in ED, depending on patient's age and clinical presentation. Furthermore, in many cases the use of ultrasound examinations in particular seems to be poorly justified.

Somewhat alarmingly, our results suggest that up to a third of abdominal ultrasound examinations in ED settings were requested without a clear working diagnosis. Moreover, the cause of

symptoms was established or confirmed in only approximately a quarter of the examinations. Of course, the acceptable percentage is debatable and depends on many issues, such as severity of the suspected condition, but our results in any case suggest a clear overuse of resources. When the physician was inclined to make a specific diagnosis the likelihood of a positive ultrasound finding was markedly higher than when the imaging was based on a vague indication such as possible explanation for symptoms. We must, however, emphasize that it was often difficult to retrospectively assess the impact of ultrasound on the treatment decision. Even if clinical suspicion and elevated CRP and WBC count increase the probability of ultrasound findings, it seems that no single symptom can reliably predict whether the cause can be found. Altogether, although in some of the cases ultrasound can provide essential information to confirm or exclude the prospective diagnosis, the benefit to the diagnostics of acute abdominal complaints is often negligible. The previously described vague indications seemed in particular to be used as an indication for ultrasound often only to placate the parents or to be “on the safe side”.

Although perhaps understandable in hectic clinical settings, such an approach is problematic. Excessive imaging consumes resources and increases costs and, even if considered safe, ultrasound may still cause anxiety and pain. Furthermore, as also seen here, it may sometimes delay the diagnosis or even give misleading information (8). Taken together, as with other diagnostic approaches, the urgency and pros and cons of imaging should be carefully considered beforehand, taking into account the clinical scenario and anticipated added value (11,12). This issue is further complicated by the fact that there are usually numerous radiologists doing on-call duties in larger hospitals and the number of paediatric ultrasound studies performed by each physician may be relatively low, which may reduce the consistency of the findings and predispose to over- or underdiagnostics.

An illustrative example of a usually poor indication for ultrasound examination is coprostasis, which is usually clinically obvious and hampers the investigation due to impaired visibility. Similarly, even if CT and abdominal X-ray were in general better targeted than ultrasound, the latter was again frequently used in subjects with coprostasis, against the current scientific evidence (13). Another

example of inconsistent and sometimes poorly justified indication for ultrasound is suspicion of pyloric stenosis. This is the most common indication for abdominal surgery in infants and with this condition the sensitivity and specificity of ultrasound have been respectively as good as 97% and 100% if appropriately targeted (14,15). However, we found this indication used for children almost as old as one year, in whom this condition is unlikely (16).

Appendicitis and its complications are the most common causes for abdominal surgery on children over the age of five years (4,17) and thus are of major importance in ED settings. The diagnosis of appendicitis in high-risk patients can generally be made based on clinical symptoms and laboratory findings while imaging is more important in intermediate risk children, in whom nonionizing modalities are preferred (18). In obvious appendicitis cases ultrasound is not needed at all. A meta-analysis of 19 studies showed ultrasound to be almost comparable with CT and MRI (4). In a study from UK, sensitivity of ultrasound was as high as 83% and specificity 97%, but the setting was different and pre-test probability higher than in our study (19). In a study from Italy sensitivity was only 34%, which is reminiscent of our unselected heterogeneous patient material (20). Another study suggests that observation or discharge are safe measures when clinical probability is low. In these cases ultrasound may even yield false positives and this can affect the decision-making process (21). We also found four patients who had false negative ultrasound and subsequently perforated appendix. Although we cannot confirm differing outcomes without imaging, it is important not to rely excessively on negative ultrasound findings in high-probability subjects (8).

It must, however, be acknowledged that ultrasound also has many benefits as a diagnostic tool. For example, according to a recent study, ultrasound alone can exclude or confirm 97% of abdominal surgical conditions in children under 10 years (21). Another study found ultrasound to be diagnostic in 48% of paediatric patients with acute abdominal pain (3). As mentioned, different clinical scenarios and patient selection may yield somewhat different results, but it is evident that ultrasound can be very helpful in children presenting with acute abdominal complaints as long as its use is more systematic and evidence-based.

The main strengths of the present study were the large cohorts of consecutive children investigated with abdominal imaging in general, surgical and paediatric EDs. We were also able to obtain comprehensive clinical, laboratory and imaging data on each patient. Furthermore, the probability of selection bias is low since all children within the preselected study timeframe were included. The main limitation was the retrospective data collection of patient records, which hampered evaluation of the indications and clinical significance of the imaging studies and increased the risk of classification bias.

## **CONCLUSION**

Abdominal imaging can be an efficient diagnostic tool in the paediatric ED. Nevertheless, we found a wide variation and unsystematic use among the indications of ultrasound examinations in particular, and in many cases the benefits of the procedure were questionable. Besides the risk of delayed diagnosis or even misleading findings, excessive imaging may lead to increased anxiety and costs. Physicians should therefore be cautious in the use of imaging with vague indications or just for reassurance. Again, cooperation between the referring physician and the radiologist is helpful in deciding which imaging modality is indicated by the frame of question and clinical picture. X-ray rounds and meetings, especially targeted to junior doctors are also encouraged to further develop this dialogue. Altogether, there is a clear need for more uniform and evidence-based guidelines for the use of imaging in children with acute abdominal complaints.

## **FINANCE**

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## **CONFLICTS OF INTEREST**

The authors have no conflicts of interest to declare.

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**Table 1.** Distribution of the abdominal imaging studies based on age and gender in 394 children investigated in emergency department

Age (median)		Boys		Girls		Total
		n	%	n	%	n
0-16.9 (7.8) years	All imaging	219	55.6	175	44.4	394
	Ultrasound	172	55.5	138	44.5	310
	Plain X-ray	38	52.8	34	47.2	72
	Computed tomography	9	75.0	3	25.0	12
<3 (1.0) years	All imaging	54	50.0	54	50.0	108
	Ultrasound (n)	41	48.8	43	51.2	84
	Plain X-ray	13	56.5	10	43.5	23
	Computed tomography	0	0.0	1	100.0	1
3.0-16.9 (10.2) years	All imaging	165	57.7	121	42.3	286
	US	131	58.0	95	42.0	226
	Plain X-ray	25	51.0	24	49.0	49
	Computed tomography	9	81.8	2	18.2	11

Table 2. Distribution of symptoms and laboratory findings in all children and percentage of cases where the cause of symptoms was found with US. Tampere University Hospital ED; 2015.

	All, n=310			<3.0 years, n=84			3-16.9 years, n=226		
	Cases	Finding		Cases	Finding		Cases	Finding	
		n	%		n	%		n	%
<i>Symptom</i>									
Nausea/vomiting	132	32	24.2	45	11	24.4	87	21	24.1
Constipation	20	10	50.0	4	3	75.0	16	7	43.8
Diarrhoea	42	9	21.4	14	3	21.4	28	6	21.4
Bloody diarrhoea	8	0	0	5	0	0	3	0	0
Flatulence/bloating	15	5	33.3	7	3	42.9	8	2	25.0
Anorexia	76	13	17.1	21	2	9.5	55	11	20.0
Fever <sup>1</sup>	130	40	30.8	30	10	33.3	100	30	30.0
<i>Laboratory finding</i>									
Leukocytosis	63	27	42.9	11	4	36.4	52	23	44.2
CRP >10	135	48	35.6	29	9	31.0	106	39	36.8

<sup>1</sup>At home or hospital emergency department  
CRP, C-reactive protein

## Figure legends

Figure 1. Abdominal imaging studies included in the present study. CT, Computed tomography

Figure 2. Percentage of abdominal ultrasound imaging studies in which the cause of symptoms was detected in children under (a) three years and over (b) three years of age. 'Other' includes postoperative complications, exacerbation of chronic or previously diagnosed diseases such as inflammatory bowel disease or liver cyst.