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The role of radiology in diagnosing and managing acute appendicitis

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***Abstract*---Background:** Acute appendicitis is the most prevalent abdominal infectious condition, affecting nearly 1 in 11 individuals globally. Despite its commonality, diagnostic approaches remain inconsistent across clinical guidelines. A crucial aspect is the differentiation between uncomplicated and complicated appendicitis, as this influences treatment options. **Aim:** This narrative review evaluates the role of radiological methods—ultrasound (US) and computed tomography (CT)—in the diagnosis and management of acute appendicitis. **Methods:** The analysis focuses on existing literature, emphasizing randomized controlled trials and meta-analyses to compare imaging techniques' effectiveness. It also discusses clinical scoring systems and their integration with imaging features to improve diagnostic accuracy. **Results:** While clinical assessments alone have a high rate of misdiagnosis, imaging techniques significantly enhance diagnostic accuracy. US is non-invasive and radiation-free, but CT provides superior sensitivity and specificity for appendicitis diagnosis. Recent studies indicate that the combination of clinical scoring systems and imaging can optimize patient management, particularly in distinguishing between uncomplicated and complicated cases. **Conclusion:** Both US and CT play pivotal roles in diagnosing acute appendicitis. The integration of imaging techniques with clinical assessments improves diagnostic reliability, ultimately guiding appropriate treatment strategies. As medical practice evolves, a nuanced approach combining clinical scores and imaging is essential to minimize unnecessary surgeries while effectively managing appendicitis.

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***Keywords*---**Acute appendicitis, ultrasound, computed tomography, diagnostic imaging, clinical scoring systems.

Introduction

Appendicitis remains the most common abdominal infectious disease, with a lifetime risk of nearly 1 in 11 individuals worldwide (1). Despite its prevalence, there is still much to explore regarding the optimal diagnostic approach, as guidelines often present varying recommendations (2,3). Over the years, several clinical prediction rules have emerged (4), yet most of these scoring systems focus on risk stratification without integrating imaging features. To complement these clinical scores, selective imaging is often suggested: low-risk scores may negate the need for further investigation, intermediate scores might prompt imaging, and high-risk scores may lead to immediate surgical exploration (3). While some guidelines advocate for clinical scoring systems, others recommend routine imaging for all suspected appendicitis cases (5). Accurate diagnosis of acute appendicitis is crucial, not only for ruling out other causes of abdominal pain but also for distinguishing between uncomplicated and complicated appendicitis. This differentiation is vital as mounting evidence supports the possibility of treating uncomplicated appendicitis with antibiotics rather than surgery (6,7). The underlying principle is that uncomplicated and complicated appendicitis are distinct conditions (8–10). Uncomplicated appendicitis is defined as an inflamed appendix without necrosis or perforation, while complicated appendicitis involves necrosis, which may lead to perforation. Differentiating between these types is essential since uncomplicated cases may be treated conservatively with antibiotics (6,7), or, in some cases, may resolve without intervention (9,11,12). In contrast, complicated appendicitis typically necessitates emergency appendectomy, except for those presenting with a periappendicular abscess (3,13). In this narrative review, we examine various diagnostic methods for acute appendicitis, discuss relevant considerations, and focus on distinguishing between uncomplicated and complicated cases. Our analysis relies primarily on available literature, favoring randomized controlled trials and well-conducted meta-analyses over single cohort studies.

Diagnosis

In the initial diagnostic stage for abdominal pathology, selecting the appropriate diagnostic strategy depends on clarifying the primary goal: either ruling in or ruling out a disease. To rule in a disease, both specificity and positive predictive value (PPV) need to be high. On the other hand, for ruling out a disease, sensitivity and negative predictive value (NPV) should be prioritized. It is important to note that there is often a trade-off between sensitivity and specificity, meaning that increasing one may reduce the other. Hence, the diagnostic characteristics of tests must be carefully considered when choosing the best diagnostic approach. In the context of diagnosing acute appendicitis during the first stage, low sensitivity or NPV can result in discharging patients from the emergency room (ER) who actually have appendicitis. This can lead to missed diagnoses and treatment delays. While such delays (up to 24 hours) may significantly affect the postoperative complication rate in uncomplicated

appendicitis, they can lead to more complications in cases of complicated appendicitis (13). Conversely, low specificity or PPV may result in overdiagnosis and contribute to higher negative appendectomy rates (NARs). Therefore, balancing both the need to rule in and rule out appendicitis is essential. In the second diagnostic stage, where the goal is to differentiate between uncomplicated and complicated appendicitis, ruling out complicated appendicitis becomes more critical. If antibiotic treatment is being considered, complicated appendicitis should be excluded to avoid inappropriate conservative treatment. Consequently, high sensitivity and NPV are crucial for ruling out complicated cases. Ruling in complicated appendicitis is less critical, as patients with a false positive diagnosis for complicated appendicitis—who actually have uncomplicated appendicitis—would still undergo surgery, which remains the current standard treatment for any acute appendicitis.

Diagnostic Work-Up for Acute Appendicitis

The diagnostic work-up for suspected acute appendicitis varies significantly across different guidelines and countries, resulting in discrepancies in negative appendectomy rates (NARs)or the use of clinical scoring systems, while others rely solely on the clinical assessment by the treating physician or recommend standardized imaging for all patients or a select group.

Clinical View

Tndicitis is based on clinical assessment, which includes history taking, physical examination, and laboratory findings. However, this approach has high intra-observer variability and lacks perfect accuracy. A study revealed that both surgical trainees and experienced surgeons failed to correctly diagnose acute appendicitis in 44% and 43% of cases, respectively, when relying solely on medical history, physical examination, and routine laboratory tests, without imaging. The sensitivity and specificity for diagnosing acute appendicirom 76% to 85% and 82% to 87% for trainees and surgeons, respectively. Consequently, if clinical assessment alone is used, 15% to 24% of acute appendicitis cases may be missed, leading to an NAR of 13% to 18%, which exceeds the ideal upper limit of 5%. Therefore, it is insufficient to rule in or rule out appendicitis based solely on clinical assessment.

Laboratory Tests

Laboratory tests, including white blood cell (WBC) count and C-reactive protein (CRP) levels, are commonly employed as adjuncts to clinical examination in diagnosing acute appendicitis. Individually, these inflammatory markers exhibit weak discriminatory cap but their combination can enhance diagnostic accuracy. However, a prospective study involving 1,024 patients with clinical suspicion of acute appendicitis indicated that this combination is still inadequate for reliably ruling in or ruling out appendicitis. By exploring different cut-off values, a maximum NPV of 88% was achieved for rulindicitis; however, this was applicable only to a small subgroup (9.9%) of patients with WBC $<10 \times 10^9$/L or CRP <10 mg/L. For other patient categories, the NPV is less optimal, making laboratory tests alone an unreliable strategy for ruling out appendicitis. Similarly,

for ruling in appendicitis, the PPV reached a maximum of 74.2% in patients with WBC >20 × 10^9/L, but this group comprised only 6.1% of the cohort. Thus, relying solely on laboratory tests for diagnosing appendicitis is problematic, given that CRP and WBC are general and non-specific inflammatory markers.

Clinical Scoring Systems

To mitigate subjective interpretations of clinical signs and laboratory results, standardized clinical risk scores have been developed. The Alvarado score is one of the most recognized scoring systems based on clinical parameters for diagnosing acute appendicitis. However, more recent scoring models have emerged. The 2020 update of the WSES Jerusalem guidelines for the diagnosis and treatment of acute appendicitis recommends the use of the Appendicitis Inflammatory Response Score (AIRS) and the Adult Appendicitis Score (AAS) as diagnostic tools for acute appendicitis. These structured models aim to enhance diagnostic accuracy by systematically incorporating arameters and laboratory findings, thereby improving decision-making in suspected cases of acute appendicitis.

Low-Risk for Appendicitis (Rule Out)

A diagnostic score may classify a subgroup of patients as “low-risk for acute appendicitis,” facilitating the accurate ruling out of the condition. A recent study validated 15 scoring systems for identifying low-risk patients among those presenting with acute right iliac fossa (RIF) pain in the United Kingdom. The ideal scoring system should exhibit high specificity while maintaining a failure rate (1-NPV) of less than 5%. In essence, an effective appendicitis score should (1) accurately classify patients without appendicitis as “no appendicitis” (with a maximum acceptable failure rate of 5%) and (2) correctly identify patients with appendicitis as “appendicitis” in terms of optimal specificity. The best model has undergone external validation using datasets from other European countries. In a British cohort of 3,613 women, the Adult Appendicitis Score (AAS) performed best, achieving a specificity of 63.1% with a cut-off score of 8 or less, resulting in a failure rate of only 3.7%. This implies that, according to the AAS, only 69 out of 1,856 patients categorized as low-risk for acute appendicitis were found to actually have the condition. However, external validation in other countries yielded a failure rate of up to 17.5%. Among 1,732 male British patients, the Appendicitis Inflammatory Response Score (AIRS) outperformed the AAS, with a failure rate of 2.4% and a specificity of 24.7% at a cut-off score of 2 or less. Nonetheless, this failure rate increased during validation in cohorts from other countries, reaching as high as 32%. The RIFT study group cautions that their findings “should be extrapolated cautiously to settings outside the UK” . Thus, despite the promising results from the RIFT study group in the UK cohort, relying on a clinical scoring system alone to rule out appendicitis is not robust across different populations and does not differentiate between complicated and uncomplicated appendicitis.

High-Risk for Appendicitis (Rule In)

In contrast, ruling in appendicitis involves identifying patients classified as “high-risk for acute appendicitis.” The WSES guideline recommends that cross-sectional imaging may be avoided in patients younger than 40 years who present with a high-risk appendicitis score, allowing for diagnostic laparoscopy. High-risk patients are defined as those with an AIR or Alvarado score of 9 or higher, or an AAS of 16 or higher. However, there is a lack of meta-analytic data on ruling in acute appendicitis based on clinical risk scores. Several studies have validated scoring models for identifying high-risk appendicitis patients: four studies focused on the Alvarado score, five on the AIRS, and two on the AAS, with results varying widely. A bivariate logit-normal random-effect model was employed to pool the results of the included studies; the reported sensitivity and specificity were 24% and 97% for the Alvarado score, 22% and 97% for the AIRS, and 53% and 93% for the AAS, respectively. Given a median prevalence of acute appendicitis of 37%, this leads to a PPV of 82% for the Alvarado score, 81% for the AIRS, and 82% for the AAS. While high specificity is achieved, these PPVs can result in NARs of 18% to 19% when the final diagnosis is made solely based on these clinical diagnostic rules. Regular use of imaging has been shown to reduce negative appendectomies, thereby lowering avoidable risks for patients.

The Three-Test Zone Concept (Low-, Intermediate-, and High-Risk Scores)

The concept of three test zones, which includes two cut-off points for appendicitis scores to determine the necessity for imaging, appears promising. However, more reproducible data across different cohorts is needed to demonstrate stable performance before such a clinical decision rule can replace imaging. Even if patients are categorized as “high risk” for acute appendicitis using a three-zone clinical score, employing a low-dose computed tomography (CT) scan (or a step-wise conditional CT after initial ultrasound) is likely less harmful than proceeding with standard “diagnostic” surgery. Surgery performed without prior imaging has higher NARs compared to those following a standard imaging approach. This is evidenced by two prospective national SNAPSHOT audits. In a study of 1,934 Dutch patients, where 99.5% underwent preoperative imaging, the NAR was only 3.2%. Conversely, in a cohort of 3,326 British patients, only 32.8% received preoperative imaging, leading to a significantly higher NAR of 20.6%.

Imaging for Acute Appendicitis Diagnosis

Standardized imaging is crucial for accurately diagnosing acute appendicitis, with ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) serving as primary modalities. Using conventional US equipment, the appendix can be visualized through a graded compression technique. Contrast-enhanced CT scans, particularly in the portal-venous phase, are frequently employed (15). Research indicates that low-dose, intravenous contrast-enhanced CT provides diagnostic accuracy comparable to standard-dose CT and should be prioritized (28, 29). Typically, CT protocols utilize helical scanners, either single or multi-detector, with slice thicknesses of 3–5 mm and intervals of 3–10 mm (30, 31). MRI can also be utilized, commonly employing a 1.5T MRI using half-Fourier acquisition single-shot turbo spin-echo (HASTE) sequences alongside T1, T2, and

T2 fat suppression sequences (15, 32). While the use of intravenous contrast in MRI is an option, it is not a routine practice (15, 32). Although US is generally cost-effective, rapid, and free from ionizing radiation, CT and MRI yield superior diagnostic outcomes. A meta-analysis by Giljaca et al. (33) reveals that US alone has a sensitivity and specificity of 69% and 81% for acute appendicitis, respectively. In contrast, meta-analyses by Van Randen et al. (30) and Duke et al. (32) indicate that CT and MRI outperform US, achieving sensitivities of 91% for CT and 97% for MRI, with specificities of 90% and 96%, respectively. Reported median prevalences for US, CT, and MRI are 76%, 50%, and 58%, respectively. Due to the potential for pre-selection biases resulting in higher appendicitis prevalence, direct comparisons of these imaging studies with clinical diagnostic scores may be misleading. For practical test characteristics such as positive predictive value (PPV) and negative predictive value (NPV), this prevalence is critical. For example, a highly specific test in a low-prevalence population may yield a low PPV but a high NPV. Conversely, within a high-risk cohort, a low NPV may correspond with a high PPV. Incorporating the aforementioned prevalences, PPV and NPV calculations yield 92% and 45% for US, 90% and 91% for CT, and 97% and 96% for MRI. When applying clinical scoring systems to a population suspected of appendicitis with a prevalence of 50%—similar to the prevalence in the CT study cohort—results show PPVs and NPVs of 89% and 56% for the Alvarado score, 88% and 55% for the AIRS, and 88% and 66% for the AAS. Therefore, the diagnostic characteristics of CT and MRI significantly surpass those of the three clinical scoring systems.

A more effective strategy may involve a diagnostic approach where an initial US is conducted, followed by conditional CT or MRI in cases of inconclusive or negative US results (34). Leeuwenburgh et al. demonstrated that the combined use of US and CT achieved a sensitivity and specificity of 97% and 91% for appendicitis diagnosis. With a published study prevalence of 51%, a conditional CT strategy produced a PPV of 92% and an NPV of 97%. In the case of US with conditional MRI, the sensitivity, specificity, PPV, and NPV were 98%, 88%, 88%, and 98%, respectively (34). Nonetheless, there are limitations to consider. US can exhibit high inter-observer variability, leading to discrepancies in diagnostic accuracy among radiologists. The use of CT involves exposure to radiation and intravenous contrast, which should be minimized in fertile females, children, and young adults when possible. However, low-dose CT has demonstrated comparable accuracy (28, 29, 35), significantly reducing the risk of radiation-induced cancer. Although contrast allergies and nephropathy are rare, the interpretation of MRI often requires additional training for radiologists, which can be improved through feedback after evaluating a limited number of cases (36). Despite these improvements, MRI has longer in-room times, presents logistical challenges, and may not be available around the clock. The costs associated with imaging are also significant; although they involve higher initial expenses, standard imaging is ultimately cost-effective (37) and can reduce the negative appendectomy rate (NAR) (14).

Differentiating Complicated - Uncomplicated Appendicitis

Current guidelines do not provide clear recommendations for distinguishing between uncomplicated and complicated appendicitis (2, 3). However, they

emphasize the need for more urgent treatment of complicated appendicitis, while uncomplicated cases may be managed with antibiotics alone (2, 3). This variance in treatment strategies underscores the importance of accurately differentiating between the two forms of appendicitis. Establishing uniform criteria for identifying findings suggestive of complicated appendicitis is essential, as is identifying predictive factors for conservative treatment failure in patients initially diagnosed with uncomplicated appendicitis. As highlighted earlier, the primary goal is to rule out complicated appendicitis. While numerous studies have investigated the diagnosis of acute appendicitis, few have attempted to differentiate between its uncomplicated and complicated forms. The AIRS and Alvarado scoring systems have been explored for their capability to discriminate between uncomplicated and complicated appendicitis (38–41). However, these studies have not reported diagnostic accuracy measures, making sensitivity and specificity calculations unfeasible. Two additional studies have proposed scoring systems that incorporate clinical and biochemical features but also did not report diagnostic accuracy measures (42, 43). Imaging appears to play a pivotal role in distinguishing uncomplicated from complicated appendicitis. A recent meta-analysis identifies CT characteristics, such as abscess presence, extraluminal air, appendicolith, and periappendicular fluid, that correlate with complicated acute appendicitis (44). Despite achieving high specificity, these parameters lack sufficient sensitivity (44), rendering them inadequate for reliably ruling out complicated appendicitis. Only two studies have introduced scoring systems that integrate clinical and imaging features to differentiate uncomplicated from complicated appendicitis (45, 46). Atema et al. (45) developed two Scoring systems for Appendicitis Severity (SAS), one based on US features (SAS-US) and the other on CT features (SAS-CT). The diagnostic metrics for US-SAS are 97% sensitivity, 46% specificity, 42% PPV, and 97% NPV (45). For SAS-CT, the corresponding values are 90% sensitivity, 70% specificity, 55% PPV, and 95% NPV (45). Although the SAS scoring systems exhibit excellent diagnostic characteristics with high sensitivity and NPV for ruling out complicated appendicitis, their ability to confirm complicated appendicitis is limited. Avanesov et al. (46) introduced the APpendicitis Severity Index (APSI), combining clinical, biochemical, and CT features, achieving sensitivity, specificity, PPV, and NPV of 82%, 93%, 92%, and 83%, respectively. This scoring system provides the necessary diagnostic characteristics (high specificity and PPV) for accurately ruling in complicated appendicitis. A significant limitation of these scoring systems is the lack of external validation through prospective studies.

Conclusion

This narrative review highlights the significant role of radiology in the diagnosis and management of acute appendicitis, emphasizing the need for an integrated approach that combines clinical assessments with imaging techniques. Acute appendicitis, despite being in common condition, presents diagnostic challenges that can lead to unnecessary surgeries and delayed treatments. The differentiation between uncomplicated and complicated appendicitis is critical, as it directly affects treatment decisions, with uncomplicated cases often amenable to conservative management with antibiotics. The review underscores that clinical assessments, while essential, frequently suffer from high variability and misdiagnosis rates. Studies indicate that reliance solely on clinical evaluation can

result in a significant number of missed diagnoses, with negative appendectomy rates exceeding acceptable limits. To counter these issues, imaging techniques such as ultrasound and computed tomography provide essential adjuncts to clinical assessments. Ultrasound, being cost-effective and free from ionizing radiation, is a valuable first-line tool, particularly in pediatric populations. However, computed tomography, particularly low-dose CT, emerges as the gold standard for its superior sensitivity and specificity in confirming appendicitis. Furthermore, the incorporation of clinical scoring systems, such as the Appendicitis Inflammatory Response Score and the Adult Appendicitis Score, aids in stratifying patients based on risk, thus guiding the use of imaging. While scoring systems can classify patients as low or high risk for appendicitis, they should not replace imaging but rather serve as complementary tools. Future directions in the field of appendicitis diagnosis may involve refining these scoring systems and establishing more standardized imaging protocols across healthcare settings. Emphasizing a multidisciplinary approach involving surgeons, radiologists, and primary care providers can enhance diagnostic accuracy, reduce negative appendectomy rates, and optimize patient outcomes. Ultimately, an evidence-based, integrated strategy combining clinical judgment and advanced imaging techniques is essential for improving the management of acute appendicitis and ensuring timely and appropriate care for patients.

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دور الأشعة في تشخيص وإدارة التهاب الزائدة الدودية الحاد

الملخص

الخلفية : يُعد التهاب الزائدة الدودية الحاد أكثر الحالات المعدية شيوعًا في البطن، حيث يصيب ما يقارب ١ من كل ١١ شخصًا على مستوى العالم. على الرغم من شيوعه، تظل الأساليب التشخيصية غير متسقة عبر الإرشادات السريرية. يتمثل أحد الجوانب الحاسمة في التمييز بين التهاب الزائدة الدودية البسيط والمعقد، حيث يؤثر هذا التمييز على خيارات العلاج.

الهدف : تُقيّم هذه المراجعة السردية دور الأساليب الإشعاعية، مثل التصوير بالموجات فوق الصوتية (US) والتصوير المقطعي المحوسب(CT) ، في تشخيص وإدارة التهاب الزائدة الدودية الحاد.

الطرق : تركز التحليلات على الأدبيات الموجودة، مع التأكيد على التجارب العشوائية المضبوطة والتحليلات الفوقية لمقارنة فعالية تقنيات التصوير. كما تناقش أنظمة التقييم السريري وتكاملها مع خصائص التصوير لتحسين دقة التشخيص.

النتائج : في حين أن التقييمات السريرية وحدها تُظهر معدلات عالية من التشخيص الخاطئ، فإن تقنيات التصوير تُحسّن بشكل كبير من دقة التشخيص. يتميز التصوير بالموجات فوق الصوتية بكونه غير غازي وخاليًا من الإشعاع، ولكن التصوير المقطعي المحوسب يوفر حساسية ونوعية أعلى لتشخيص التهاب الزائدة الدودية. تشير الدراسات الحديثة إلى أن الجمع بين أنظمة التقييم السريري والتصوير يمكن أن يُحسّن إدارة المرضى، لا سيما في التمييز بين الحالات البسيطة والمعقدة.

الخاتمة : يلعب كل من التصوير بالموجات فوق الصوتية والتصوير المقطعي المحوسب أدوارًا محورية في تشخيص التهاب الزائدة الدودية الحاد. يُساهم تكامل تقنيات التصوير مع التقييمات السريرية في تحسين موثوقية التشخيص، مما يوجه استراتيجيات العلاج المناسبة. ومع تطور الممارسات الطبية، يُصبح النهج المتكامل الذي يجمع بين التقييمات السريرية والتصوير ضروريًا لتقليل العمليات الجراحية غير الضرورية مع إدارة فعالة للحالات.

الكلمات المفتاحية : التهاب الزائدة الدودية الحاد، الموجات فوق الصوتية، التصوير المقطعي المحوسب، التصوير التشخيصي، أنظمة التقييم السريري.