

Methodological Ultrasound Approach and Imaging Evaluation of Stages of Acute Appendicitis in Children: A Pictorial Review

Dr. Mohammed Asrari Gaffoor¹, Dr. Prashant G Patil², Dr. Darshita Basappa³

¹Post Graduate, Department of Radio - Diagnosis, Akash Institute of Medical Sciences and Research Center, Bangalore

²MDRD, Professor and HOD, Department of Radio - Diagnosis, Akash Institute of Medical Sciences and Research Center, Bangalore

³MDRD and DNB, Assistant Professor, Department of Radio - Diagnosis, Akash Institute of Medical Sciences and Research Center, Bangalore

Abstract: *Acute appendicitis is one of the most common surgical causes of acute abdomen requiring emergent surgery. Delay in diagnosis / incomplete evaluation can either lead to progression to complicated appendicitis or increase likelihood of negative appendectomies. Ultrasound (USG) staging can triage treatment options for appendicitis by directing emergent laparoscopic appendectomy for uncomplicated cases, open appendectomy for complicate cases, and conservative management (antibiotics with percutaneous drainage) for perforated appendicitis with abscess formation. The severity of appendicitis was classified according to layer patterns of the appendiceal wall as described by Yuasa in 1986.*

Keywords: Appendicitis, Ultrasound staging, Surgical options, Diagnosis delay, Appendiceal wall

1. Learning Objectives

- To describe a step wise ultrasound (USG) methodology for suspected acute appendicitis.
- To illustrate USG features of progressive stages of appendicitis (uncomplicated to complicated disease).

2. Imaging Features

Step wise approach for a comprehensive evaluation of appendix.

- Small bowel loops are displaced by gentle compression of the abdominal wall using the high frequency US probe.
- The ascending colon is visualised as a non peristalsing structure containing gas and fluid in the right flank.
- The probe is then moved inferiorly toward the caecum, the appendix should be visualised arising from it, separate to the terminal ileum i. e. a compressible structure undergoing peristalsis.

Definition:

Appendicitis is characterized by inflammation of the vermiform appendix and typically presents acutely within 24 hours. However, the presenting symptoms may be more indolent and less severe in cases with perforation with a contained abscess. (1, 2, 3, 4)

Notably, acute appendicitis is the leading cause of abdominal surgery in children and the most prevalent abdominal surgical emergency worldwide. (5, 6)

Understanding the clinical features and distinctive nature of appendicitis is vital in providing timely care and preventing complications associated with this common condition.

Epidemiology Incidence:

The incidence of appendicitis is approximately 233 per 100,000 population per year, with a lifetime incidence risk ranging from 6.7 to 8.6%. (7, 8)

Clinical Presentation:

Acute appendicitis typically begins with diffuse or periumbilical abdominal pain, which is initially vague due to the stimulation of visceral T8 - T10 afferent nerve fibers. As the inflammation progresses, the pain becomes localized to the right lower quadrant, corresponding to irritation of the parietal peritoneum in the adjacent area. This pain may worsen with movement, such as walking or coughing, and can even wake patients from sleep. Along with the abdominal pain, individuals may also experience anorexia, nausea (with or without vomiting), diarrhea, malaise, and urinary frequency or urgency. (9)

Method of Examination

A comprehensive USG evaluation of appendicitis should involve tracing the appendix from base to tip, measurement of maximal diameter, assessing the integrity of submucosal layer, periappendiceal changes and presence of appendicolith.

Stages of Appendicitis

A key microscopic feature of acute appendicitis is the presence of neutrophilic infiltration in the appendiceal muscularis propria. The extent and severity of the inflammation observed are directly related to the infection's severity and the duration of the disease. As the condition advances, the inflammation spreads to the appendiceal fat and surrounding tissues. (10)

Acute appendicitis is classified into three main categories based on histopathological findings: suppurative (or phlegmonous), gangrenous, and periappendicitis.

Suppurative or phlegmonous appendicitis is marked by neutrophilic infiltration across the appendiceal mucosa,

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submucosa, and muscularis propria. The inflammation affects the entire appendiceal wall and may lead to significant ulceration. Additionally, intramural abscesses and vascular thrombosis can be present. The gross appearance of suppurative appendicitis is variable, though common findings include poorly - defined serosa, appendix dilation, surface blood vessel congestion, and fibrinopurulent serosal exudate. However, an enlarged appendiceal diameter alone is not definitive and must be considered alongside other clinical and histopathological features.

Gangrenous appendicitis is characterized by necrosis of the appendix wall. If untreated, this condition may lead to

perforation. In cases where perforation occurs, transmural inflammation, areas of necrosis, and extensive mucosal ulceration are evident. Perforation is thus a complication of untreated gangrenous appendicitis. Grossly, the appendix wall may appear friable and take on purple, green, or black hues.

Periappendicitis primarily involves serosal and subserosal inflammation without extending into the muscularis propria. The gross appearance of periappendicitis varies from normal serosa to congestion, accompanied by exudative infiltration. (11)

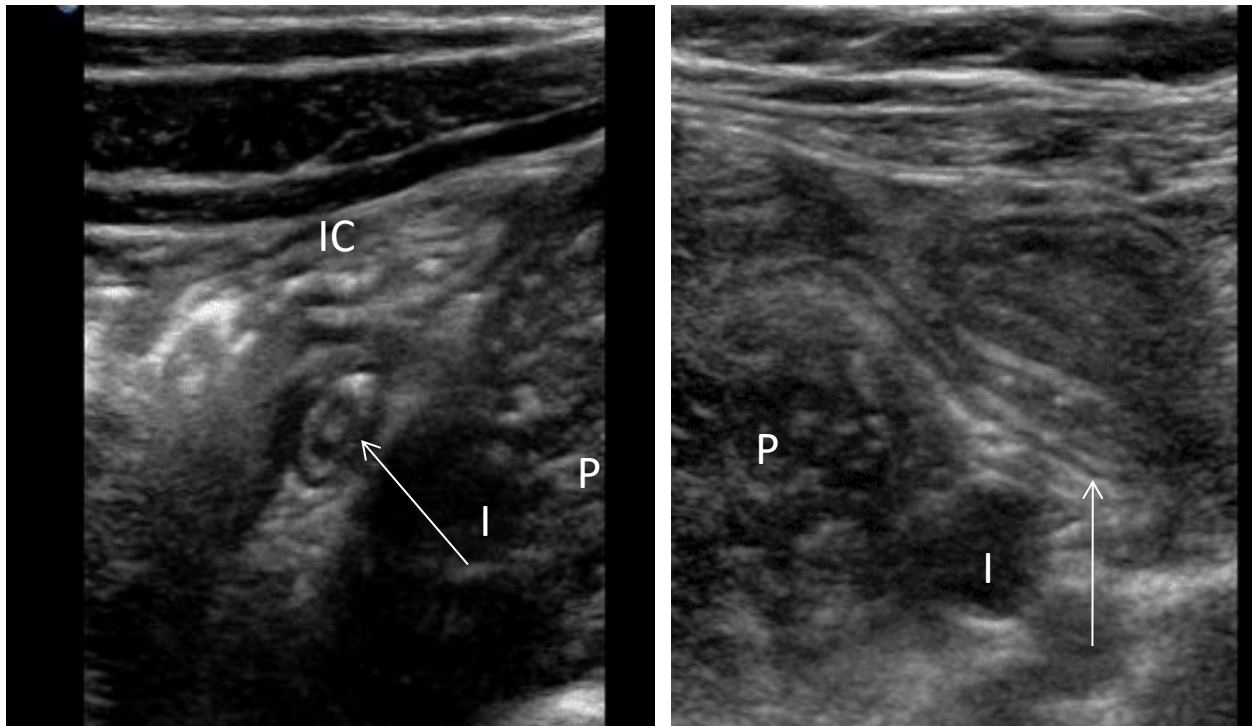


Figure 1: (A & B) High frequency transducer shows normal IC junction & normal appendix (white arrow). P – psoas muscle, I – iliac vessel

Stage 1

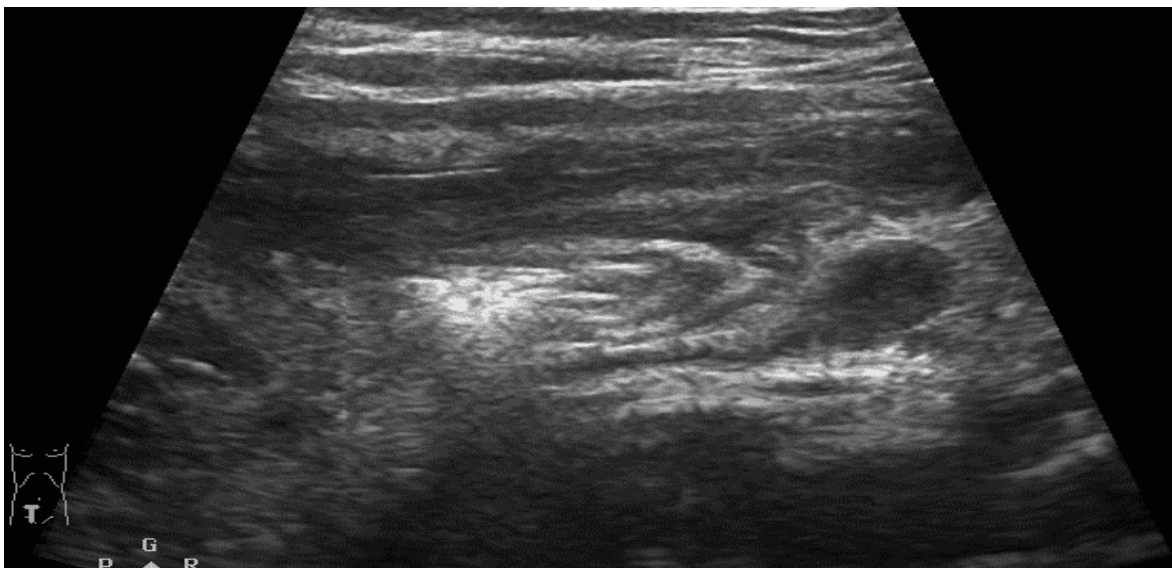


Figure 2: Demonstrates a dilated appendix from base to tip in longitudinal plane (measured 8.6mm in diameter) with preserved wall stratification and thin echogenic submucosa. No e/o periappendiceal fluid/ appendicolith

Stage 2

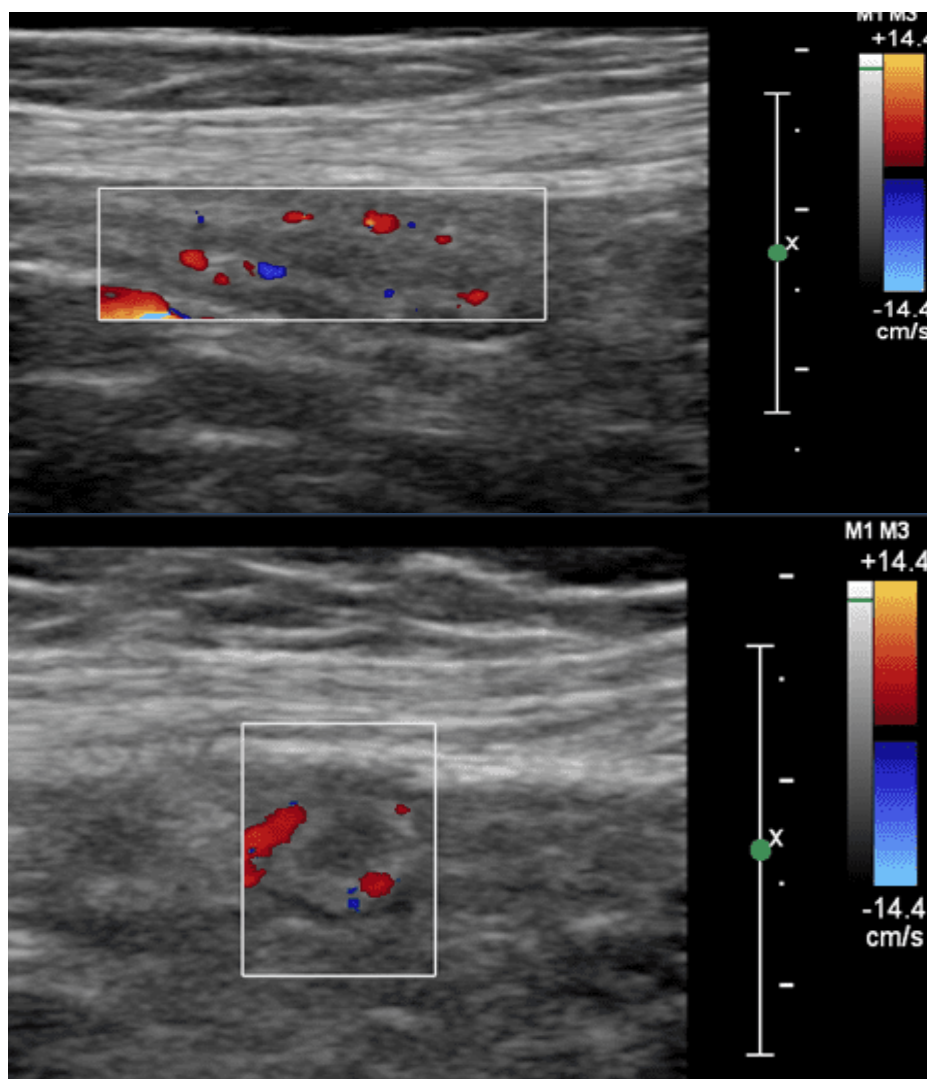
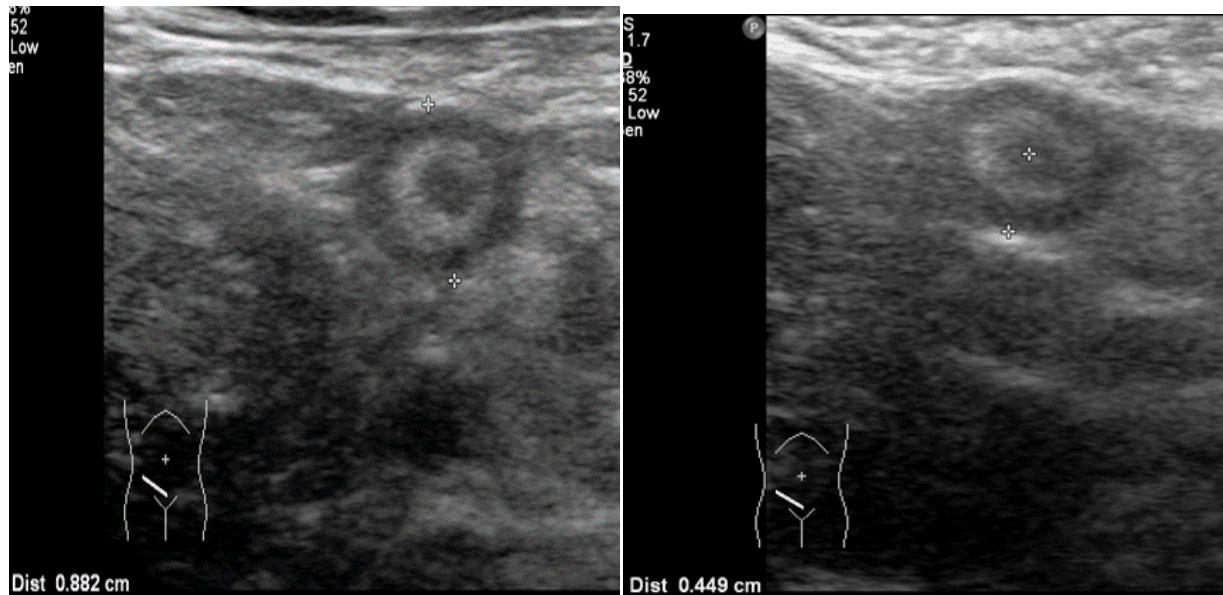


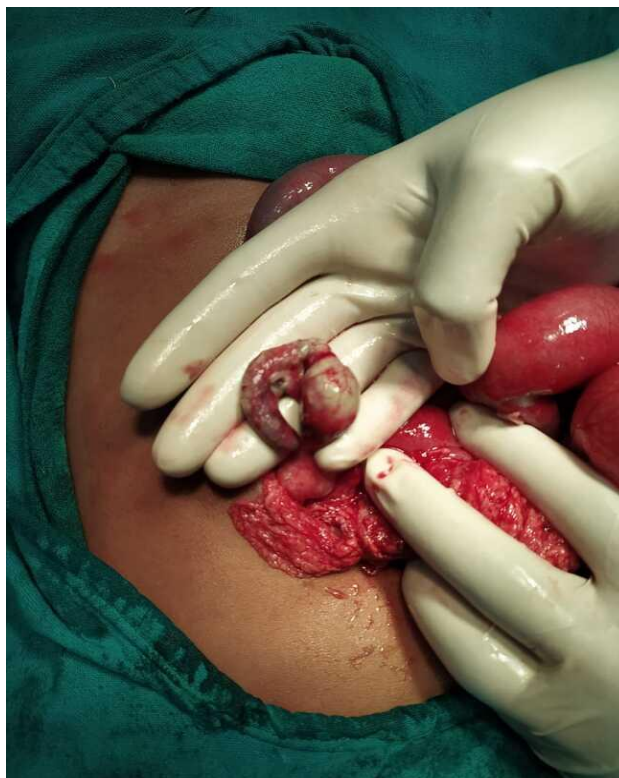
Figure 3: Demonstrates a dilated appendix with outer wall to wall diameter of 0.8cms (A), single wall thickness of 4.4mm (B) on transverse section with thick echogenic submucosa showing increased vascularity on color Doppler flow imaging (CDFI) as shown in C and D - S/O suppurative appendicitis

Stage 3



Gangrenous appendicitis: Focal/ global loss of the echogenic submucosal layer or loss of wall stratification with decreased/ absent vascularity on CDFI.

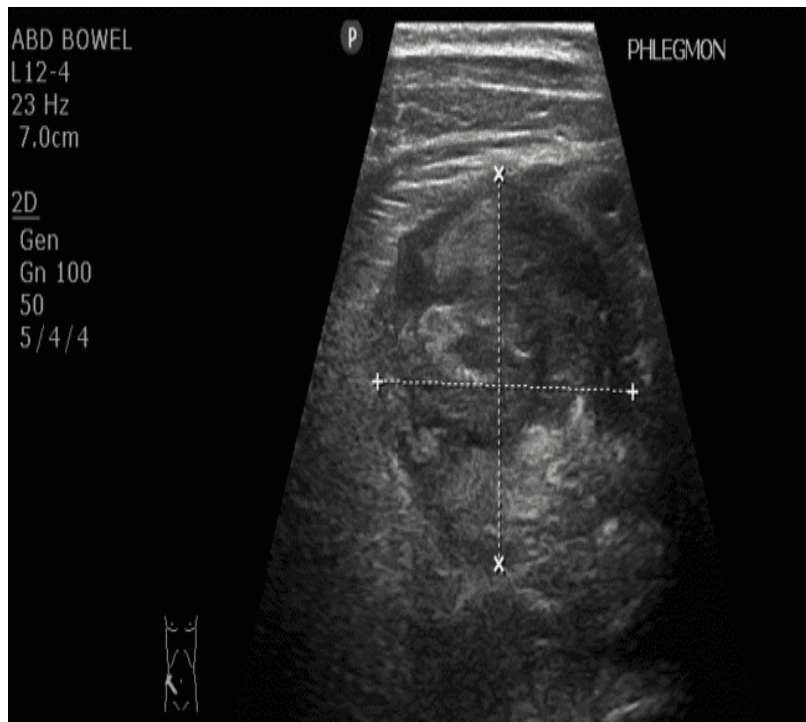
A demonstrates gangrenous appendicitis with loss of wall stratification and a focal wall defect (thick arrow) in the body of dilated appendix, with periappendiceal collection (thin red arrow) and appendicolith at the base (thin yellow arrow).



Intraoperative findings (B) confirmed the USG findings

Stage 4

Perforated appendix with phlegmon/abscess formation: Appendix may be difficult to identify with variable amount of periappendiceal mixed echogenic fluid. A walled - off perforation can progress to form a phlegmon/abscess in the right iliac fossa.



High frequency USG images demonstrate partly visible appendix (thin red arrow) surrounded by a heterogenous mass (thick arrow) formed by surrounding echogenic mesentery, bowel loops and periappendiceal fluid (thin yellow arrow) with echoes. s/o abscess within phlegmon



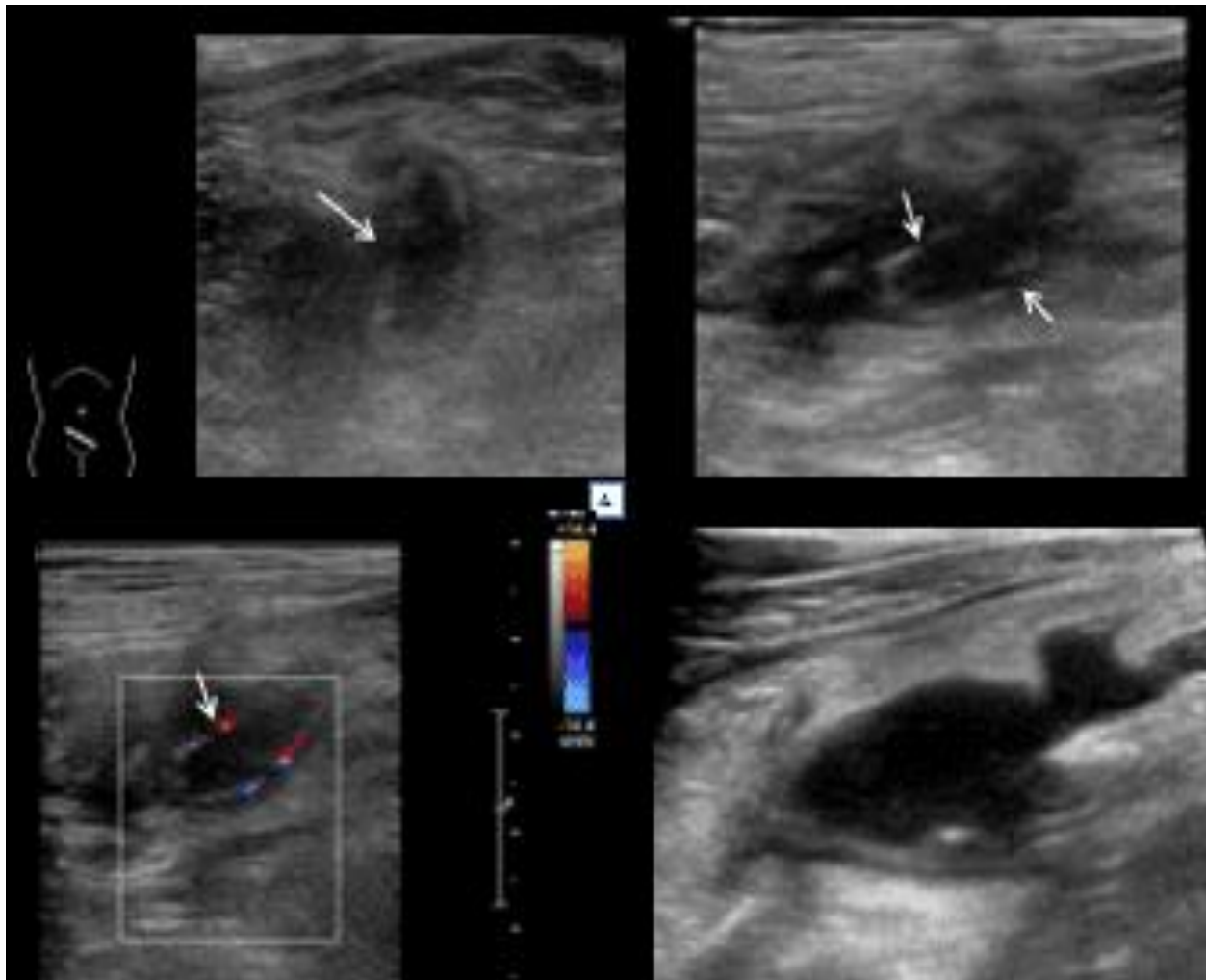


Figure 4: USG with high frequency transducer in another perforated appendix case shows focal defect in appendiceal wall (large white arrow in 1). Loss of echogenic submucosa at multiple areas (small white arrows in 2 and 3) with loss of color in these region (small white arrows in 3). Periappendiceal collection noted. Free fluid in RIF - 4.

3. Complications

The most common complication of appendectomy is an infection of the surgical site; this risk is highest in patients with complicated appendicitis with perforation. Surgical site infections include postoperative abscesses and wound infections. Hematomas and postoperative pain are also common complications of appendectomy. (6)

Recurrent appendicitis can occur in almost half of the patients managed nonoperatively; reported recurrence rates vary by study and length of follow - up. An interval appendectomy may be performed to mitigate the risk of recurrent appendicitis. Another form of recurrent appendicitis is stump appendicitis, resulting from an incomplete appendectomy and subsequent inflammation in the residual appendiceal stump. While stump appendicitis is most often seen following operative management of complicated appendicitis with perforation, it can occur whenever an excessively long appendiceal stump is left in situ. A stump size ≤ 5 mm minimizes the risk of stump appendicitis. Stump resection via an open or laparoscopic approach is the definitive therapeutic option; perforated appendiceal stumps often require extensive bowel resection. (12)

Sepsis and diffuse peritonitis are serious side effects of complex or untreated appendicitis. Significant morbidity and, in certain situations, even death may result from these disorders.

4. Conclusion

Increasing trend towards antibiotic therapy for uncomplicated appendicitis and surgical intervention for complicated cases with gangrenous/perforated appendix has accentuated the role of USG not just in the accurate diagnosis but also in differentiating between various stages of acute appendicitis.

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