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Systematic Review

Accuracy of Ultrasound and CT scans in the Diagnosis of Acute Appendicitis in Children: A Systematic Review

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Abstract

Acute appendicitis (AA) is the most common surgical emergency in childhood. Accurate and early diagnosis is important because any delay in diagnosis may lead to perforation or abscess formation. Today, abdominal ultrasonography (US) and computed tomography (CT) scans are the most common imaging methods used for diagnosis. The aim of this study was to evaluate the accuracy of US and CT scans in the diagnosis of AA in children. We started our research by using online libraries as our database. We searched PubMed, Google Scholar, the Cochrane Library, and the Web of Science for our data collection. We used both the medical subject headings (MESH) and regular keywords. Our review investigated English-language articles regarding the accuracy of US and CT scans in the diagnosis of AA in children (2013-2023) according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Articles were screened by title, abstract, inclusion and exclusion criteria, and quality assessment tools. The search identified 513 studies; eight were eligible for inclusion in the analysis. A total of 3341 pediatric patients were included across the eight observational studies in our systematic reviews. The included articles revealed that low-dose CT showed the highest accuracy in the diagnosis of AA. Whereas the US showed the lowest. However, the combination of US as the primary examination followed by CT in a non-diagnostic US yielded the highest sensitivity, specificity, and accuracy. Also, some studies revealed that several factors decreased the sensitivity of CT and US in diagnosing AA in children, like different hospital settings, the radiologist's experience, age, sex, body mass index, and disease severity. According to the review articles, a CT scan is the most accurate test and has high sensitivity and specificity; however, the radiation hazards are minimized using a CT scan as a primary tool for diagnosis. US is easily accessible, cost-effective, and has high sensitivity. However, it is operator-dependent, has low specificity, and is incompatible with some young children, so it can be used as a first-choice and low-dose CT scan in complicated cases and non-diagnostic US. Ideally, more randomized clinical trials are also required.

Introduction and Background

Acute appendicitis is the most common surgical emergency in the pediatric age group (1). Appendicitis, however, is often challenging to diagnose due to its varied presentation in terms of symptoms, signs, and predictive laboratory values. Particularly in the pediatric population, diagnosis is more difficult due to the communication barrier and poor coordination during abdominal examinations (2). Also, history-taking and physical examination cannot be relied on in most cases due to anatomical variation of the appendix and atypical clinical symptoms such as irritability, diarrhea, absence of guarding and rebound tenderness. Thus, the diagnosis may be delayed or even missed at initial presentation, possibly leading to complications such as perforation, abscess formation, and peritonitis and resulting in increased morbidity and mortality (3, 4). Therefore, an early and accurate diagnosis of appendicitis is critical in pediatric patients because it will decrease the rate of peritonitis, postoperative complications, negative appendicectomies, and cost to the patient.

There are several findings used to diagnose acute appendicitis, such as leucocytosis, elevated C-reactive protein, abdominal X-rays, and the Alvarado scoring system; however, all of these tests are non-specific and cannot be used to make an accurate diagnosis (5). Radiographic imaging studies such as ultrasound and computed tomography are frequently ordered to aid in the diagnosis of patients who present with symptoms consistent with acute appendicitis. However, the diagnostic accuracy of these images is unclear. A preoperative abdominal pelvic CT scan is highly sensitive, specific, and widely available (6). However, it is expensive and associated with radiation exposure, up to 25 mSv per study (7). Abdominal ultrasound is cost-effective, easily accessible, highly specific, and lacks radiation exposure; however, ultrasound is operator-dependent, and its sensitivity is variable (8) and availability is less consistent (9,10). Also, we cannot safely exclude appendicitis, especially in high-risk and complicated patients, even if the result of the US is negative [11].This article presents a systematic review of various studies to provide a better basis for assessing the accuracy of US and CT scans in the diagnosis of appendicitis in children.

Review

Methodology

We conducted our systematic review using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines [12]

Databases
We started our research on November 17, 2023, using online libraries as our database. We searched PubMed, Google Scholar, the Cochrane Library, and the Web of Science for our data collection.

Search Strategy
The following electronic databases were searched in order to conduct a systematic literature review: PubMed, Google Scholar, Cochrane Library, and Web of Science. In the PubMed database, we used both the medical subject headings (MESH) and regular keywords and combined them together with the use of boolean operators. In the Cochrane Library, Google Scholar, and Web of Science, we only used regular keywords for our search strategy. To eliminate duplication, the search results were imported into Endnote. The articles were initially screened at the title/abstract level, and then the whole text was reviewed. The most relevant papers were selected for the analysis after inclusion and exclusion criteria and quality assessment tools were applied.

Our online database search results and keywords is summarized in the table 1.

	Keyword/MESH keyword	Database	Search result number	
	"Appendicitis" OR "acute appendicitis" OR "appendiceal inflammation") AND ("Pediatrics" OR "Child" OR "Adolescent" OR children OR pediatric OR adolescent OR infant OR youth) AND ("Tomography, X-Ray Computed" OR "CT scan" OR "computed tomography" OR "CAT scan") AND ("Ultrasonography" OR ultrasound OR sonography OR ultrasonographic) AND (diagnosis OR diagnostic OR diagnosing) AND (accuracy OR sensitivity OR specificity OR "diagnostic accuracy")	PubMed	110	
	Appendicitis and CT scan and US and imaging or diagnostic imaging and accuracy and child	Google Scholar	115	
	Appendicitis, and CT, and ultrasonography, and pediatric or child	Web of Science	211	
	Appendicitis and CT scans, and US and children	Cochrane Library	77	

Table 1: Database search results and keywords

Inclusion Criteria
Our inclusion criteria were all full-text, peer-reviewed articles evaluating the accuracy of US and CT scans in diagnosing appendicitis in pediatrics in the English language published in the last ten years. We included observational studies conducted on humans.

Exclusion Criteria
We excluded gray literature and animal studies. We also excluded studies done before ten years and published in non-English language. We also excluded narrative reviews, case reports or series, systematic reviews, and meta-analyses.

Quality Assessment Tools
We used the New Castle Ottawa questionnaire for observational studies. And we excluded studies that were of low quality and had a high risk of bias.

Data Collection
Of the 513 studies that were found through the search, eight papers were qualified for analysis after removing duplicates, screening by title, abstract, and full-text reading, using inclusion and exclusion criteria, and evaluating for quality assessment.

Result
After a thorough online search in four major databases, we found 513 articles: 110 were from PubMed, 77 were from the Cochrane Library, 115 were from Google Scholar, and 211 were from the Web of Science. Out of 513, 16 were excluded due to duplicates. We screened 497 articles by title and abstract and excluded 460; 37 were left for retrieval. After reading the full text, five were excluded because there were no full-text articles. As a result, 32 articles were left and went through eligibility criteria, and 24 were excluded after using exclusion, inclusion criteria, and quality assessment tools. At the end, eight full-text, relevant observational studies were included for review.

Our online process to find relevant articles for this systematic review is summarized in the PRISMA chart in Figure 1.

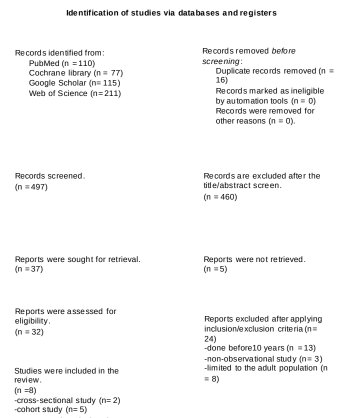

Figure 1: Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) 2020 flow diagram.

We employed the Newcastle-Ottawa questionnaire for quality assessment of the remaining eight observational studies. Table 2 displays the assessment for the eight articles.

Study	Year	Selection	Comparability	Outcome	Overall(max9)
Ashjaei et al. [13]	2022	****	*	***	8, Good
Baykara et al. [14]	2023	**	*	***	6, Good
Kim et al. [15]	2020	***	*	***	7, Good
Miano et al. [16]	2015	***	*	***	7, Good
Nishizawa et al.[17]	2018	***	*	***	7, Good
Saito et al.[18]	2013	**	*	***	6, Good
Sayed et al.[19]	2017	****	*	***	8, Good
Schuh et al.[20]	2015	****	*	***	8, Good

Table 2: Quality assessment of observational studies using the Newcastle-Ottawa questionnaire

The Baseline Characteristics of the Studies Included:
There were eight included studies: two cross-sectional studies, four retrospective cohort studies, one prospective cohort study, and one retrospective case-control study.

The study characteristics of the included studies are shown in Table 3.

Author	Year	Journal	Sample Size	Country	Study Design	Aim of study	Results
Ashjaei, B. [13]	2022	African Journal of Paediatric Surgery	108	Iran	Cross-sectional study	Evaluating the value of different sonographic findings in the diagnosis of AA in children	The sensitivity of the US in diagnosing AA is higher than in other studies, but its specificity is lower. US accuracy and efficacy to diagnose AA in children are high enough to allow clinicians to do it as an imaging modality of first choice and, in problematic cases, to assist in correct clinical diagnosis by avoiding unnecessary X-ray exposure, decreasing negative appendectomies, decreasing perforation rate, and lowering the cost of patients. And second US can greatly assist clinicians in making the correct diagnosis.
Baykara, A. S. [14]	2023	Cureus	263	Turkey	Retrospective cohort study	to evaluate the diagnostic efficacy of US and CT scans for AA in children.	In cases of suspicion of AA, the US may be the first choice because it is inexpensive and easily accessible. However, considering patient incompatibility and subjective factors in children, US may sometimes be insufficient. The CT should be performed as an advanced examination method in cases where the US is not compatible with the patient's condition.
Kim, I. [15]	2020	Medicine (Baltimore)	292	Korea	Retrospective case-control study	Computed tomography scan usage when US results are non-diagnostic for suspected AA in children.	Despite negative or non-diagnostic US results, children with suspected AA who have vomiting, high CRP, and a high white blood cell (WBC) count should be evaluated for a CT scan.

Miano, D. I. [16]	2015	Western Journal of Emerg ency Medicine	1493	USA	Retrospective cohort study	Children with suspected AA do not have better outcomes with abdominal CT.	Comparing individuals who had a pre-operative abdominal CT scan to those who had not, the former group was equally likely to have pathology-proven appendicitis, perforated appendices, or negative appendectomies.
Nishizawa, T. [17]	2018	AMERICAN JOURNAL OF EMERGENCY MEDICINE	328	Japan	Retrospective cohort study	Predicting the need for an additional CT scan in children with a non-diagnostic US for appendicitis in the emergency department	Ordering CT should be considered after non-diagnostic US for appendicitis only when children meet at least 2 predictors of right lower quadrant (RLQ) tenderness, peritoneal signs, and WBC N 10,000 in mm (3). (
Saito, J. M. [18]	2013	Pediatrics	423	USA	Retrospective cohort study	Use and accuracy of diagnostic imaging by hospital type in pediatric appendicitis.	Widespread preoperative imaging did not eliminate unnecessary pediatric appendectomies. When variables that may be linked to referral bias are taken into account, a CT scan was more likely to be performed in children initially evaluated at community hospitals compared with the children' s hospital.
Sayed, A. O. [19]	2017	Therapeutics and Clinical Risk Management	140	Egypt	Retrospective cross-sectional study	Diagnostic accuracy of a low-dose CT scan, US, and pediatric appendicitis score in children with suspected acute appendicitis.	Although CT remains the most accurate and less operator-dependent diagnostic tool for pediatric appendicitis, the radiation hazards could be minimized using the pediatric appendicitis score (PAS) as an excluding tool and US as the primary imaging modality, followed by low-dose CT for inconclusive cases only.
Schuh, S. [20]	2015	ACADEMIC EMERGENCY MEDICINE	294	Canada	Prospective cohort study	Characteristics of the Serial US Clinical Diagnostic Pathway for Suspected Appendicitis and Associated CT Use.	Using the serial US clinical diagnostic pathway results in fewer CT scans being needed. This pathway consists an initial US followed by a clinical reassessment in all cases and an interval US and surgical consultation in patients whose first US is equivocal and who continue to have persistent appendicitis concerns. This has substantially higher than expected diagnostic accuracy compared to the original US.

Table 3: Study characteristics of the included studies.

A total of 3341 patients were included across the eight studies in this systematic review. All cases were children who were suspected of AA, presented to the hospital with abdominal pain, and underwent an abdominal and pelvic US, CT scan, or both.

The results of this study showed that there was a significant correlation between the diagnosis of AA and the following characteristics: the appendix's non-compressibility ($P < 0.001$), the maximal outer diameter (MOD) equal to or above 6 mm ($P = 0.001$), the presence of appendicolith ($P = 0.006$), and the appendix's round shape in transverse view ($P < 0.001$). But there was no apparent association between the presence of loculated fluid surrounding the appendix, mass surrounding the appendix, or echogenicity surrounding the appendix when appendicitis was diagnosed. Based on a comparison between the surgical reports following appendicectomy and the sonographic results of patients with acute appendicitis, perforated appendicitis, and normal appendices, the author concluded that the overall sensitivity and specificity of US in appendicitis were 97.56% and 69.23%, respectively [13]. When detecting acute appendicitis in children, CT proved to be more accurate than abdominal US. US, CT, or both imaging modalities were used preoperatively, and the results of the histology were compared with the surgical results. whereas CT had a sensitivity and specificity rate of 88.1% and 57.1%, respectively, and an 81.8% diagnostic accuracy rate. The US had a sensitivity and specificity rate of 77.2% and 52.6%, respectively, and a diagnostic accuracy rate of 70.5% [14]. Despite negative or non-diagnostic US results, the author of this study found that if a child has vomiting, a high CRP, and a high WBC count and is suspected of having acute appendicitis, a CT scan should be addressed. These false-negative groups included children who had vomiting, elevated WBC counts and CRP levels, and a significantly higher CT appendicitis score. These findings were obtained by comparing the results of CT scans, US scans, or both in children who underwent this diagnostic imaging procedure to rule out acute AA [15].

The author of this study discovered that the rate of complications was similar for children with suspected acute appendicitis, regardless of the type of diagnostic imaging used. For example, children who obtained pre-operative CT scans had a similar probability of pathology-proven appendicitis, the rate of perforation, and a negative appendectomy as children without CT scans. Additionally, it was the same for children who underwent an abdominal US, a CT scan, or neither. FPR for CT and US was 12% and 16%, and FNR for CT and US was 16% and 23%, respectively [16]. The study revealed that younger children and those with peritoneal symptoms, such as vomiting, RLQ tenderness, or a WBC count > 10,000 in mm3, had a higher probability of having appendicitis on CT. If two or three of these variables had been taken into account, the results for appendicitis on CT would have been 94% sensitivity, 67% specificity, 57% positive predictive value, and 96% negative predictive value [17].

According to this study, a number of factors, including confounding variables and diverse hospital settings, contributed to the lower sensitivity of CT and US in the diagnosis of appendicitis in children. While overall CT sensitivity for any form of appendicitis was high, it was significantly lower in community hospitals compared to children's hospitals (P =.07). Overall, CT sensitivity for perforated appendicitis was modest, and it was considerably lower in CT scans conducted at community hospitals. While overall US accuracy and sensitivity for appendicitis were fair, they were much worse in studies conducted in girls and at community hospitals. In general, ultrasound detection of perforated appendicitis was not very reliable [18]. According to this research, low-dose CT had the best diagnostic accuracy for acute appendicitis, with a 97.8% sensitivity, 100% specificity, and 99.3% accuracy. US data, on the other hand, gave the lowest results (sensitivity of 55.6%, specificity of 85%, and accuracy of 71%). However, when the US was used as a primary examination and a CT scan was used for non-diagnostic US evaluation, a 100% sensitivity, 85% specificity, 92% accuracy, 7.9% negative appendectomy rate, and no missed positive appendicitis cases were obtained. Thus, in circumstances where the US examination is unclear, low-dose CT can be used as the final resort, and the clinical score assessment is the first diagnostic method [19]. The findings of the study indicate that the diagnostic accuracy of the serial ultrasound clinical pathway was greater than that of the initial US alone in the diagnosis of AA in children ($p < 0.0001$). Upon clinical examination and interval US, in the patients who had an equivocal initial US, the concerns regarding appendicitis diminished. The interval US confirmed or ruled out appendicitis in 55% of children with an equivocal initial US [20].

Discussion

Recurrent and Accurate Ultrasound Examination:
In pediatric emergency rooms, acute appendicitis is one of the most common and challenging diagnoses, making decisions very challenging in some situations [21]. An assisted early diagnosis could decrease the risk of appendix perforation and related complications, which would be beneficial for these patients. When diagnosing acute appendicitis clinically, graded compression sonography is valuable. However, a recent study indicating a low sensitivity (29%) for diagnosing appendicitis in patients who have perforation highlights a potential drawback of this technique. It is likely that the appendix's widespread necrosis makes it difficult to see clearly. Also the focal peritonitis caused by a perforation may result in inadequate compression [22].

According to the study's author, Kim, I., non-compressibility was observed in 87.1% of patients whose appendix was visible on the ultrasonography. This finding had a high diagnostic sensitivity of 98.68% and a specificity of 64.7%. Additionally, the diagnostic value of MOD equal to or greater than 6 mm was 95% specific and 65% sensitive, comparable to incompressibility. In comparison to conventional diagnostic criteria like MOD and incompressibility, MMT equal to or more than 3 mm showed 62% sensitivity and 82% specificity. More evaluation of the accuracy of each sonographic parameter in the diagnosis of acute appendicitis in children, along with more effective criteria and cutoffs, could lead to increased diagnostic accuracy of sonography in acute and complicated appendicitis and help in the earlier detection of this condition. Additionally, in certain situations where an MRI or CT scan cannot be performed, a second US evaluation may be necessary. The author, Schuh, S., supports this by demonstrating that, in cases of suspected appendicitis, the serial US clinical diagnostic pathway results in very few CT scans and has an acceptable diagnostic accuracy that is much greater than that of the initial US. This approach appears to be most useful in children with equivocal initial US in whom appendicitis was diagnosed or ruled out by the combination of clinical reassessment and interval US/surgical consultation. Due to the fact that the US frequently cannot view the appendix and is heavily operator-dependent, this study shows that a staged US-CT protocol, which could eliminate most of the currently recommended CTs, and a combination of US and clinical reassessment are both very helpful in diagnosing appendicitis. The reassessment is a powerful tool for identifying children at high risk of appendicitis and may decrease the CT rate significantly. In only 3% of the uncertain US was a CT necessary. However, there are expenses involved with using time and resources in this serial US clinical diagnostic pathway. While obtaining CT scans for kids with equivocal initial US results may shorten hospital stays overall, radiation-related morbidity must be taken into account. The decision on whether to do an interval US is complex and somewhat based on US availability, the ED physician's and surgeons' opinions, and other factors. There are a number of cases of ovarian pathology that mimic acute appendicitis in children who underwent negative operations. Therefore, despite the great sensitivity of the targeted pathway, it may be marginally more accurate in detecting appendicitis than ruling it out. This study was unable to analyze the results for a few patients since there were few occurrences of diagnostic errors using the serial US clinical approach. Also, a small group of children with equivocal first US and ongoing symptoms underwent surgical consultations without US intervals. As a result, comments on the US performance in this group during the interval are unknown [20].

Imaging and diagnosis

Baykara, A. S. [14], The primary methods used to diagnose AA are a thorough physical examination and a history. But because it can be challenging to take a medical history and do a physicalexamination, children and confused patients may experience delays in diagnosis and treatment [23]. Onesignificant laboratory result that helps confirm the AA diagnosis is a high white blood cell count. However, priorresearch showed leukocytosis sensitivity ranging from 19% to 60% [24]. Diagnostic imaging techniques are frequently used, particularly in individuals with atypical clinical symptoms, because laboratory tests have low sensitivity. Nowadays, abdominal US and CT are the most commonly utilized techniques. Imaging is used to diagnose acute AA with the goal of reducing medical risks and expenses while improving diagnostic efficiency. Ultrasonography has been the imaging method of choice for many years because of its many advantages, including its lack of radiation, availability at many facilities, and bedside availability [25]. In this study, the diagnostic accuracy rate was 70.5%, PPV was 81.2%, NPV was 46.5%, and the sensitivity and specificity of US were calculated as 77.2% and 52.6%, respectively. The knowledge and skills of the individual completing the study have a significant impact on the quality and accuracy of the results for the US, which is why there are significant discrepancies between study outcomes. For this exam, this can therefore be a serious disadvantage. The incompatibility of a child experiencing abdominal pain and lacking communication skills, the existence of gas-filled intestines in the right lower quadrant of the abdomen in obese patients, and the lack of high-resolution transducers are additional drawbacks associated with the use of US. The sensitivity and specificity of CT in this study were 88.1% and 57.1%, respectively, in the diagnosis of AA. Also, 81% was the diagnostic accuracy, PPV was 88.8%, and NPV was 55.1%. CT has many disadvantages, even though studies have shown that it is more accurate than US in the diagnosis of AA. For instance, ionizing radiation exposure and increased health costs are associated with CT. The additional drawbacks include contrast agent reactions and a prolongation of time before surgery [26]. In suspected cases, surgeons usually prefer to undergo an appendectomy because a delay in diagnosis might lead to very significant complications. As an outcome, inaccurate diagnoses of AA result in a negative appendectomy. Adhesions inside the abdomen, anesthesia-related difficulties, and a lower quality of life as a result of unnecessary surgery are among the issues that might arise from a negative appendectomy [27]. The rate of negative appendectomy in this study was 14.3%.

Role of CT scans in non-diagnostic Ultrasound

Kim, I. [15]According to this study, the false-negative group had greater WBC, segmented neutrophil count, CRP, and more frequent vomiting in addition to poor oral intake. When comparing the two groups, there was no significant distinction in age, sex, or body weight. There was abdominal pain in every patient in both groups; however, peritoneal signs, fever, and pain in the right lower quadrant did not correlate with the outcome. This finding implies that among patients who are clinically high-risk and have negative or non-diagnostic US results, these characteristics do not contribute to the diagnosis. On the other hand, the false-negative group had higher rates of vomiting and poor oral intake. Also, some variables might be correlated with appendicitis complications, such as paralytic ileus, which results from intra-abdominal inflammation. Therefore, the author revealed that CT scans should be performed for individuals who have a strong suspicion of having AA, particularly if they have vomiting or poor oral intake and their initial US results are negative or non diagnostic.Surprisingly,the results were unrelated to theradiologist's training status or the timing of the sonographic examination. Even though the performer's skill is crucial in an ultrasonographic examination and its accuracy.

In children, AA diagnosis can be difficult. Essential clues for this diagnosis can be obtained through imaging studies. Despite its lower sensitivity and specificity as compared to CT, US is still used as the primary diagnostic imaging modality in children because of the lower radiation risk associated with it [28]. Conclusive US reports indicating acute appendicitis are helping clinicians in diagnosis, but non-diagnostic results are frequent due to poor visualization or borderline sizing. Even negative reports for AA may be false negatives. Despite the findings, this study has some weaknesses, such as a small sample size, a single-center study, and excessive radiation exposure because all the patients underwent both US and CT scans.

Nishizawa, T. [17], According to this study, a CT scan is probably only necessary for children with suspected appendicitis who have had a non-diagnostic US exam by an emergency physician and at least two of the following symptoms: peritoneal signs, RLQ tenderness, or a high WBC of 10,000 in mm3. The author believed that they could have avoided almost 65% of CT scans that were negative for appendicitis with a substantially lower false negative rate of 4% if they had implemented this decision criterion in the study group. Furthermore, children's appendicitis diagnosis accuracy can be increased by using CT imaging following an inconclusive US. Despite the phased imaging strategies that are often used for children with non-diagnostic US appendicitis [29], a lot of children continue to undergo unnecessary CT scans. Also, point-of-care US is becoming a more prominent imaging modality used by ED doctors to assess appendicitis [30]. According to reports, the diagnostic accuracy of the US varies a lot and is greatly impacted by operator experience . Given that US performed by an ED physician alone has been found to have relatively low sensitivity (44%) (31), the high rate of non-diagnostic US described in this study is consistent with that reported in the literature. Since younger residents conducted the majority (56%) of the US examinations in this study, the low sensitivity found may have resulted from the residents' rigorous evaluation of their proficiency with point-of-care ultrasound, which included an assessment of their ability to diagnose appendicitis.

Leukocytosis (WBC N 10,000 in mm3), RLQ tenderness, and peritoneal signs were found to be mostly positive in children with non-diagnostic US whose CT scans later revealed appendicitis compared to those whose CT scans showed no appendicitis. According to this study, 85% of patients with appendicitis and a non-diagnostic US reported RLQ tenderness on exam, which is a usual finding in appendicitis. Because ovarian hemorrhage, diverticulitis, and gastroenteritis are among the other conditions that might produce RLQ tenderness, the study's specificity was only 34.7%. It's possible that the low specificity led to unnecessary CT scans or negative appendices (32). Peritoneal signs were classically associated with appendicitis, but they only caused a small increase in the likelihood of appendicitis (33). Also, the study revealed that the sensitivity of peritoneal signs was 70%. This relative low sensitivity meant physical findings did not rule out appendicitis. The study found three predictors with a high NPV, especially when US was non-diagnostic, and the decisions on the type of imaging modality were left to the clinician. Practice variation may play a role in the findings. Also, it is possible that some children were discharged after a US visit and went to another facility where they were diagnosed with appendicitis. Patients who presented with AA at a different institution after being discharged with no appendicitis on CT would have been incorrectly categorized as negative CT in this analysis.

CT does not improve the outcome of Acute Appendicitis.

Miano, D. I. [16], The study's findings showed that, in comparison to individuals who did not receive a pre-operative abdominal CT scan, those who did had an equivalent chance of developing pathology-proven appendicitis, ruptured appendices, or negative appendectomies. Furthermore, children who had a diagnostic CT scan or US and children who did not get any diagnostic imaging had comparable rates of negative appendectomy and perforations. Additionally, the study showed that children with pre-operative CT scans were more likely to have a perforated appendix (31%) at the time of surgery. The increased perforation rate in children with CT scans could be caused by postponing treatment, surgery, or transfer because of the scan.Concerning symptoms of a ruptured appendix, a longer latency period before presenting to the ED, and unclear US studies are other possible factors that could have prompted the physicians to conduct a CT scan. Furthermore, the majority of patients at community hospitals (61%) got abdominal CT scans, while just 11% of patients had abdominal US scans at a community hospital. These findings might have originated in community hospitals' insufficient training of US professionals and lack of US availability, particularly during the night. It has been demonstrated that ordering fewer CT scans and using US as the main imaging modality for children with suspected AA is both practical and cost-effective. This strategy will not only reduce expenses but also protect some children from potentially harmful radiation exposure. The institution's pediatric surgeons are willing to operate on children with suspected appendicitis if they have a typical history, exam, and laboratory results; however, when the diagnosis is uncertain, US is used. Because the rate of complications is similar and CT carries the added risk of radiation, the study concluded that the use of CT should be reserved for children who pose diagnostic challenges or risks of other pathologies.

Diagnosis in different hospital settings

Saito, J. M. [18], In this study, preoperative imaging was performed on most of the children receiving operational treatment at a single tertiary-care children's hospital for suspected appendicitis. The choice and precision of diagnostic imaging varied according to the original evaluation site. The results of preoperative abdominal-pelvic CT scans were significantly correlated with initial evaluations at community hospitals, while abdominal ultrasounds were more likely to be obtained with initial evaluations at children's hospitals. According to reports on variations in CT use by hospital type, community hospitals' CT and ultrasonography examinations were less accurate in detecting appendicitis than those conducted at children's hospitals. The utilization of diagnostic imaging varies by initial evaluation location for pediatric appendicitis, which could be caused by a number of factors, including the perceived requirement for diagnosis confirmation or imaging availability. Firstly, the widespread usage of CT scans in community hospitals may be explained by their easy accessibility as compared to ultrasound. Over the last ten years, emergency rooms have used CT scans significantly more frequently to evaluate children with abdominal pain. On the other hand, the use of ultrasound has remained stable over time [34, 35]. This pattern may be explained by a decrease in or inconsistent availability of emergent ultrasonography in community hospitals, as well as a potential association between CT use and concerns about diagnostic errors in US examinations. Lastly, when it comes to appendicitis, practitioners may be more confident in CT scans than in US examinations. The finding of more frequent US use at the children's hospital, however, may be the result of intentional attempts to limit exposure to ionizing radiation. However, in clinically confusing cases, imaging with both CT and US may have been obtained, and in many cases, non-diagnostic ultrasonography was followed by CT scans. CT accuracy was lower in a community setting, even with frequent use. The children's hospital's CT scans were somewhat more sensitive than those at the facilities they were referred to. The children's hospital's CT scans showed much higher sensitivity for perforated appendicitis. One potential reason for diminished accuracy is that multi-detector CT, which is used at the children's hospital, might be less available at referring community hospitals. Multi-detector CT offers the advantages of improved resolution through thinner sections and coronal reconstructions that could enable visualization of the appendix (36). In contrast to the children's hospital, the quality of CT scans done at referral hospitals may have been impacted by a lack of intravenous contrast [37], inadequate intravenous contrast bolus timing, and patient movement, particularly in smaller children. Lastly, one possible explanation for the variation in CT accuracy is a difference in how general and pediatric radiologists read the scans [38]. The US had substantially lower sensitivity for appendicitis than the CT scan, and community hospital ultrasounds had much lower sensitivity for both appendicitis and perforation. The children's hospital-evaluated patients often underwent ultrasound alone, but the low rate of negative appendectomy combined with fair to moderate accuracy suggests a clinical impression that is based on symptoms, physical examination findings, and laboratory results that influenced clinical decision-making in cases where ultrasound results were inconclusive. The accuracy of both CT and US was also affected by patient-specific features such as obesity, male gender, and younger patient age. In order to address the use of CT in community hospitals, clinical patient assessment and clinical decision-making require specialized surgical or pediatric expertise. Pre-transfer CT scans before going to a center for surgical care might be minimized in this way. The patient's age, gender, body type, symptoms, possible differential diagnosis, imaging modality accuracy for the patient subtype, and hospital resources are some of the variables that may affect optimal imaging. The benefits of diagnostic confirmation in preventing unnecessary hospital admissions, transfers between facilities, surgeries, and treatment delays must be balanced against the risks associated with CT radiation exposure and the expenses associated with maintaining pediatric competence and ultrasound technical competency.This retrospective, single-center study has a number of other weaknesses as well. For example, it was unable to determine the precise role that imaging played in the assessment of children who may have had appendicitis, and the subjects' initial symptoms and physical examination results were not consistently documented enough to allow for a thorough examination of the relationship between imaging use and clinical presentation. Moreover, a small number of individuals who did not get imaging at the time of the initial assessment might have had more obvious clinical signs of appendicitis. The percentage of procedures carried out for a normal appendix can be underestimated if the appendix is not removed.

Diagnosis by pediatric appendicitis score, ultrasound, and CT scan

Sayed, A. O. [19], CT has been extensively used for the management of appendicitis because of its excellent diagnostic accuracy; however, this comes with a higher risk of radiation exposure. A low-dose CT scan in pediatric patients has been proposed as one of the two main approaches to reducing radiation exposure while maintaining high diagnostic accuracy [39]). The other approach is to minimize the use of CT by utilizing a clinical score and US examination in place of or in addition to CT, which can be performed in the case of doubt. Every patient in this study followed a low-dose regimen. The accuracy of diagnosis was unaffected by the low-dose approach, despite the lower image quality output. 97.8% sensitivity, 100% specificity, and 99.3% accuracy were observed during the CT examination. Additionally, a small proportion of patients (38 cases) underwent graded compression US. Compared to CT, it demonstrates lower sensitivity (55.6%), specificity (85%), and accuracy (71%) for two key reasons. First, a general radiologist conducted all sonographic exams in an institution rather than a pediatric radiologist. Secondly, because a large portion of the appendices (36%) were positioned retrocecally, the US was unable to detect these abnormalities. Because surgeons in this study are less confident in US results than in CT, which has higher sensitivity and specificity and is in fact less operator-dependent, all patients undergoing appendectomy in this study had received a preoperative CT scan, even if the patient had a US diagnosis of appendicitis. Despite being more costly than US, CT is still less expensive than having a negative appendectomy or treating complications like ruptured appendices. In addition, some parents find it difficult for doctors to persuade their child that their child has acute appendicitis based only on clinical and US findings. So, the surgeons believe that a CT scan can be less dangerous than an unnecessary appendectomy with potential surgical complications. The primary disadvantage of US is its high operator dependence, whereby the examiner's experience has an impact on its accuracy. The use of CT scans is therefore more common in general hospitals than in pediatric specialty institutions. Although appendicitis scoring systems have been created as a diagnostic tool for individuals with suspected AA, low-dose CT and PAS still showed significant differences in accuracy. Therefore, compared to utilizing US or PAS alone, this method will reduce the number of cases of missed appendicitis and negative appendectomy while decreasing the use of CT.

This article is one of a few systematic reviews that collected documents from eight different observational studies regarding the accuracy of US and CT scans in diagnosing AA in pediatric patients.

Limitations

Our systematic review has several limitations, even after using all available searching methodologies and accessible records. We limited our analysis to the English-language literature published between 2013 and 2023, focusing exclusively on the pediatric age group and excluding the adult population. We omitted a few abstracts for which the complete text could not be located. There were no non-peer-reviewed articles included. Furthermore, all of the included articles were observational studies, and there isn't ample clinical trial literature about it.

Conclusion

According to the review articles, the CT scan is the most accurate test for diagnosing acute appendicitis in children, with high sensitivity and specificity. However, because of its radiation exposure, the CT scan cannot be utilized as the primary diagnostic tool. Although US is operator-dependent, has less specificity, and is unsuitable for some young children, it can be utilized as a first imaging modality due to its high sensitivity, cost-effectiveness, and accessibility. Therefore, a low-dose CT scan is needed for complicated AA and equivocal or non-diagnostic US. As a result, there will be a decrease in radiation exposure, negative appendectomy rates, perforation rates, and patient costs. A review of a few of our articles revealed that recurrent US examinations and clinical assessment could improve US accuracy. In order to achieve the best outcome, the physicians need to evaluate the clinical presentation, and skilled radiologists have to conduct the US examination. Future studies Ideally, randomized clinical trials are also required to compare the pathological reports of appendectomy cases with the results of CT and US examinations.

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