ORIGINAL ARTICLE

Comparative study of imaging features in uncomplicated and complicated acute appendicitis

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ABSTRACT

BACKGROUND: Acute appendicitis is a common cause of acute abdominal pain necessitating surgical intervention. While the traditional treatment has been urgent appendectomy, recent studies suggest that an antibiotics-first approach can be safe for uncomplicated cases. Classifying appendicitis into uncomplicated and complicated categories is crucial for guiding treatment decisions and predicting patient outcomes. This study aims to evaluate the distinct imaging findings associated with uncomplicated appendicitis and its complicated subtypes-phlegmonous, gangrenous, and perforated appendicitis—to aid in differential diagnosis.

METHODS: This retrospective observational study was conducted from January 2014 to December 2023 and included 1,250 patients (492 women, 758 men) who underwent an appendectomy with available pathology results. After excluding 56 patients with normal pathology, 52 with non-appendicitis pathologies, and 48 with inaccessible computed tomography (CT) images, 1,094 patients were analyzed. CT images were evaluated for appendiceal diameter, wall thickness, cecal wall thickness, periappendiceal fat stranding, effusion, lymphadenopathy, intraluminal and free periappendiceal air, mucosal hyperenhancement, and the presence of appendicolith.

RESULTS: The diameter of the appendix, along with the presence of periappendiceal air, effusion, and intraluminal appendicolith, were significantly higher in the perforated appendicitis group compared to other groups ($p<0.05$). Periappendiceal fat stranding, evaluated as a binary variable, did not show significant differences among the groups. Appendiceal wall thickness was higher in the perforated group and lower in the non-perforated gangrenous group compared to the uncomplicated group ($p<0.05$). No significant correlation was found for mucosal hyperenhancement between the appendicitis subgroups. Intraluminal air, though normal in a healthy appendix, was a specific predictor of complicated appendicitis when combined with other findings.

CONCLUSION: This study provides a detailed analysis of distinct imaging findings associated with uncomplicated and complicated appendicitis. Key differentiators such as appendiceal diameter, periappendiceal air, effusion, and intraluminal appendicolith are crucial for accurate diagnosis. The findings highlight the importance of these parameters in distinguishing various types of appendicitis, offering valuable insights for clinical practice. Future prospective studies and advanced imaging techniques are needed to validate these findings and enhance the diagnosis and management of acute appendicitis and its complications.

Keywords: Acute appendicitis; complications of acute appendicitis; computed tomography.

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INTRODUCTION

Acute appendicitis is one of the most common causes of acute abdominal pain that necessitates surgical intervention.[1] Historically, the standard treatment for acute appendicitis has been an urgent appendectomy to prevent complications. However, recent systematic reviews have concluded that an antibiotics-first approach can safely be used in the majority of cases of uncomplicated appendicitis.[2] Furthermore, studies have demonstrated that treating patients diagnosed with a periappendiceal abscess at the time of diagnosis with antibiotic therapy and optional percutaneous drainage, rather than emergency surgery, significantly reduces surgical complications.[3] Nonetheless, the decision to perform elective surgery on these patients remains a topic of debate.[4]

Building on this knowledge, the classification of acute appendicitis has gained a crucial role in understanding its pathophysiology and in guiding the management plan according to the specific type and severity of the condition. This classification not only aids in diagnosing the exact nature of the appendicitis but also helps predict potential complications and outcomes. Acute uncomplicated appendicitis is defined as transmural inflammation of the appendix vermiformis, without signs of gangrene, perforation, phlegmon, or abscess. The European Association of Endoscopic Surgery (EAES) defines complicated appendicitis as gangrenous appendicitis with or without accompanying perforation, contained periappendiceal phlegmon, or periappendiceal abscess formation.[5]

Recently, it has been proposed that complications of acute appendicitis may have different prognoses and should be classified separately to facilitate more personalized diagnosis and treatment guidance.[6] Hoffmann et al. have proposed a new classification for complicated acute appendicitis as a) phlegmonous appendicitis, b) gangrenous appendicitis without perforation, and c) appendicitis with free perforation.[7]

Computed tomography (CT) has become essential in evaluating patients with suspected appendicitis due to its high sensitivity and specificity. However, due to the radiation exposure associated with CT, the CT-first approach is being questioned, and ultrasound (US) imaging is usually the first step in diagnosis, especially in the pediatric population.[8]

Numerous studies have investigated the radiological findings that differentiate between complicated and uncomplicated appendicitis. However, there is a lack of research specifically distinguishing between different complications of appendicitis. This study aims to evaluate the distinct imaging findings of uncomplicated appendicitis and its various complications and to discuss their differential diagnosis.

MATERIALS AND METHODS

Study Design

This retrospective observational study was conducted from January 2014 to December 2023. Ethics committee approval was received on December 1, 2023 (Approval Number: 831892).

Study Population

A total of 1,250 patients (492 women, 758 men) who underwent appendectomy and had pathology results available were included in the study. Among these, 56 patients with normal pathologies and 52 patients with pathologies other than acute appendicitis were excluded. Additionally, 48 patients who were diagnosed solely with ultrasound and did not have accessible CT images in the Picture Archiving and Communication System (PACS) were excluded. Thus, 1,094 patients (472 women, 622 men) were included in the final analysis.

Imaging Protocols

All abdominal images were obtained using one of two CT scanners equipped with 128 detectors: the SOMATOM Definition AS (Siemens Healthcare, Forchheim, Germany) or the Revolution HD (General Electric Systems, Waukesha, WI, USA). The CT scan parameters for the abdominal imaging protocol included a tube voltage of 100 kV, a current of 200 mA, a matrix size of 512 x 512, and a slice thickness of 1.25 mm.

Classification and Image Evaluation

Patients were classified according to the pathological findings as having uncomplicated appendicitis, phlegmonous appendicitis, gangrenous appendicitis, or perforated appendicitis. The radiological findings investigated on the CT images included:

- Appendiceal diameter: the greatest diameter including walls.
- Appendiceal wall thickness.
- Cecal wall thickness.
- Presence of periappendiceal fat stranding.
- Presence of periappendiceal fluid collection.
- Presence of lymphadenopathy: Lymph nodes with a short axis greater than 5 mm were considered significant.
- Presence of air in the appendix lumen.
- Presence of free periappendiceal air.
- Mucosal hyperenhancement of the appendix: Compared to the bowel mucosa.
- Presence of an appendicolith within the lumen.

All CT scans were retrospectively evaluated via the PACS system by two radiologists (R.H. and E.Y.Ö.) in consensus who were blinded to the patient's clinical information. In the event of a discrepancy, one of the board-certified radiologists (S.Ş. or O.T.), with 7 and 18 years of experience in abdominal imaging respectively, was consulted.

Statistical Analysis

Descriptive statistics of the data included mean, standard deviation, median, minimum, maximum, frequency, and percentage values. The distribution of variables was assessed using the Kolmogorov-Smirnov test and the Shapiro-Wilk test. For the analysis of quantitative independent variables that did not follow a normal distribution, the Kruskal-Wallis test and the Mann-Whitney U test were employed. For the analysis

of qualitative independent variables, the Chi-square test was used, and when the conditions for the Chi-square test were not met, Fisher's exact test was utilized.

Software Program: All analyses were performed using the SPSS 28.0 software (IBM SPSS Statistics for Windows, Version 28.0, Armonk, NY, USA: IBM Corp.).

RESULTS

Descriptive Statistics

The age of the patients ranged from 1 to 96 years, with a median age of 27.0 years and a mean age of 29.8±16.9 years.

Pathological Findings

Among the different types of appendicitis, perforated appendicitis was identified in 8.8% of cases (96 patients), phlegmonous appendicitis in 39.9% (436 patients), gangrenous appendicitis in 24.9% (272 patients), and uncomplicated appendicitis in 26.5% (290 patients).

CT Findings

The appendiceal wall thickness varied from 1.3 mm to 17.3 mm, with a median thickness of 3.1 mm and a mean thickness of 3.3±1.3 mm. The cecal wall thickness ranged from 0.9 mm to 6.6 mm, with a median thickness of 1.8 mm and a mean thickness of 2.0±0.7 mm. The diameter of the appendix ranged from 4.8 mm to 37.2 mm, with a median diameter of 10.5 mm and a mean diameter of 11.1±3.4 mm (Table 1).

The appendiceal wall thickness was higher ($p<0.05$) in the perforated appendicitis group (median value 3.23 mm) than in the uncomplicated appendicitis group (median value 2.90 mm) (Fig. 1).

The cecal wall thickness was significantly higher ($p<0.05$) in the perforated and phlegmonous appendicitis groups com-

Table 1. Radiological features of appendicitis subtypes

	Perforated	Phlegmonous	Gangrenous	Uncomplicated	p
Appendiceal WT					
Mean±SD	3.43±1.11	3.19±1.06	3.21±0.91	3.24±1.89	0.010[K]
Median	3.23	3.09	3.14	2.90	
Cecal WT					
Mean±SD	2.09±0.66	1.97±0.62	2.01±0.76	1.89±0.53	0.039[K]
Median	1.91	1.84	1.84	1.78	
Appendiceal diameter					
Mean±SD	12.0±3.1	11.2±3.5	11.1±2.9	10.6±3.3	0.002[K]
Median	11.2	10.5	10.5	10.1	
LN Short Axis					
<5 mm					
n-%	35 36.5	168 38.5	108 39.7	130 44.8	0.300[X²]
≥5 mm					
n-%	61 63.5	268 61.5	164 60.3	160 55.2	
Periappendiceal Fat Stranding					
n-%	86 89.6	389 89.2	246 90.4	246 84.8	0.163[X²]
Periappendiceal Fluid Collection					
n-%	72 75.0	273 62.6	166 61.0	158 54.5	0.004[X²]
Air in Appendix Lumen					
n-%	31 32.3	98 22.5	75 27.6	56 19.3	0.022[X²]
Free Periappendiceal Air					
n-%	25 26.0	8 1.8	35 12.9	0 0	0.000[X²]
Mucosal Hyperenhancement					
n-%	18 18.8	109 25.0	58 21.3	56 19.3	0.244[X²]
Appendicolith					
n-%	32 33.3	81 18.6	51 18.8	57 19.7	0.010[X²]

[K]Kruskal-Wallis (Mann-Whitney U test)/ [X²]Chi-square test (Fisher's exact test); WT: Wall Thickness; LN: Lymph Node; SD: Standard Deviation; n: Number.

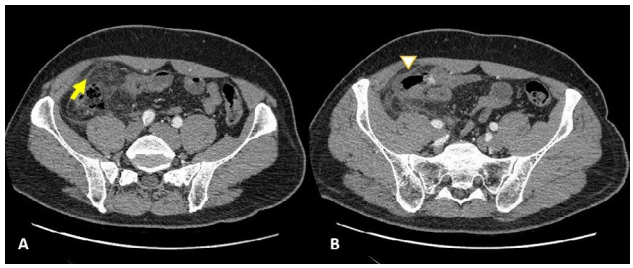

Figure 1. Perforated appendicitis. Note the periappendiceal effusion **(a)** and increased appendix wall thickness **(b)**.

pared to the uncomplicated appendicitis group. There was no significant difference (p>0.05) in cecal wall thickness between the perforated, phlegmonous, and gangrenous appendicitis groups, or between the gangrenous, phlegmonous, and uncomplicated appendicitis groups.

The diameter of the appendix in the perforated appendicitis group was significantly higher (p<0.05) than in the phlegmonous, gangrenous, and uncomplicated appendicitis groups. There was no significant difference (p>0.05) in appendix diameter between the phlegmonous, gangrenous, and uncomplicated appendicitis groups, or between the gangrenous and uncomplicated appendicitis groups.

The rate of periappendiceal effusion in the perforated appendicitis group was significantly higher (p<0.05) than in the phlegmonous, gangrenous, and uncomplicated appendicitis groups (Fig. 1). The rate of periappendiceal effusion in the phlegmonous appendicitis group was also significantly higher (p<0.05) than in the uncomplicated appendicitis group. There was no significant difference (p>0.05) in the periappendiceal effusion rate between the gangrenous appendicitis group and the phlegmonous and uncomplicated appendicitis groups.

The presence of air in the appendix lumen was significantly higher (p<0.05) in the perforated appendicitis group compared to the phlegmonous and uncomplicated appendicitis groups, and in the gangrenous appendicitis group compared to the uncomplicated appendicitis group. There was no significant difference (p>0.05) in the presence of air in the appendix lumen between the perforated and phlegmonous appendicitis groups, or between the phlegmonous and gangrenous appendicitis groups.

The presence of free periappendiceal air (Fig. 2) was significantly higher (p<0.05) in the perforated appendicitis group compared to the phlegmonous, gangrenous, and uncomplicated appendicitis groups. Additionally, the presence of free periappendiceal air was significantly higher (p<0.05) in the gangrenous appendicitis group compared to the uncomplicated appendicitis group.

Table 2. Radiological features of appendicitis subtypes

	Perforated			
	Mean±SD/n-%	**Median**	**Min-Max**	**IQR**
Appendiceal Wall Thickness (WT)	3.4±1.1	3.2	1.3-6.3	2.6-4.0
Cecal WT	2.1±0.7	1.9	1.3-4.5	1.6-2.4
Appendiceal Diameter	12.0±3.1	11.2	6.8-19.6	9.6-14.0
	Phlegmonous			
	Mean±SD/n-%	**Median**	**Min-Max**	**IQR**
Appendiceal WT	3.2±1.1	3.1	1.3-8.4	2.5-3.6
Cecal WT	2.0±0.6	1.8	1.0-6.6	1.6-2.1
Appendiceal Diameter	11.2±3.5	10.5	0.0-37.2	8.9-12.8
	Gangrenous			
	Mean±SD/n-%	**Median**	**Min-Max**	**IQR**
Appendiceal WT	3.2±0.9	3.1	1.3-7.0	2.6-3.6
Cecal WT	2.0±0.8	1.8	0.9-6.0	1.6-2.1
Appendiceal Diameter	11.1±2.9	10.5	6.1-21.4	9.1-12.5
	Perforated			
	Mean±SD/n-%	**Median**	**Min-Max**	**IQR**
Appendiceal WT	3.2±1.9	2.9	1.5-17.3	2.4-3.4
Cecal WT	1.9±0.5	1.8	1.0-4.8	1.5-2.0
Appendiceal Diameter	10.6±3.3	10.1	0.0-33.6	8.7-12.2

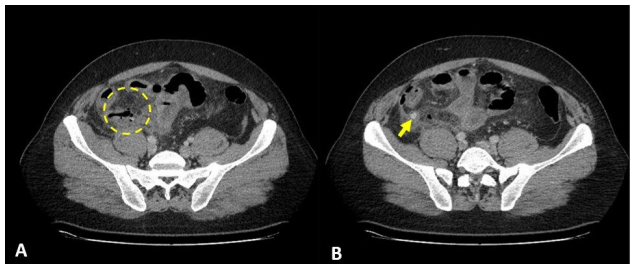

Figure 2. Perforated appendicitis. Presence of periappendiceal free air **(a)** and appendicolith **(b)**.

The presence of an appendicolith (Fig. 2) in the perforated appendicitis group was significantly higher ($p<0.05$) than in the phlegmonous, gangrenous, and uncomplicated appendicitis groups. There was no significant difference ($p>0.05$) in the presence of an appendicolith between the phlegmonous appendicitis group and both the gangrenous and uncomplicated appendicitis groups, nor between the gangrenous and uncomplicated appendicitis groups.

There was no significant difference ($p>0.05$) in the rate of periappendiceal lymph nodes, periappendiceal fat stranding, and mucosal hyperenhancement among the perforated, phlegmonous, gangrenous, and uncomplicated appendicitis groups. Additionally, the minimum-maximum values and the first quartile-third quartile (Q1-Q3) values are also summarized in Table 2.

DISCUSSION

In this retrospective study of 1,094 patients with acute appendicitis, we evaluated the distinct imaging findings associated with uncomplicated appendicitis and its complications separately. To the best of our knowledge, this is the first study to discriminate among the subtypes of complications. Previous studies have shown heterogeneity in defining complicated appendicitis; some[8-10] define complicated appendicitis as gangrenous and perforated appendicitis, while others[11,12] include phlegmonous appendicitis and abscess formation as well.

One of the most important findings of our study was that the diameter of the appendix and the presence of periappendiceal air, periappendiceal effusion, and intraluminal appendicolith were significantly higher in the perforated appendicitis group compared to all other groups. The presence of periappendiceal air, periappendiceal effusion, and intraluminal appendicolith have been proven to be helpful in differentiating between complicated and uncomplicated appendicitis in many studies,[8-11] and they are the only radiological parameters used in the Severity Scored Appendicitis CT (SAS-CT) classification method proposed by Atema et al.[13] On the other hand, different studies use varying cutoff values for the diameter of the appendix, leading to different sensitivity and specificity values.[9,11,12]

Periappendiceal fat stranding is another parameter we examined. In the literature, this finding has been shown to be significant in distinguishing between complicated and uncomplicated appendicitis, especially when classified into three subcategories: mild, moderate, and severe. However, the subjective nature of this classification has been highlighted in several studies, suggesting variability in its assessment.[10] Lin et al. have developed a model to specifically standardize this finding for differentiating complicated and uncomplicated appendicitis.[14] Due to this inherent subjectivity, we chose to evaluate periappendiceal fat stranding as a binary variable (present or absent). We believe this approach might have contributed to our study's lack of significant results regarding this parameter. By simplifying the evaluation to a binary outcome, we aimed to reduce observer variability, though this may have also limited the sensitivity of detecting nuanced differences in periappendiceal fat stranding among the groups.

Another important finding of our study was that appendiceal wall thickness was significantly higher in the perforated appendicitis group and lower in the non-perforated gangrenous appendicitis group compared to the uncomplicated appendicitis group. Most, if not all, studies group perforated and non-perforated gangrenous appendicitis cases together, and a significant difference between these two groups could be an important radiological marker for differentiation. In their scoring system, Avanesov et al.[15] identified appendiceal wall thinning as a specific finding for complicated appendicitis.

Mucosal hyperenhancement is another parameter included in some studies.[9,11] However, we did not find a significant correlation between appendicitis subgroups, possibly due to different CT protocols or interpretation methods.

Lastly, the presence of intraluminal air is a unique finding. Although intraluminal air is normal in a healthy appendix vermiformis,[16,17] it has been found to be a specific predictor of complicated appendicitis when combined with other findings in many studies.[10,11,15]

Our study has several limitations. The first limitation is the retrospective nature of the study, which inherently poses challenges to standardization. Prospective studies could more clearly delineate the pathological correlations of radiological findings. The second limitation is that we included only patients who underwent emergency surgery. Patients with abscesses were treated nonoperatively with antibiotic therapy and elective appendectomy and thus were not included in our study. The third limitation is the reliance solely on pathological findings without incorporating intraoperative observations into the classification. Intraoperative findings could potentially influence the classification and provide additional insights, particularly in distinguishing between perforated appendicitis and phlegmonous appendicitis.

CONCLUSION

This study provides a comprehensive evaluation of the distinct imaging findings associated with uncomplicated appendicitis and its complications, highlighting key differentiators.

Our findings underscore the importance of these parameters in distinguishing between various types of appendicitis, offering valuable insights for clinical practice. Future research should focus on validating these findings through prospective studies and exploring advanced imaging techniques to further enhance the diagnosis and management of acute appendicitis and its complications.

Ethics Committee Approval: This study was approved by the Cerrahpasa Medical Faculty Ethics Committee (Date: 31.10.2023, Decision No: 1094756).

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Authorship Contributions: Concept: O.Ş., O.T.; Design: O.Ş., O.T.; Supervision: O.Ş., N.K., O.T.; Resource: O.Ş., Y.Ö.I., S.E., O.T.; Materials: O.Ş., Y.Ö.I., R.H., S.E., N.K., O.T.; Data collection and/or processing: S.Ş., Y.Ö.I., R.H., N.K.; Analysis and/or interpretation: S.Ş., Y.Ö.I., R.H.; Literature search: S.Ş., Y.Ö.I., R.H., O.T.; Writing: O.Ş., S.Ş., Y.Ö.I., R.H., O.T.; Critical Reviews: O.Ş., M.K., O.T.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Komplike ve komplike olmayan akut apandisitin görüntüleme özelliklerinin karşılaştırmalı incelemesi

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AMAÇ: Akut apandisit, cerrahi müdahale gerektiren akut karın ağrısının yaygın bir nedenidir. Geleneksel tedavi acil apendektomi iken, yakın zamanlı çalışmalar, non-komplike vakalar için antibiyotiklerle öncelikli tedavi yaklaşımının güvenli olabileceğini öne sürmektedir. Apandisit vakalarının komplike ve non-komplike olarak sınıflandırılması, tedaviyi yönlendirmek ve sonuçları öngörmek açısından kritik öneme sahiptir. Bu çalışmanın amacı, ayırıcı tanıya yardımcı olmak ve tedaviyi yönlendirmek için komplike (flegmonöz, gangrenöz ve perfore) ve non-komplike apandisitin görüntüleme bulgularını değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif gözlemsel çalışma Ocak 2014 ile Aralık 2023 tarihleri arasında apendektomi yapılan ve patoloji sonuçları mevcut olan 1250 hastayı (492 kadın, 758 erkek) kapsamaktadır. Normal patolojiye sahip 56 hasta, apandisit dışı patolojilere sahip 52 hasta ve erişilemeyen BT görüntüleri olan 48 hasta dışlandıktan sonra, 1094 hasta değerlendirmeye alındı. BT görüntüleri, apendiks çapı, duvar kalınlığı, çekum duvar kalınlığı, periapendiküler yoğunluk artışı, efüzyon, lenfadenopati, lümen içi ve serbest periapendiküler hava, mukozal kontrastlanma artışı ve apendikolit varlığı açısından değerlendirildi.

BULGULAR: Apendiks çapı, periapendiküler hava, periapendiküler efüzyon ve lümen içi apendikolit varlığı, perfore apandisit grubunda diğer gruplara kıyasla anlamlı olarak daha yüksekti ($p<0.05$). Periapendiküler yoğunluk artışı, ikili değişken olarak değerlendirildiğinde gruplar arasında anlamlı fark göstermedi. Apendiks duvar kalınlığı, perfore grupta daha yüksek ve non-perfore gangrenöz grupta non-komplike gruba göre daha düşüktü ($p<0.05$). Mukozal kontrastlanma artışı, apandisit alt grupları arasında anlamlı bir korelasyon göstermedi. Lümen içi hava, sağlıklı bir apendikste normal bir bulgu olmakla birlikte akut apandisitin diğer bulguları ile kombine edildiğinde komplike apandisit için özgül bir belirteç olarak bulundu.

SONUÇ: Bu çalışma, komplike ve non-komplike apandisit ile ilişkili belirgin görüntüleme bulgularının ayrıntılı bir analizini sunmaktadır. Apendiks çapı, periapendiküler hava, periapendiküler efüzyon ve lümen içi apendikolit gibi bulgular ayırıcı tanıda anlamlı bulundu. Bulgular, apandisit türleri arasında ayrım yaparken bu parametrelerin önemini vurgulamakta ve klinik uygulamalar için değerli bilgiler sunmaktadır. Akut apandisit ve komplikasyonlarının tanı ve yönetimini geliştirmek için gelecekte prospektif çalışmalara ve gelişmiş görüntüleme tekniklerine ihtiyaç vardır.

Anahtar sözcükler: Akut apandisit; apandisit komplikasyonları; bilgisayarlı tomografi.

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