MINISYMPOSIUM

The role of imaging in children with suspected appendicitis: the UK perspective

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Abstract The diagnosis of uncomplicated acute appendicitis is often straightforward, allowing timely appendicectomy without the need for expensive tests or imaging. Repeated clinical examination by an experienced surgeon has traditionally been the key to making the diagnosis in both straightforward and difficult cases. Nonetheless, all surgeons will remove some normal appendices. Sometimes it can be particularly difficult to make the diagnosis, especially in the child under 5 years of age, in teenage girls, in young women and in the elderly. When difficult to make, the diagnosis may be significantly delayed and since the pathology is progressive, the patient may suffer potentially avoidable complications. This paper looks at two potential roles for imaging. Firstly, can imaging, applied selectively, help make the difficult diagnosis less difficult and so reduce delays and morbidity? Secondly, could imaging all patients with suspected appendicitis reduce the number of normal appendices removed from children who seem to have all the signs and symptoms of straightforward uncomplicated acute appendicitis but who actually have presumed self-resolving non-appendiceal pathology? The answer to these questions may depend on three factors that are not entirely independent: a surgical unit's current audited negative appendicectomy rate, population base/case mix and the expertise of the examining surgeon. Individual surgeons and some surgical units, by policy, use modern imaging techniques with quite different frequencies that may be appropriate depending on these three factors. This article argues that a careful history and repeated clinical examination is the key to making the diagnosis, with imaging, primarily ultrasonography, being used in patients with a palpable mass or in those having had 48 h of hospital observation without progress. In Europe, imaging has played a limited role in the investigation of the child with suspected appendicitis with the diagnosis relying on repeated examination by an experienced clinician. Ongoing changes in surgical training in the UK may affect the acquisition of clinical expertise that is crucial to this clinical management. High-quality surgical training and surgical audit are needed to monitor the delivery of care and to ensure that the care pathway being used is appropriate for the local resources and population.

Keywords Appendicitis · Ultrasonography · Children · Surgical training

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Introduction

Appendicitis is common in childhood and is potentially serious because early acute appendicitis can progress rapidly into complex pathologies. Appendicitis should always be considered when a child presents with acute central or lower abdominal pain, vomiting, loose stool or suspected urinary tract infection. The latest UK surgical trainees in their foundation years continue to be taught that the diagnosis of uncomplicated acute appendicitis is often straightforward allowing timely appendicectomy without the need for expensive tests or imaging [1].
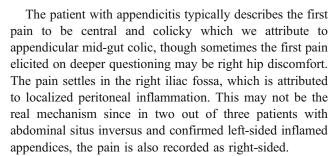
Acute abdominal pain

The management of the child with acute abdominal pain requires the expertise gained from the aggregate experience of managing a large number of children presenting with abdominal pain, each closely and repeatedly examined. It is this expertise that training needs to foster under the threat of reduced hours and shift systems. Of the surgical causes of abdominal pain, appendicitis is top of the bill. In over half such children admitted to hospital, the pain resolves undiagnosed and may be attributed to 'mesenteric adenitis' or 'nonspecific abdominal pain' which, like much small print, are poorly defined terms and conditions. The inexperienced can miss appendicitis, allowing it to progress, and they should remember that only rarely is a urinary tract infection or gastroenteritis the correct final diagnosis when the main presenting problem is abdominal pain rather than dysuria or diarrhoea. And it is important to remember that complex appendicitis can present with bacteriuria or diarrhoea or both when an inflamed mass irritates a ureter, the bladder or the rectum.

Clinicians assessing a child with abdominal pain know to check the hernial orifices and hip joints and to consider lower lobe pneumonia that may have pain referred to the abdomen. In the child with generalized peritonitis and a history consistent with appendicitis, imaging is not needed since an operation is usually indicated. Rarely, primary peritonitis can present similarly and is also sometimes seen in patients with ascites from nephrotic syndrome or liver disease, when no operation is needed. Diabetic ketoacidosis or sickle crises may cause severe abdominal pain, but peritonitic signs are usually absent. However, one should remember that appendicitis can precipitate diabetic ketoacidosis or a sickle crisis. Two further difficult scenarios are seen in distinguishing meconium ileus equivalent from appendicitis in the child with cystic fibrosis and in managing the neutropenic child with right iliac fossa pain and distinguishing so-called *typhlitis* from appendicitis.

Clinical history

The patient with appendicitis almost invariably has anorexia. A very good appetite is only rarely claimed and indeed this combination is only seen in an obese child, suggesting discordance between appetite and normal gastrointestinal signalling mechanisms in these individuals. Some prepubescent boys who have appendicitis claim they are hungry, but when offered something to eat decide they are not hungry.

The patient with appendicitis has typically vomited once or twice, but rarely more than a few times. Once the stomach is empty the vomiting ceases. This contrasts with the child with gastroenteritis who may have vomited profusely.

The patient with appendicitis typically describes the first pain to be central and colicky which we attribute to appendicular mid-gut colic, though sometimes the first pain elicited on deeper questioning may be right hip discomfort. The pain settles in the right iliac fossa, which is attributed to localized peritoneal inflammation. This may not be the real mechanism since in two out of three patients with abdominal situs inversus and confirmed left-sided inflamed appendices, the pain is also recorded as right-sided.

If the history is longer than 48 h then features of complex appendicitis may be elicited. Perforation with gross generalized peritonitis will not be easily missed, but there may be some interesting features in the history. A history consistent with early appendicitis may be obtained with a sudden resolution of the pain before marked clinical deterioration. The resolution of pain is attributed to loss of tension in the appendix upon rupture. However, in the existing model this could account for loss of central abdominal pain but not the loss of localized right iliac fossa pain, which is what is typically seen.

Making the clinical diagnosis

In the child with a good history one may see a flushed face and detect oral fetor. There is usually a low-grade fever of 37.2–38°C when taken orally, but often the temperature is poorly taken, well before the thermometer has come into thermal equilibrium with the patient. In a personal series of 122 children with early acute appendicitis the oral temperature was recorded when a mercury thermometer had reached equilibrium with the patient (i.e. the reading had stopped rising on two successive observations). The temperature on first examination was between 37.2°C and 38°C in all but two patients. Only one boy had a temperature of 37°C and one a temperature of 38.2°C. This is important because often a child with a short history and a very high temperature (39°C or more) has pain and mild tenderness that are most likely to resolve on observation and not need an operation. These symptoms are usually attributed to a viral illness. In these patients the surgeon may be misled if the temperature has been wrongly recorded in the range 37.2–38°C. Likewise the child who is truly apyrexial is highly likely to settle whilst closely observed.

The key to deciding the need for operation is finding persistent tenderness/guarding in the right iliac fossa at McBurney's point. Appendicitis can be difficult to confidently exclude early in the disease and if a well patient with a very short history and mild signs is not thought to have appendicitis and is sent home from an emergency department without a period of observation then some sort of review, even if only by phone, is important to avoid

missing a case of appendicitis. No imaging is needed in such cases. Appendicitis is a progressive condition and so repeated observation and clinical review are key to making the diagnosis in those admitted to hospital with persistent guarding in the right iliac fossa being the indication for appendicectomy. Leucocytes or organisms in the urine are not uncommon since an inflamed appendix may be adjacent to the ureter or bladder and does not rule out the diagnosis.

In the child under 5 years of age the diagnosis is more difficult and perforation is more common. Perforation may be more common because the omentum is less well-developed and fails to wall-off impending perforation. In this age group it is also sometimes very difficult to assess children and repeated assessment by an experienced examiner is important. Perforation is not more common in young children because of delay in making the diagnosis since time from first symptoms to diagnosis is not protracted [2].

Complicated appendicitis includes appendiceal mass, abscess and perforation. If there is a palpable mass in the right iliac fossa, the rest of the abdomen is soft and fluids and diet are tolerated, it is reasonable to elect for conservative management with intravenous antibiotics. If the symptoms and the mass resolve, an interval appendicectomy is considered after 6 weeks. If symptoms progress than a laparotomy is indicated. If an abscess is confirmed on abdominal sonography then operative drainage and appendicectomy may be appropriate. If there is generalized guarding consistent with perforation, it is important to ensure that fluid resuscitation and intravenous antibiotics are given prior to laparotomy.

Improving diagnostic accuracy without imaging

Apart from imaging, a number of adjuncts have been looked at to see if the negative appendicectomy rate or delays in diagnosis can be reduced. The first are blood tests. Electrolyte levels are measured to help with intravenous fluid management and a white cell count and CRP are frequently taken at that time. One school of thought dismisses the white count since a patient with a low white count or CRP in the face of persistent guarding gets an operation and a patient with a soft abdomen and a high white count or CRP does not get an operation. More than 10 years ago, Calder and Gajraj [3] showed that an elevated white blood cell count has a low predictive value. Scoring systems are no better than expert clinical judgement [4–6].

Imaging

Ultrasonography, CT and MRI have been shown in some studies to improve diagnostic accuracy and improve some

outcomes, but their routine use in all patients is not well established. It is important to remember that CT necessitates irradiation of the child and there can be reactions to intravenous contrast medium. In some studies the clinicians' estimated probability of a patient having appendicitis is compared with the probability estimated by a radiologist from a modality of imaging and these are related to the final diagnosis [7, 8]. Imaging proves to be better with this methodology. However, the clinical reality is that the surgical diagnosis is not made on one or two examinations, but on a series of examinations.

What to do when the diagnosis is not clear may depend on case mix

If a selective approach to imaging is taken there are a number of care pathways or algorithms that can be used, but the best approach may vary depending on the age and sex mix of the population a unit treats and the pattern of referrals. We have developed our own guideline based on an analysis of our retrospective data, but these guidelines may not be appropriate for other units, particularly those with older populations for the reasons outlined below.

We provide a secondary and tertiary service in a specialist children's hospital, and reviewed our use of sonography in our hospital in children with suspected appendicitis. Over a 2-year period ending in 2002 we admitted 888 children with acute right iliac fossa pain. Pain resolved without intervention in 692 (78%) and none returned with problems, whilst 196 (22%) had an appendicectomy. Of these 196, 180 had appendiceal pathology and 16 (8%) had a normal appendix removed. This is a very low negative appendicectomy rate and sounds impressive compared with other published data. For example, in the United States in 2002, Flum and Koepsell [9] reported that 15% of 261,134 patients who had appendicectomies in 1997 had no pathological features of appendicitis on histology. My own personal audit during training was to remove only 7 normal appendices in 122 appendicectomies, which is consistent with our 8% departmental figure and arose from a similar population base. What is important to note is that these rates are not comparable with published data without adjustment for age and sex [2]. Our nearby adult hospitals who also manage children had much higher negative appendicectomy rates for the same time period, but they manage proportionally many more teenage girls and refer on to us all the younger children in whom the diagnosis is often straightforward. Ultrasonography was performed in 42 (5%) of our 888 children (8 boys, median age 13 years; 34 girls, median age 14 years). Details of the scans are shown in Table 1.

Table 1 Details of 42 children with suspected appendicitis who underwent sonography

Condition	Details
Palpable mass (n=6)	Two boys, four girls; all six scans were helpful. Appendix mass confirmed in 2. Abscess in 2 (both drained). Normal in 1. Lymphoma in 1.
No palpable mass (n=36)	Sonography altered management in only 1 child when acute appendicitis was correctly diagnosed on a scan within 24 h of admission. However, appendicitis would most likely have been diagnosed clinically in due course with appropriate observation. Sonography revealed a thickened loop of bowel in the right iliac fossa in 1 girl and an appendicectomy was performed on clinical grounds 3 days later for appendicitis. Sonography revealed free pelvic fluid in 7 children (2 boys, 5 girls). In 5 the pain resolved within 48 h of admission and they were discharged and remained well. In 2 an appendicectomy was performed for persistent pain (1 appendicitis, 1 normal). Sonography revealed no abnormality in 27 children (4 boys, 23 girls). Appendicectomy was performed on clinical grounds in 8, with 6 of the 8 having appendicitis. In the remaining 19, the pain resolved within 48 h of admission.

On the basis of these data we have limited the use of sonography in acute right iliac fossa pain in children presenting to our hospital to those with a palpable mass. If there is no mass then frequent clinical examination is continued for 48 h from admission before considering abdominal sonography if the diagnosis remains difficult. If this guideline had been used then 887 of the 888 children would have been managed as they were. However, only 7 or 8 scans would have been performed instead of 42. One girl would have waited 24 h for a diagnostic scan or had a clinical diagnosis made on repeated examination before a scan at 48 h from admission. So we concluded that in children with acute right iliac fossa pain our local data support our use of sonography in those with a mass. We found benefit in only 1 of 36 of those without a mass scanned within 48 h of admission.

Recent changes in training and the delivery of service in the UK may affect diagnostic skills and increase the reliance on imaging

With the introduction of the time restrictions of the European Working Time Directive, new shorter training programmes and shift systems, surgical trainees may be less skilled at diagnosing appendicitis than their predecessors. Repeated clinical examination by the same skilled examiner is the key to establishing the progression or resolution of right iliac fossa signs. The decision to operate rests on these serial assessments in appropriately selected patients. The earliest sign is pain or tenderness, which is reported by the patient or evident on their face on very gentle pressure from the examining hand in the right iliac fossa. There is no increased anterior abdominal wall resistance to the pressure applied compared to normal at this stage. Then the pain assessed in this way usually increases with time in appendicitis, though analgesia may affect this assessment. The same examiner makes the best assessment of progression. As appendicitis advances there is an increase in the muscle tone evident on gently increasing the examining pressure; this then increases steadily and is called guarding. Again one examiner who is now familiar with the patient is the best person to assess progression. These assessments require continuity of care and are very difficult to hand over from one team to another. The ideal way to hand over such patients is for both doctors to review the patient together during handover. The concern with shorter training and lack of continuity of care is that the aggregate experience necessary to build expertise is being eroded.

Imaging all patients

Rosendahl et al. [10] reviewed several studies examining the accuracy of imaging strategies in children with abdominal pain and suspected appendicitis and concluded that sonography should be the initial imaging technique in *all* children with suspected appendicitis with CT as a complementary tool. They considered clinical assessment to have an accuracy of only 70–90% with 13–25% of patients having a normal appendix removed.

Accuracy is a measure of how often a test is correct (true positive + true negative)/all. In our series the accuracy of clinical management using sonography selectively in only 5% of cases was $(180+692)/888=98\%$ (95% CI 97%–99%). *Sensitivity* is often an unhelpful measure being true positive/ all who are disease-positive. In our series this was 100% since no patient with appendicitis was missed. *Specificity* is true negative/all who are disease-negative. In our series this was $692/708=97.7\%$ (95% CI 96.6%–98.8%). A more informative measure is *positive predictive value*, i.e. the probability that a subject who tests positive is truly positive (true positive/all who are test-positive). In our series this was $180/196=92\%$ (95% CI 88%–96%), where the test is clinical examination with selective use of sonography.

Rosendahl et al. [10] claim that preoperative imaging using sonography and/or CT reduces the negative appendi-

cectomy rate to 3–7% without an increase in perforation rate. Our own data showed that of 888 patients with right iliac fossa pain, only 8% of 196 children had normal appendices removed and we had no evidence that delay during observation increased our perforation rate. Rosendahl et al. [10] reported the sensitivity of sonography to vary between 87% and 95% and of helical CT to vary between 95% and 97%, with specificities of 85–98% for sonography and 94–97% for helical CT. One study [10] showed that compared with sonography alone, a combination of sonography and helical CT increases the sensitivity from 86% to 99%, while the specificity decreases from 95% to 89%. The authors concluded that imaging should be performed in all children with suspected appendicitis and that sonography should be the initial tool. But as illustrated, our own data do not support that argument.

Plain abdominal radiography

A plain abdominal radiograph is generally not indicated when the differential diagnosis is between nonspecific abdominal pain and appendicitis. However, in the uncooperative child under 5 years of age who has abdominal pain there may be a role for an abdominal radiograph since a fecolith may show on the film, though sonography might be just as good. Our data do not allow us to answer this question.

Removing a histologically normal appendix

It is usually considered to be less than ideal when a normal appendix is removed for right iliac fossa pain. However, two things have to be considered. Firstly, nearly all these patients (8% in our series) are cured of their right iliac fossa pain and recover swiftly without complication. It is possible that appendicectomy is beneficial in some of these patients. This hypothesis could only be tested by randomizing patients to appendicectomy or leaving the appendix in situ. An adequate study of this design has not been performed. Secondly the life-time risk of appendicitis is reported to be between 7% and 10% in men and up to 25% in women [7, 12, 13]. Thus some of the children having normal appendices removed may have been saved a future episode of appendicitis with its attendant complications.

Conclusion

In our centre the diagnosis of appendicitis is often straightforward and made from a detailed history with the indication for surgery being persistent guarding in the right iliac fossa. This is established by repeated clinical examination by a skilled clinician. In 95% of patients no further imaging is needed. When the diagnosis is not clear, management options for suspected appendicitis include further observation or diagnostic imaging. We have found sonography to be of most benefit when there is a palpable mass or observation has continued in hospital for 48 h without improvement in the patient or convincing clinical signs warranting operation. Imaging in this way is cost effective. Surgical training is changing and needs to focus on gaining expertise without the old apprenticeship system. This will be a challenge and on-going audit is crucial to maintain the quality of service delivery.

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