PAEDIATRIC SURGERY

Ann R Coll Surg Engl 2011; **93:** 405–409
doi 10.1308/003588411X582672

Ultrasonography aids decision-making in children with abdominal pain

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ABSTRACT

INTRODUCTION Although regular clinical assessment of the acute abdomen is considered best practice, ultrasonography confirming the presence of appendicitis will add to the decision-making process. The aim of this study was to assess the accuracy of ultrasonography and its usefulness in diagnosing acute appendicitis in a regional paediatric surgical institution.

METHODS Retrospectively and in this order, radiology, theatre and histopathology databases were searched for patients who had presented with acute abdominal pain, patients who had undergone an appendicectomy and all appendix specimens over a two-year period. The databases were cross-referenced against each other.

RESULTS A total of 273 non-incidental appendicectomies were performed over the study period. The negative appendicectomy rate was 16.5% and the perforation rate 23.7%. Thirty-nine per cent of children undergoing an appendicectomy had at least one pre-operative ultrasound scan. Ultrasonography as a diagnostic tool for acute appendicitis in children had a sensitivity of 83.3%, a specificity of 97.4 %, a positive predictive value of 92.1% and a negative predictive value of 94.0%.

CONCLUSIONS Ultrasonography is used liberally to aid in the decision making process of equivocal and complicated cases of acute appendicitis and it achieves good measures of accuracy. As a diagnostic tool it is unique in its ability to positively predict as well as exclude. A high negative predictive value suggests that more patients could be managed on an outpatient basis following a negative scan.

KEYWORDS

Appendicitis – Ultrasonography – Child – Abdomen, acute

Accepted 31 March 2011

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The prompt diagnosis of appendicitis in children is made difficult not only by the challenging nature of a paediatric history and examination but also by the protean behaviour of the symptoms. We know that almost half of children will present with some atypical features of appendicitis and that one quarter will have primarily atypical features.[1] However, delay in diagnosis correlates with an increased risk of perforation.[2] In the US this diagnostic challenge has resulted in appendicitis being the second most common diagnosis involved in paediatric emergency medicine malpractice claims, the most common being meningitis. Diagnostic error accounted for 39% of these claims.[3]

While we are still taught to consider appendicitis as a clinical diagnosis, over the past two decades ultrasonography and computed tomography (CT) have emerged as tools to assist in this diagnostic challenge. There has been much debate within the literature over which imaging modality is superior.[4–6] Graded compression sonography offers a rapid, non-invasive and inexpensive means of imaging an inflamed appendix. The examination can be performed at the site of greatest tenderness, enabling correlation of imaging findings with patient symptoms, and in this way it is dynamic.[7]

For these reasons, within the UK, it has become the primary imaging modality in the diagnosis of acute appendicitis. Nevertheless, its role in the management of a child with acute abdominal pain varies between different institutions and its use extends beyond specialist paediatric centres. Given the operator-dependent nature of this imaging modality, it is essential that we audit departmental accuracy. However, few institutions have published such figures in the UK literature.[8–10] This study aims to demonstrate the value of ultrasonography as a tool in the decision-making process by providing the fundamental rates of negative appendicectomy and perforation for comparison and measures of the accuracy of ultrasonography for this regional unit.

Methods

This was a cross-sectional retrospective study using three routine hospital databases. A search was performed on the theatre information database for appendicectomies and these were then matched with corresponding pathological reports on appendix specimens. The radiology information system returned a database of reports on abdominal ultra-

Table 1 Positive diagnostic criteria used to analyse ultrasonography reports

Visualised	
Definitive statement	
Required details	• non-compressible[12,25] • threshold diameter >6mm[13,25] (blind-ending tubular structure and at the point of maximum discomfort)[12] • definite periappendiceal abscess[12,26]
Features suggestive of appendicitis	• appendicolith, faecalith, echogenic foci within the lumen with clean acoustic shadowing[12,25–27] • echogenic submucosa with a fluid-filled lumen[12] • circumferential hyperaemia using colour Doppler sonography[25,26] • echogenic perienteric fat and omental wrapping[25] • sympathetic thickening of adjacent ileum, caecum, ascending colon[25] • fluid collection[26]

Table 2 Outcomes of the appendicectomies in relation to the pathology report

	n	Normal appendix	Negative appendicectomy rate	Inflamed appendix	Positive appendicectomy rate	Perforated appendix	Number with prior ultrasonography
Boys	150	19	12.7%	131	87.3%	29 (22.1%)	39 (26.0%)
Girls	123	26	21.1%	97	78.9%	25 (25.8%)	68 (55.3%)
Total	**273**	**45**	**16.5%**	**228**	**83.5%**	**54 (23.7%)**	**107 (39.2%)**

Table 3 Negative histology and perforation rates following appendicectomies

	n	Positive histology
Appendicectomy with ultrasonography	107	22 (19.6%)
Appendicectomy without ultrasonography	166	23 (13.9%)

sonography. Once the two sets of reports had been analysed, the three databases were cross-referenced against each other.

The study reviewed appendicectomies and requests for abdominal ultrasonography over a two-year period starting in May 2004. Infants and children up to the age of 16 years were included. Incidental procedures (eg one performed during a Ladd procedure) and those without a corresponding pathology report were excluded, as were pathology reports describing other histological diagnoses (eg lymphoid hyperplasia, vascular congestion or intussusception). Interval procedures, performed some time after the acute episode, were included in the results to gain a true representation of the perforation rate within the institution.

As the clinical history accompanying the request for ultrasonography of the abdomen is not coded, reports that stated 'abdominal pain' (including right iliac fossa and lower abdominal pain), 'query appendicitis' or 'right iliac fossa mass' were viewed.

To confirm the diagnosis of acute appendicitis an acute inflammatory infiltrate into the muscularis mucosa had to be present. Features suggestive of previous appendicitis[11] were noted so as to include interval appendicectomies in the positive result. Appendices were defined as perforated on the basis of histological demonstration, not by operative findings.

The criteria for the sonographic diagnosis are defined by Puylaert[12] and Jeffrey *et al.*[13] The reports were recognised as being positive for appendicitis if either a definite statement was made or if the required details for the diagnosis were stated (eg a blind-ending, non-compressible tubular structure measuring >6mm in diameter at the point of maximum discomfort or the presence of a definite periappendiceal abscess). Features suggestive of appendicitis were also recorded. Table 1 displays the full criteria used. All other reports were listed as negative. Where the required details were lacking, a senior paediatric radiologist viewed the reports. These were then only recorded as positive if features suggestive of appendicitis were stated such that the impression of the report read of acute appendicitis. Equivocal reports were considered negative.

The serial use of ultrasonography within a single episode of pain was not analysed. Instead we considered ultrasonography to be positive if any of the examinations were reported as such. Scans greater than a month apart were considered a separate episode of pain after ensuring they were not part of an interval procedure.

Table 4 Outcome of all patients who underwent ultrasonography as an investigation for appendicitis

	Patient episodes	Appendicectomy performed		No operation performed
		Evidence of appendicitis in pathology specimen	No evidence of appendicitis in pathology specimen	
Positive ultrasonography	76	70 (92.1%)	2 (2.6%)	4 (5.3%)
Negative ultrasonography	235*	14 (6.0%)	21 (8.9%)	200 (85.1%)

Results

A total of 273 non-incidental appendicectomies were performed over the 2-year period. Of these, 258 were simple open or laparoscopic procedures and 15 were interval. Thirteen cases from the theatre information database were excluded from analysis as eleven had no corresponding pathology report and an alternative pathological diagnosis was found in two others. The mean age of the children undergoing an appendicectomy was 11 years and ages ranged from 0 to 15 years.

When considering the pathological outcome of the operation (Table 2), the overall positive appendicectomy rate was 83.5 %, the negative appendicectomy rate was 16.5% and 23.7% of appendix specimens removed were perforated. More boys had an appendicectomy during the study period and they had a higher likelihood of having an inflamed appendix removed (87.3%). Girls had a higher negative appendicectomy rate (21.1%). During the study period, ultrasonography was performed on 311 children with abdominal pain and equivocal cases of appendicitis. Following the scan, 107 children went on to have an appendicectomy. Preoperative ultrasonography was therefore used as a diagnostic tool in 39.2% of children before their appendicectomy (26.0% of boys and 55.3% of girls).

If a direct comparison is made between children who received pre-operative ultrasonography and those who did not (Table 3), the imaged group actually had a higher negative appendicectomy rate (19.6% vs 13.9%) and a much higher perforation rate (34.1% vs 17.5%).

The outcomes of all children who underwent ultrasonography for abdominal pain and equivocal cases of appendicitis are reported in Table 4. The outcome was defined by whether they were operated on or not and, if so, the pathological report of the appendix specimen. These outcomes were used to calculate the overall figures of accuracy seen in Table 5. A positive ultrasonography was considered a true positive if the diagnosis of appendicitis was confirmed by histology and a false positive if the specimen showed no features of inflammation or the child did not go to theatre. By the same token, a negative ultrasonography was considered a true negative if the specimen showed no features of inflammation or if the child did not go to theatre and a false negative if histology confirmed appendicitis.

Ultrasonography as a tool in the diagnosis of acute appendicitis in children had a sensitivity of 83.3%, a specificity of 97.4%, a positive predictive value of 92.1% and a negative predictive value of 94.0% (Table 5).

Discussion

The figures most frequently used as benchmarks for comparison between institutions are the negative appendicectomy and perforation rates. Within our department, 16.5% of appendicectomies were negative and in 23.7% of cases the specimen removed was perforated. Flum and Koepsell reported that of 261,134 patients who had undergone an appendicectomy in the US in 1997 15% had no pathological features of appendicitis.[14]

Some institutions do report admirable negative appendicectomy rates of below 10%. However, these figures are often without adjustment for age and sex.[10] For example, many hospitals admit proportionally fewer teenage girls or young infants, two high risk groups. Others use the macroscopic appearance of an appendix intraoperatively to diagnose appendicitis. Dilley *et al* retrospectively reviewed 1,007 children who had undergone an appendectomy at a large children's hospital in Houston, Texas.[15] Their negative appendicectomy rate was 15.6% and the perforation rate was 26.1%. They used pre-operative ultrasonography in 58%, a level they considered to be high. A recent analysis of data from 30 paediatric hospitals in the US saw a median perforation rate of 36%.[11]

In Europe imaging has traditionally played a limited role in the diagnosis of acute appendicitis. Physical examination by a skilled and confident physician is crucial to its diagnosis. Furthermore, best practice is to continually reassess children on the basis that appendicitis has inevitable progression.[2] Jones formalised this as 'active observation'.[16] This approach, however, is time-consuming and, in our performance-driven health service, expensive. With recent changes to surgical training and working hours we can also be less sure of expertise and that serial examinations are carried out by the same examiner. As we know, a negative procedure is associated with significant morbidity and cost implications.[14] We therefore continue to rely on tools that aid diagnosis.

Scoring systems have tried to incorporate the best clinical features of the disease and laboratory findings and tie them in with clinical impression. However, few have found them to be remarkably accurate.[17–19] A white blood cell count and C-reactive protein levels are both good negative predictors and are therefore good at excluding perforated appendicitis and showing objectivity.[1,20] By visualising the disease entity in the right iliac fossa, imaging allows us to positively predict as well as exclude.

Table 5 Measures of ultrasonography accuracy in the diagnosis of acute appendicitis

Patient episodes	TP	FP	TN	FN	Sensitivity	Specificity	Positive predictive value	Negative predictive value
311	70	6	221	14	83.3%	97.4%	92.1%	94.0%

TP = true positive, FP = false positive, TN = true negative, FN = false negative

Doria *et al*'s meta-analysis informed us that in a paediatric population CT achieves higher measures of accuracy than ultrasonography.[21] The pooled sensitivity and specificity were 94% and 95% respectively as opposed to 88% and 93% with ultrasonography. However, many papers, including theirs, highlight the current consensus that the use of CT should be limited as we cannot justify the routine use of ionising radiation in this radiosensitive population. In this light, the performance of ultrasonography can be considered good. This supports its place as the primary imaging modality.

The data from this institution demonstrate results of a similar magnitude to the criteria set in the meta-analysis. It achieved a sensitivity of 83.3% and a specificity 97.4% in the radiological diagnosis of acute appendicitis within our department. Of greater interest is the ability of ultrasonography to predict positively. Within our department, 92% of the children who had positive ultrasonography actually had acute appendicitis. In this way sonography is a unique diagnostic tool.

An equally high negative predictive value of 94.0% suggests that greater weight could also be given to a negative result. In our department, 8.9% of patients with negative ultrasonography went onto have an unnecessary appendicectomy. If we assumed they had not been operated on and recalculated our overall negative appendicectomy rate, it would stand at 8.8%. It would be interesting to review time intervals from admission to scan and then from scan to theatre. This would demonstrate the value of negative ultrasonography to the surgeon. Could we manage more patients on an outpatient basis?

There were 15 false negatives in this study and, of these, 9 were actually equivocal reports. The radiologist gave appendicitis as part of a differential or was not descriptive enough to establish a clinical impression. We cannot be sure of the impact on the decision-making process of such a report but it is unlikely to be as negative as our results cautiously suggest. Seven of these scans were performed out of hours.

It is difficult to make a direct comparison between the outcomes of the group that had pre-operative ultrasonography and the group that did not without stratifying patients on the clinical presentation.[22,23] In our department we reserve imaging for the equivocal and complex cases. A child who presents a diagnostic dilemma is more likely to have an unnecessary appendicectomy (19.6%) and have a specimen that is perforated (34.1%). In this situation there is a lower incidence of acute appendicitis in the imaged group and, on top of this, the result is more likely to sway the decision to operate.

Those who present atypically often mimic gastroenteritis and are more likely to be referred to a paediatrician than a surgeon, delaying the diagnosis.[24] Therefore, by identifying a fluid collection or appendix mass, we may not have achieved our diagnostic goal and prevented perforation. Nevertheless, reliable images of the right iliac fossa are invaluable when deciding on further management, be it surgery, percutaneous drainage or conservative management.

The intentional use of databases and reports instead of clinical records can be described as a limitation of this study. It is possible for parents to refuse to consent to an operation if their child's condition is improving. A patient could also present within this hospital, undergo ultrasonography and have an appendicectomy elsewhere at a later date. In either case one cannot say that the child did not have an inflamed appendix. Our approach, however, was efficient and, importantly, it is reproducible.

Conclusions

Our institution has an overall negative appendicectomy and perforation rate similar to larger institutions in the literature. Ultrasonography is used liberally to aid in the decision-making process of equivocal and complicated cases of acute appendicitis and it has achieved good measures of accuracy. As a diagnostic tool in comparison with laboratory investigations it is unique in its ability to predict positively as well as exclude. A high negative predictive value suggests that more patients could be managed on an outpatient basis following negative ultrasonography. This study highlights the need to audit the performance of ultrasonography within any institution using it as a diagnostic tool on children presenting with acute abdominal pain.

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