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Imaging the patient with suspected appendicitis

Patients presenting with suspected appendicitis are often taken to theatre based purely on clinical findings. This article discusses the imaging modalities that can be used to confirm the diagnosis, thereby reducing the rate of negative appendectomies and associated complications.

Non-traumatic right lower quadrant abdominal pain is a common presentation and encompasses a large differential diagnosis, from benign self-limiting conditions (such as ovarian cyst complications) to surgical emergencies with high morbidity such as appendicitis and ectopic pregnancies. Once ectopic pregnancy has been excluded, acute appendicitis remains the most frequent cause of right lower quadrant pain (Marincek, 2002).

The first unequivocal account of appendicitis was described in 1711 by Lorenz Heister, and in 1866, Reginal Heber Fitz, the Shattuck Professor of Pathological Anatomy at Harvard University, coined the term appendicitis, described the clinical features of appendicitis and proposed the surgical removal of the inflamed appendix. By 1889, McBurney published the first of several important papers regarding early surgical intervention of appendicitis and the muscle-splitting incision that bears his name and is still commonly used today. In England, King Edward VII suffered from appendicitis 2 weeks before his initial planned coronation in June 1902 after the death of Queen Victoria in 1901. Initially reluctant, he finally consented to surgery under the care of Lord Joseph Lister and Sir Fredric Treves on 24 June 1902, recovering successfully and reigning as king for the next 8 years of his life. The publicity and successful outcome of his treatment advanced appendicitis as a discreet disease entity and appendectomy as its treatment (Prystowsky et al, 2005).

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In some patients, spontaneous resolution of appendicitis does occur, presumably with the rising intraluminal pressure dislodging the obstructing material and relieving the distension and inflammatory process. Approximately 9% of patients presenting with acute appendicitis have had a similar episode in the past and up to 4% report having more than one previous attack. In a study of 1000 patients, before modern imaging methods, the overall negative appendectomy rate was 20%, but in women between the ages of 20 and 40 years it exceeded 40%, with two thirds of the negative appendectomies the result of non-surgical lesions (Prystowsky et al, 2005).

The mean duration from the start of abdominal pain in appendicitis to development of gangrene is 46.2 hours, and 70.9 hours to perforation (Bennion et al, 1990). While some patients may present early with the first onset of abdominal pain, others may avoid seeking help and present late to the emergency department, reducing the window for early intervention and converting a potentially uncomplicated case into one with substantial morbidity and complications.

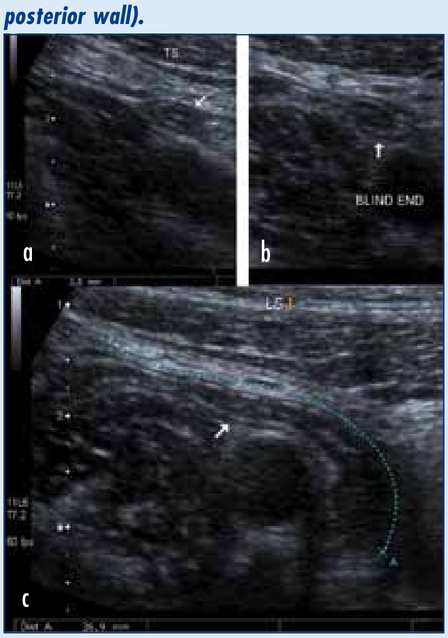
While many patients with unequivocal presentation of appendicitis may undergo surgery without imaging, further work up with biochemical tests and imaging may be required in cases with atypical symptoms. Negative appendectomy rates where the diagnosis is based purely on clinical acumen and laboratory tests vary between 16 and 47% (mean 26%) but drop to

6–10% when imaging is performed (Gaitini, 2011). Complications from appendectomy include development of intra-abdominal adhesions and adverse effects related to anaesthesia, encountered in approximately 2% of negative appendectomies (Bendeck et al, 2002). With gangrenous or perforated appendicitis, complication rates are much higher and include repeat surgery, sepsis, dehiscence and infertility. In the past a 20% negative appendectomy rate was generally accepted as the risk of gangrene and perforation far outweighed the risk of a negative appendectomy. However, with the availability of better imaging techniques in the modern health-care setting, greater emphasis has been placed on early and accurate diagnosis of appendicitis with the aid of imaging to reduce both false negative rates and associated complications.

Plain radiographs

In many centres, a plain radiograph of the abdomen and an erect chest radiograph will be undertaken as part of the routine work up for patients presenting with non-traumatic abdominal pain. While up to 50% of these radiographs will be normal (Marincek, 2002), they may help exclude other potential causes of right lower quadrant pain that can mimic appendicitis. Alternatively, subtle classical signs such as the presence of an appendicolith, localized adynamic ileus, air–fluid level in the caecum and terminal small bowel, increased soft tissue density in the right lower quadrant and rarely a gas-filled appendix may be present to confirm the diagnosis of acute appendicitis (Thorpe, 1979). However, if there is strong clinical suspicion of appendicitis, waiting for plain radiographs and a formal report may unnecessarily delay further more appropriate imaging before intervention.

Figure 1. Normal appendix. a. Non-peristaltic luminal structure, compressible and measures <6 mm. b. Blind end of non-peristaltic structure. c. Longitudinal section of normal appendix (spline line follows the more anterior wall of the appendix, white arrow indicates the posterior wall).



Ultrasound

The use of graded compression ultrasound to help the diagnosis of appendicitis was first reported by Puylaert (1986) and rapidly followed up with a large prospective study demonstrating a high sensitivity of 75% in acute appendicitis and 100% specificity in ruling out appendicitis (Puylaert et al, 1987). Many other studies soon followed and ultrasound has remained a useful but non-routine tool for the diagnosis of appendicitis since the late 1980s, acknowledging difficulties in 24-hour ultrasound service provision and operator dependency (Pearson, 1988). The availability of ultrasound for suspected appendicitis still varies significantly among different institutions.

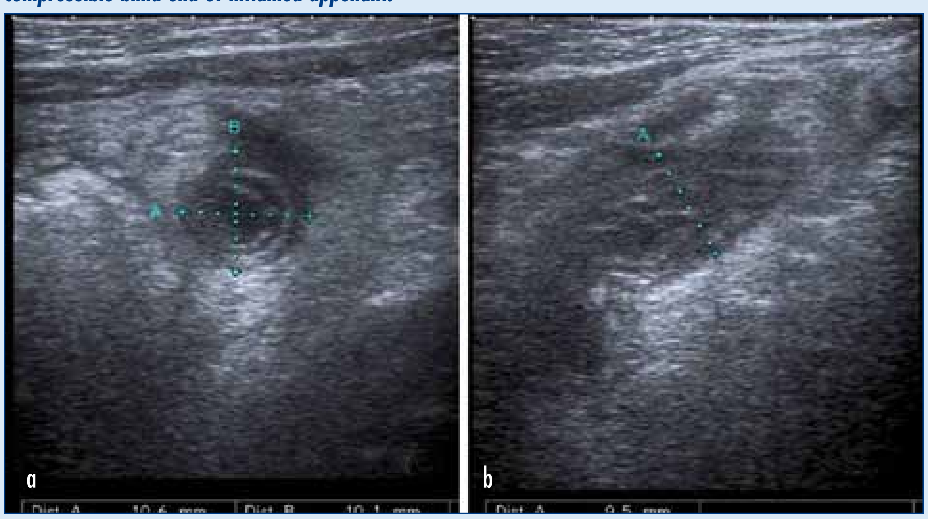
The normal appendix (*Figure 1*) can be visualized from the base of the caecum as a gut-like, compressible, non-peristaltic blind-ended tube with a lumen, a wall thickness of 2 mm or less and a diameter up to 6–7 mm (Gaitini, 2011). It may not be visible in non-symptomatic patients, especially in patients who are either obese or very muscular, or if in a retrocaecal location.

In appendicitis (*Figure 2*), the inflamed appendix remains a blind-ended gut-like non-peristaltic structure, and owing to the inflammatory process is often more easily visualized than the normal appendix. Despite graded compression, it will be non-compressible, with a thickened wall and a diameter greater than 6–7 mm. Colour or power Doppler may demonstrate a surrounding hyperaemic wall and there may be localized inflammation of the mesenteric fat appearing hyperechoic in nature, and surrounding tissue oedema. The identification of an appendicolith provides strong support for the diagnosis of appendicitis. In severe cases, perforated appendicitis may be visualized as a peri-appendicular abscess (Gaitini, 2011).

Computed tomography

The first published use of computed tomography in aiding the diagnosis of appendicitis was as early as 1985, in five cases where computed tomography imaging was used to supplement information gained from barium enema studies and clinical examination (Gale et al, 1985). It was not until the mid-1990s that Rao and colleagues at the Massachusetts General Hospital performed and reported the first prospective study demonstrating the high sensitivity of computed tomography for

Figure 2. Acute appendicitis. a. Appendix with mucosal wall thickening and surrounding oedema. b. Non-compressible blind end of inflamed appendix.



appendicitis (Rao et al, 1997). Since then the use of computed tomography for suspected appendicitis has taken off and it is the most useful imaging investigation for suspected appendicitis in adults.

Different computed tomography protocols are used in different institutions for the diagnosis of appendicitis. The choice of protocols is often determined by local expertise. Broadly, they can be divided by anatomical extension examined and by contrast medium used. The anatomical extension of some examinations may include the abdomen and pelvis while others focus on the right iliac fossa. Differences in contrast medium studies include unenhanced studies, those with intravenous contrast medium, and variable use of oral and/or rectal contrast medium (Whitley et al, 2009; Gaitini, 2011). However, computed tomography uses ionizing radiation and the estimated lifetime attributable risk from cancer secondary to an abdominal computed tomography scan at 240 mAs ranges from 0.14% for a neonate to 0.01% in the elderly (Brenner and Hall, 2007). More recently studies comparing low dose computed tomography with standard contrast enhanced computed tomography examinations have reported comparable results in the sensitivity and specificity of diagnosis of appendicitis (Kim et al, 2011).

The normal appendix (*Figure 3*) is usually visible in over 80% of the adult population on an abdominal-pelvic computed tomography scan. Its location relative to the caecum is variable and the diameter ranges from 3–10 mm, with the presence of intraluminal content associated with greater diameters. In some patients, oral or rectal contrast medium can be seen to fill the appendiceal lumen (Tamburrini et al, 2005). Visualization rates can be increased up to 90–100% with the use of oral and/or rectally introduced contrast medium (Whitley et al, 2009).

On computed tomography the inflamed appendix *(Figure 4)* shows wall thickening and peri-appendical fat stranding. On unenhanced computed tomography, in 30% of the patients, the appendix will appear hyperdense in relation to the adjacent caecal wall. In patients imaged with intravenous contrast medium in the portal-venous phase, there is iso-enhancement of the mucosal wall. Where oral and/or rectal contrast medium is administered, the inflammation may prevent the opacification of the appendiceal lumen. Occasionally, a calcified appendicolith will be identified, but care should be taken not to misinterpret a calcified mesenteric lymph node as the appendicolith (Whitley et al, 2009).

Historically, in patients imaged with both rectal and oral contrast medium, the arrowhead sign (where the pelvic appendix is thickened and inflamed with thickening of the caecal pole forming the image of an arrowhead) may be present in approximately 30% of patients with acute appendicitis and is a highly specific sign of appendicitis on computed tomography

***Figure 3. A normal appendix demonstrated by a computed tomography examination performed on the same patient 1 year before the ultrasound examination shown in* Figure 2.**

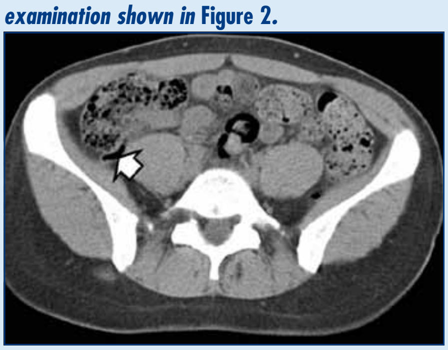
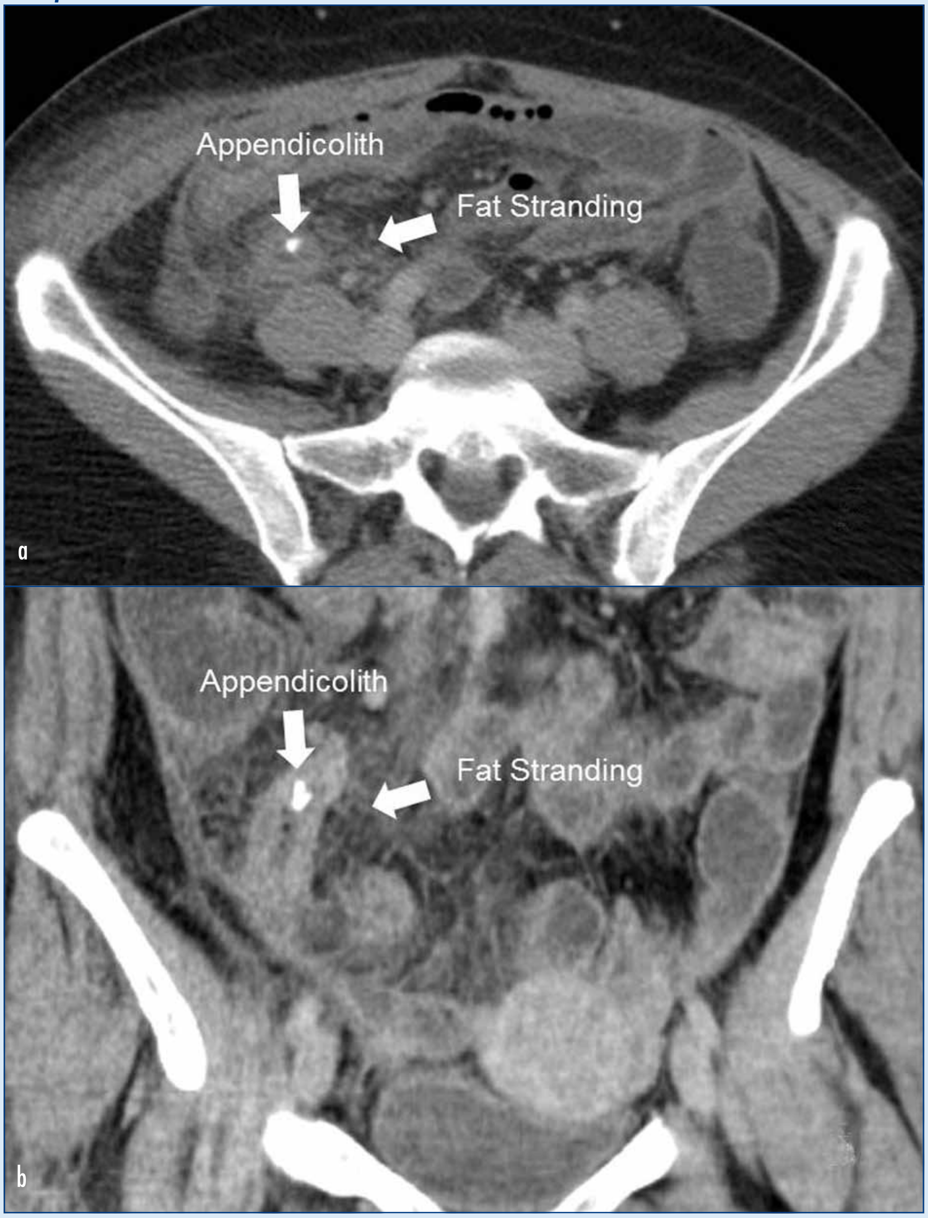


Figure 4. a. Wall thickening and peri-appendical fat stranding of a distended and inflamed appendix in a 43-year-old woman in axial view. b. Appendicitis with fat stranding and presence of appendicolith of the same patient in coronal view.



(Whitley et al, 2009). However, this is no longer routine practice.

Imaging in the pregnant patient

In pregnant patients where ultrasound is not available or unable to confirm the diagnosis of appendicitis because of technical limitations, magnetic resonance imaging may be performed as a non-ionizing radiation imaging modality. The first study evaluating magnetic resonance imaging for appendicitis in pregnancy was performed by Incesu et al (1997), demonstrating magnetic resonance imaging examinations to be slightly superior to pure ultrasonography alone. By the late 2000s magnetic resonance imaging was well established as the alternative imaging technique, with well-described sequences taking into account the changes in both physiology and anatomy in the different gestational stages of pregnancy (Lee et al, 2008).

Similar to computed tomography, the normal appendix in magnetic resonance imaging is seen as a blind-ended tubular structure exiting from the caecum. In acute appendicitis (*Figure 5*), the appendix on magnetic resonance imaging will appear enlarged with diameters greater than 7 mm and signs of peri-appendicular inflammation. These are seen as band-like areas of high signal intensity on T2-weighted images or fat-suppressed images. The diagnostic appendicolith, if present, appears as a low signal intensity focus in the middle of the appendiceal lumen. As gadolinium-based contrast medium is still not licensed for routine use in pregnancy magnetic resonance imaging examinations for suspected appendicitis will be performed without intravenous contrast medium (Gaitini, 2011). The first trimester of pregnancy is considered to be a (relative) contraindication to magnetic resonance imaging.

Discussion

While some patients may present with classical symptoms and signs of appendicitis and proceed straight to surgery, imaging has a significant role in the diagnostic pathway of patients presenting with right iliac fossa pain. There are many diagnoses that may mimic the presentation of appendicitis, such as ovarian and other gynaecological pathologies, torsion of Meckel's diverticulum, inflammatory bowel disease and right-sided diverticulitis. The availability of high quality imaging will help significantly in arriving at the correct diagnosis for the patient presenting with right iliac fossa pain.

The combined early and late complication rate from a negative appendectomy can be as high as 14%. However, with modern imaging techniques of ultrasound, computed tomography and magnetic resonance imaging, it has been clearly demonstrated that there is a significant reduction in negative appendectomy rates when patients undergo imaging before appendectomy. As such, early imaging should be considered as part of the patient care pathway.

Many articles and reviews have been published comparing and pooling the data of specificity and sensitivity of computed tomography and ultrasound as the imaging modality of choice for suspected appendicitis. Computed tomography sensitivity and specificities have been reported to be between 91–100% and 90–100%; ultrasound sensitivity ranges from 36–88% and specificity from 83–99%, and magnetic resonance imaging has been demonstrated to be 100% sensitive and 93% specific.

In most centres, computed tomography is widely available, even out of hours, and together with its high sensitivity and specificity, is the single most useful investigation in adults with suspected appendicitis. While studies using low dose computed tomography have shown comparable results to those obtained with standard abdominal computed tomography, it is still not commonly used in young children or pregnant women with suspected appendicitis.

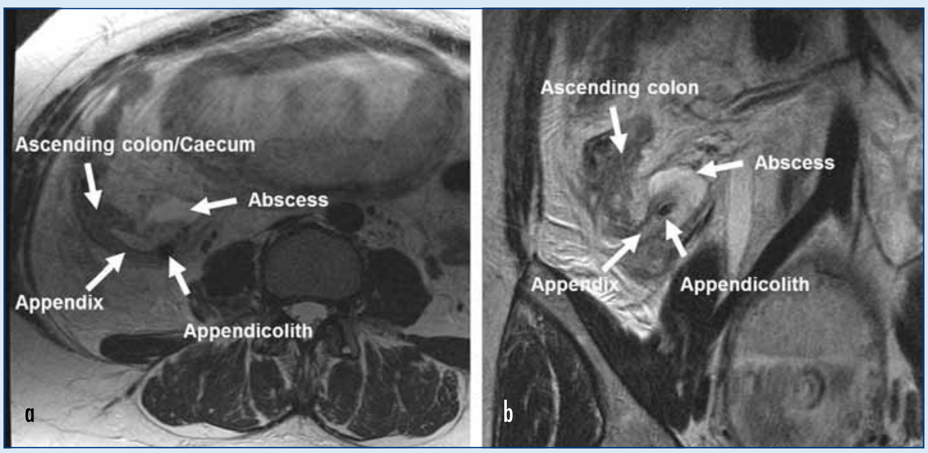
Ultrasound is safe and, unlike computed tomography, does not require the use of ionizing radiation. In addition, an ultrasound examination of younger paediatric patients does not require sedation or general anaesthesia (which may be required for computed tomography or magnetic resonance imaging). However, it may not be available as a 24-hour service in some centres and it is highly operator dependent. Technical difficulties may also be encountered with difficulty in visualizing the appendix in pregnant or obese patients, or patients with a retro-caecal appendix and overlying gas-filled bowel loops. In addition, it is of lower sensitivity than computed tomography and patients with equivocal ultrasound findings will often require computed tomography as a second examination.

The biggest advantages of magnetic resonance imaging are that it does not require the use of ionizing radiation, nor is it operator dependent. In addition, it often gives good soft tissue resolution and may afford alternative diagnoses for the cause of right iliac fossa pain. However, limitations for its routine use include issues with cost, patient claustrophobia, long examination time and lower general availability than computed tomography or ultrasound.

Conclusions

Currently, there are no clear guidelines for the imaging modality of choice, but there is strong evidence supporting the need for

Figure 5. Acute appendicitis of a pregnant patient on magnetic resonance imaging. a. T2-weighted axial and (b) coronal magnetic resonance imaging through the pelvis of a 28-year-old woman who was 22 weeks pregnant demonstrating an appendicolith with a perforated distal appendix with a gas–fluid level.



rapid and accurate imaging for patients presenting with suspected appendicitis. The imaging modality or imaging pathway of choice at individual institutions will depend heavily on local availability, resources and experience. BJHM

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KEY POINTS

- Appropriate use of imaging can reduce the rate of negative appendectomies and associated complications.
- Ultrasound is a fast, reliable and ionizing radiation-free imaging modality to rule out or confirm appendicitis in the majority of patients presenting with right iliac fossa pain.
- Computed tomography is highly sensitive and specific for the diagnosis of appendicitis, and is readily available but consideration has to be given to the ionizing radiation used, in particular in pregnant women and children.
- Magnetic resonance imaging also has high sensitivity and specificity but is costly, time consuming and less readily available as a routine service.