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Invited Review

Diagnosis of acute appendicitis☆

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ABSTRACT

Appendicitis is the most common abdominal emergency. While the clinical diagnosis may be straightforward in patients who present with classic signs and symptoms, atypical presentations may result in diagnostic confusion and delay in treatment. Abdominal pain is the primary presenting complaint of patients with acute appendicitis. Nausea, vomiting, and anorexia occur in varying degrees. Abdominal examination reveals localised tenderness and muscular rigidity after localisation of the pain to the right iliac fossa. Laboratory data upon presentation usually reveal an elevated leukocytosis with a left shift. Measurement of C-reactive protein is most likely to be elevated. The advances in imaginology trend to diminish the false positive or negative diagnosis. Radiographic image of faecal loading image in the caecum has a sensitivity of 97% and a negative predictive value that is 98%. In experienced hands, ultrasound may have a sensitivity of 90% and specificity higher than 90%. Helical CT has reported a sensitivity that may reach 95% and specificity higher than 95%. Despite all medical advances, the diagnosis of acute appendicitis continues to be a medical challenge.

1. Introduction

Appendicitis is the most common abdominal emergency. The lifetime risk of developing appendicitis is approximately 7% and usually requires surgical treatment. The overall incidence of this condition is approximately 11 cases per 10,000 population per year. Acute appendicitis may occur at any age, although it is relatively rare at the extremes of age. There is an increased incidence in white skin patients between the ages of 15 and 30 years during which time the incidence increases to 23 per 10,000 population per year. Thereafter, the disease incidence declines with age.[1–6]

A male preponderance exists, with a male to female ratio of 1:1 to 3:1. The overall lifetime risk is 9% for males and 6% for females. A difference in diagnostic error rate ranges from 12% to 23% for men and 24%–42% for women. These values are a mean of the world experience, including the less advanced medical services. Most of patients are of white skin colours (74%) and is very rare in black skin colour (5%).[1–4,7] While the clinical diagnosis may be straightforward in patients who present with classic signs and symptoms, atypical presentations may result in diagnostic confusion and delay in treatment.[8]

2. Clinical aspects

Abdominal pain is the primary presenting complaint of patients with acute appendicitis. The diagnostic sequence of colicky central abdominal pain followed by vomiting with migration of the pain to the right iliac fossa is present in only 50% of patients. Typically, the patient describes a periumbilical colicky pain, which intensifies during the first 24 h, becoming constant and sharp, and migrates to the right iliac fossa. The initial pain represents a referred symptom resulting from the visceral innervation of the midgut, and the localised pain is caused by involvement of the parietal peritoneum after progression of the inflammatory process. Loss of appetite is often a predominant feature. Constipation and nausea with profuse vomiting may indicate development of generalised peritonitis after perforation but is rarely a major feature in simple appendicitis (Table 1).[1–3,5,8,9]

Patients with acute appendicitis usually have a low-grade fever. Perforation should be suspected whenever the temperature exceeds 38.3 °C. If perforation does occur, periappendiceal phlegmon or abscess will result if the terminal ileum, caecum, and omentum are able to "wall off" the inflammation. Peritonitis usually develops if there is free perforation into the abdominal cavity (Table 1).[1–3,8]

3. Diagnosis

The diagnosis of appendicitis can be challenging even in the most experienced hands, and is predominantly a clinical one. Accurate anamnesis and physical exam are important to prevent unnecessary surgery and avoid complications. The probability of appendicitis depends on patient age, clinical setting, and symptoms.[10,11]

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Table 1
Accuracy (likelihood ratio) of findings from the history and physical examination in the diagnosis of appendicitis in adults and children.[1–3,10]

Clinical finding	Adults	Children
Right lower quadrant pain	8.4	–
Migration (periumbilical to right lower quadrant)	3.6	1.9–3.1
Initial clinical impression of the surgeon	3.5	3.0–9.0
Psoas sign	3.2	2.5
Fever	3.2	3.4
Pain before vomiting	2.7	–
Rebound tenderness	2.0	3.0
Rectal tenderness	–	2.3

The Alvarado score, originally described in 1986, is the most widely reported scoring system for acute appendicitis. However, this score alone is not accurate enough to diagnose or exclude appendicitis (Table 2).[11,12]

The overall accuracy for diagnosing acute appendicitis is approximately 80%, which corresponds to a mean false-negative appendectomy rate of 20%. Diagnostic accuracy varies by sex, with a range of 78%–92% in male and 58%–85% in female patients (Table 3).

4. Anamnesis

For the majority of patients who present to the emergency department with acute appendicitis, abdominal pain will be their chief complaint. Those presenting within the first few hours of onset often describe a poorly defined, constant pain referred to the periumbilical or epigastric region. Nausea, vomiting, and anorexia occur in varying degrees, though are usually present in more than 50% of cases in all studies. With disease progressing as previously outlined, pain becomes well defined and localises in the right lower quadrant near McBurney's point.[2] Accordingly, the clinician should not consider it the *sine qua non* for the diagnosis of acute appendicitis. A failure to recognize other presentations of acute appendicitis will lead to a delay in diagnosis and increased patient morbidity. Patients with a retrocaecal appendix or those presenting in the later months of pregnancy may have pain limited to the right flank or costovertebral angle. Male patients with a retrocaecal appendix may complain of right testicular pain. Pelvic or retroileal locations of an inflamed appendix will refer to the pelvis, rectum, adnexa, or rarely, the left lower quadrant. Subcaecal and pelvic suprapubic pain and urinary frequency may predominate.

5. Physical examination

By far, the most likely physical finding is abdominal tenderness, which occurs in over 95% of patients with acute appendicitis. Patients often find the right lateral *decubitus* position with slight hip flexion as the position of maximal comfort. The abdomen is generally soft with localised tenderness at or about McBurney's point.[1]

The patient is often flushed, with a dry tongue and an associated *faetor oris*. A difference between axillary and rectal temperature higher than 1 °C indicates pelvic inflammation that may be due to appendicitis or other pelvic inflammation.

Abdominal examination reveals painful tenderness and muscular rigidity in the right iliac fossa. Rebound tenderness is present, but should not be elicited to avoid distressing the patient. Patients often find that movement exacerbates the pain, and if they are asked to cough the pain will often be limited to the right iliac fossa.

Percussion tenderness, guarding, and rebound tenderness are the most reliable clinical findings indicating a diagnosis of acute appendicitis. Voluntary muscle guarding in the right lower quadrant is common and usually precedes the tenderness. The follow signs of acute appendicitis are the mostly described, but all of them occur in less than 40% of patients with acute appendicitis, and even their absence should not prevent the examiner from establishing an accurate diagnosis[1,2,7]:

- Blumberg's rebound pain; (Fig. 1A)
- Rovsing's sign – pain that is referred to the area of maximal tenderness during percussion or palpation of the left lower quadrant; (Fig. 1B)
- a positive psoas (right lower quadrant pain with extension of the right hip); (Fig. 1C)
- obturator (right lower quadrant pain with flexion and internal rotation of the right hip) sign depends on the location of the appendix in relation to these muscles and the degree of appendiceal inflammation. (Fig. 1D)

Rectal examination offers little towards furthering diagnostic accuracy. Rectal examination should be reserved for those in whom pelvic or uterine pathology is suspected, or in atypical presentations that suggest pelvic or retrocaecal appendicitis.[1]

6. Laboratorial findings

Laboratory data upon presentation usually reveal an elevated leukocytosis with a left shift. Neutrophilia greater than 75% will occur in the majority of cases. This is not true for elderly, immunocompromised patients, with conditions such as malignancy or AIDS; leukocytosis is observed in less than 15% of such patients.[1]

Measurement of C-reactive protein (CRP) is most likely to be elevated in appendicitis if symptoms are present for more than 12 h. Interestingly, the combination of an elevated CRP, elevated WBC, or neutrophilia greater than 75% improves the sensitivity to 97%–100% for the diagnosis of acute appendicitis. Thus, for patients with normal values for all three studies, the likelihood of acute appendicitis would be low.

Table 2
Alvarado score for the diagnosis of appendicitis.[11,12]

Clinical finding	Points
Migration of pain to the right lower quadrant	1
Anorexia	1
Nausea and vomiting	1
Tenderness in the right lower quadrant	2
Rebound pain	1
Elevated temperature (≥99.1 °F = 37.3 °C)	1
Leukocytosis (≥10,000 white blood cells per mm^3)	2
Shift of WBC count to the left (>75 percent neutrophils)	1

Patients with a score of ≥7 points have a high risk of appendicitis. Patients with a score of <5 points have a very low risk of appendicitis.

Table 3
Sensibility and specificity of symptoms and signs on the diagnosis of acute appendicitis.[7,10,11]

Symptoms and signs	Sensibility	Specificity
Hyporexia	58%–91%	37%–40%
Nauseas e vomitings	40%–72%	45%–69%
Diarrhoea	9%–24%	58%–65%
Fever	27%–74%	50%–84%
Rebound pain	80%–87%	69%–78%
Leukocytosis	42%–96%	53%–76%
C-reactive-protein	41%–48%	49%–57%

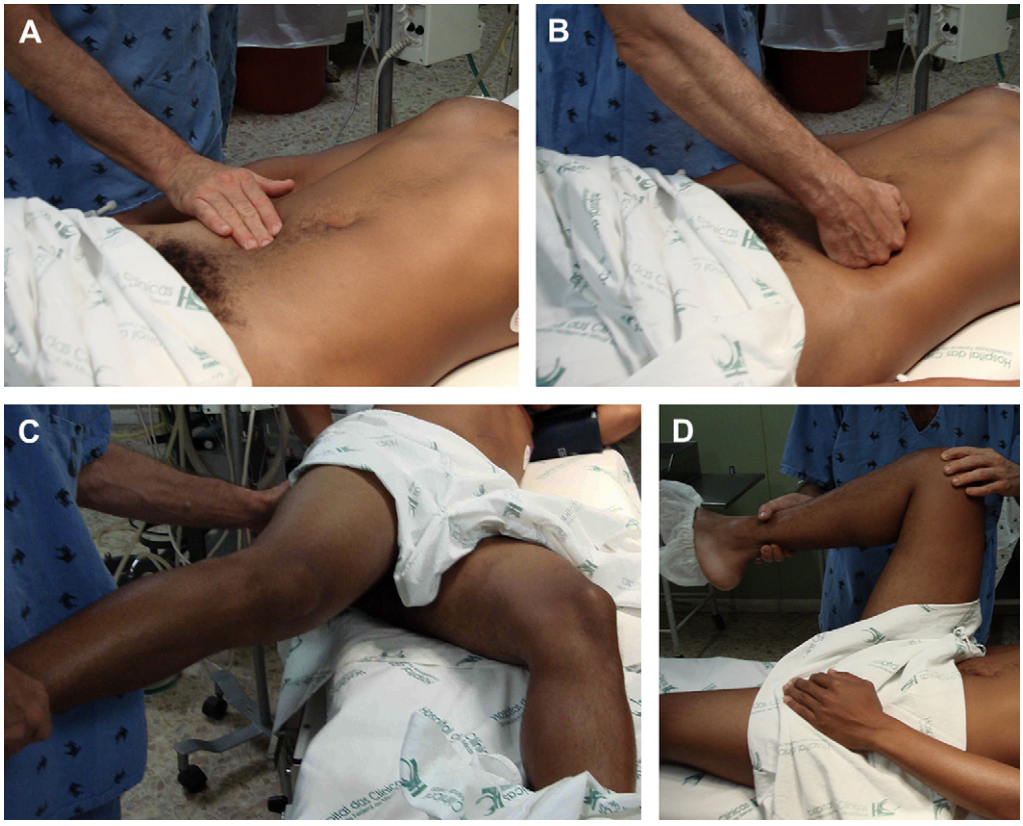

Fig. 1. Physical exam of a patient with right abdominal pain. A - Blumberg's sign. B - Rovsing's sign. C - Psoas sign. D - Obturator sign.

The urinalysis is abnormal in 19%–40% of patients with acute appendicitis. Abnormalities include pyuria, bacteriuria, and haematuria.

7. Imaginological findings

Imaginological investigations should be done only in patients in whom a clinical and laboratorial diagnosis of appendicitis cannot be made (Table 4).[7,8]

7.1. Radiography

Plain abdominal radiographs are abnormal in 95% of patients with appendicitis. Radiographic signs suggestive of appendicitis include appendiceal faecalith; gas in the appendix; air-fluid levels or distension of the terminal ileum, caecum, or ascending colon (signs of localised paralytic ileum); loss of the caecal shadow; blurring or obliteration of the right psoas muscle; rightward scoliosis of the lumbar spine; density or haziness over the right sacroiliac joint; and free intraperitoneal air or fluid. A calcified appendicolith is visualized on an abdominal film in 13%–22% of patients with acute appendicitis; (Table 5).[1,2,13–16]

Since 1999, we have studying a new radiological sign, characterized by faecal loading image in the caecum. In a study, with 460 patients with confirmed appendicitis, we verified this radiological sign has a sensitivity of 97% and a specificity of 85% when compared with other inflammatory conditions of the right abdomen, such as cholecystitis, pelvic inflammatory diseases and nephrolithiasis. Another important finding is the negative predictive value that is 98%. Thus in the absence of faecal loading image in the caecum, the possibility of acute appendicitis is 2%. This sign disappears during the first day after appendectomy in 94% of patients (Fig. 2A).[14,15,16] This sign seems to be due to the caecal ileum, provoked by the inflammatory process. The caecal content is storaged and cannot be conducted to the right colon since little movement occurs in the caecum. This condition lead to enlargement of the caecum and presence of faecal loading identified at the plain abdominal radiography (Fig. 2A).[14–16]

Table 4
Accuracy of the images for the diagnosis of acute appendicitis.[3,6,7,8,14–16]

Exams	Sensibility	Specificity	Predictive values	
			Positive	Negative
Abdominal radiography[a]	97.05%	85.33%	78.94%	98.08%
Ultrasound	44%–90%	47%–95%	89%–94%	89%–97%
Computed tomography	72%–97%	91%–99%	92%–98%	95%–100%
Scintigraphy	91%–98%	91%–99%		

[a] Faecal loading image in the caecum.

Table 5
Sensibility (percentage) of radiographic findings on diagnosis of acute appendicitis.[1,2,3,13–16]

Radiographic signs	Sensiblity (%)
Faecal loading image in the caecum	97,05
Localized adynamic ileum	15–55
Image of increasing in soft tissue density	12–33
Image of air inside the appendix	<2
Appendicoliths	7–22
Lumbar scoliosis	1–14
Disappearance of caecal image	1–8
Deformity of the caecum	4–5

7.2. Ultrasound (US)

US is rapid, non-invasive, inexpensive, and requires no patient preparation or contrast material administration.[3,8,17,18] Although operator skill is an important factor in all US examinations, it has particular importance in the examination of the patient with right-lower-quadrant pain. In experienced hands, US has reported sensitivities of 75%–90%, specificities of 86%–95%, accuracies of 87%–96%, positive predictive values of 91%–94%, and negative predictive values of 89%–97% for the diagnosis of acute appendicitis.[3,8,9,17–19]

The appendix appears on ultrasound as a lamellated, elongated, blind-ending structure. Unlike normal bowel, the inflamed appendix is fixed, non-compressible, and appears round on transverse images. Measurements of appendix are performed with full compression. Traditionally, the diagnosis of appendicitis is made when the diameter of the compressed appendix exceeds 6 mm. In contrast, the thick-walled and non-compressible appendix, maintained in a fixed position by the compressing transducer, will show circumferential colour when inflamed. Appendiceal perforation can be diagnosed when the appendix demonstrates irregular contour or when periappendiceal fluid collections are identified (Fig. 2B).[3,8,17,18]

Doppler US examination usually reveals increased vascularity in and around the acutely inflamed appendix. This examination is useful as an adjunct sign of appendicitis when the appendiceal measurement is equivocal, in which it is uncertain as to whether the imaged appendix is normal or inflamed (Fig. 2C).[3,8,9,17,18]

7.3. Computed tomography (CT)

CT represents an excellent diagnostic alternative for all other patients. CT is complementary to US and is recommended whenever US results are suboptimal, indeterminate, or normal in patients with acute abdominal pain. US is also complementary to CT and may be particularly useful in thin patients in whom the results of initial CT, no matter how it is performed, are equivocal. Analysis of the data for CT and US revealed higher sensitivity (96% *vs* 76%), accuracy (94% *vs* 83%), and negative predictive value (95% *vs* 76%) for CT.[2,3,6,8,17,18,20]

Helical CT has reported sensitivities of 90%–98%, specificities of 91%–98%, accuracies of 94%–98%, positive predictive values of 92%–98%, and negative predictive values of 95%–98% for the diagnosis of acute appendicitis.[2,3,6,8,17,18,20]

The inflamed appendix appears as an enlarged blind-ending tubular structure, frequently associated with inflammatory stranding in the surrounding fat. Traditionally, the threshold diameter of 6 mm was used for diagnosis of appendicitis. However, studies of healthy adults revealed that the normal range of

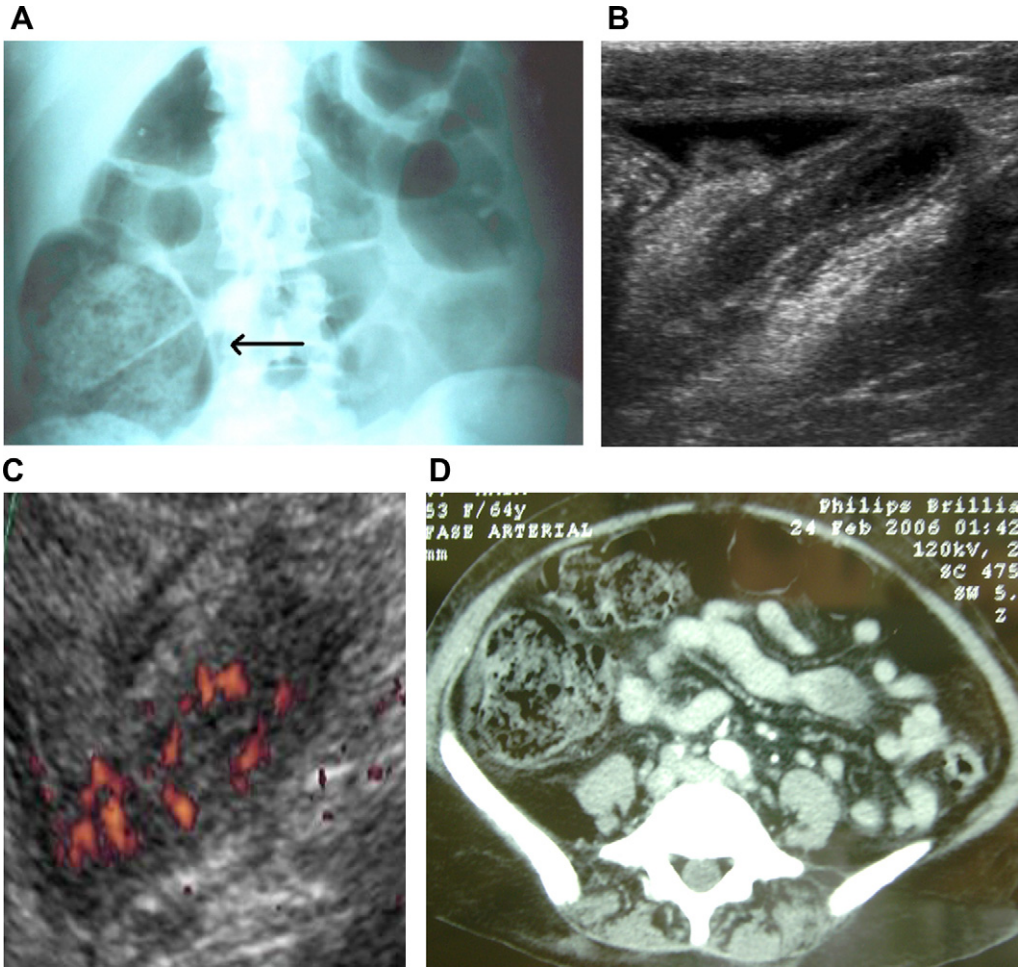

Fig. 2. Abdominal images of appendicitis. A - abdominal plain radiography showing distension of the caecum with faecal loading image. B - abdominal ultrasound showing an enlarged appendix with a thick wall. C - Doppler ultrasound showing an inflamed appendix D - computed tomography of a patient with appendicitis. Observe the faecal loading in the caecum.

appendiceal size in an adult patient is 3–10 mm. Thus, using an appendiceal threshold size of 9 mm is more accurate for diagnosis of appendicitis. The same radiographic image of faecal loading inside a dilated caecum may be visualised at CT in presence of acute appendicitis (Fig. 2D).[6,8]

7.4. Magnetic resonance (MR)

MR imaging is emerging as an alternative to CT in pregnant patients and in patients who have an allergy to iodinated contrast material. MR imaging has a limited role in the work-up of suspected appendicitis. Although the use of MR imaging avoids ionising radiation, it has several disadvantages, including high cost, long duration of studies, and limited availability on an emergent basis. According some authors, the use of MR imaging is limited to pregnant patients in whom ultrasound is inconclusive. On MR imaging, the appendix is identified as a tubular structure with intraluminal T1 and T2 prolongation. Appendicitis is diagnosed using thresholds of the size used for CT. Inflammatory changes are visualized as T2 hyperintensity in the periappendiceal fat.

There are no known adverse effects of MR imaging in human pregnancy, but the safety of MR imaging has not been proven unequivocally. Although tissue heating from radiofrequency pulses, acoustic stimulation potentially harm the foetus. It remains there for an indefinite amount of time, excreted by the foetal kidneys and subsequently swallowed by the foetus with amniotic fluid. Although there is no evidence of mutagenic or teratogenic effects of gadolinium in humans, mutagenic effects were seen in animal studies. Therefore a conservative approach avoids using gadolinium when possible in the first trimester.

7.5. Scintigraphy

An inflamed bowel has strong chemotactic properties, and leukocytes actively invade the appendix in acute appendicitis. The migration and accumulation of radioactive leukocytes in the appendix is the basis for this study in patients believed to have acute appendicitis. Indium-111–labelled leukocyte scanning had a sensitivity of 86% and specificity of 93% for the diagnosis of acute appendicitis. Although the majority of these scans were performed at 2 h after injection, occasionally delayed images up to 17–24 h were required.

Technetium-99 m-albumin–colloid–labelled leukocyte (TAC-WBC) scanning appears to be superior to indium-111 because it is less expensive, requires shorter preparation time, requires less delay in time to positive scan (within 2 h), and has a lower radiation-absorbed dose, compared with indium-111. The overall sensitivity of this method is of 89% and its specificity is of 92%. It is not reliable in diagnosing appendicitis in women, with only a 75% sensitivity and 43% positive predictive value in this subgroup. Limitations of radionuclide-labelled leukocyte scanning include cost, delay in diagnosis, exposure to radiation, relatively large percentage of indeterminant scans and decreased sensitivity and specificity in women.[1]

8. Final considerations

In spite of disturbances associated with the right side abdominal pain having been described since centuries ago under many different names and presumable pathophysiologies, the appendicitis is still a disease full of mysteries. Many thousands researches have been developed on all fields related to the appendix, but it is still not known the role of this organ and what is the exact pathophysiology of appendicitis. All theories are controversial and no symptom or sign may be ascribed to acute appendicitis as patognomonic. Thus the diagnosis of this inflammatory disease continues to be a medical challenge.

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Conflict of interest

There is no conflict of interest related to this article.

Author contribution

Andy Petroianu is the only author and all the revision, writing and presentation of this manuscript were performed by himself. All pictures were from his personal archive.

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