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Original Research

The correlation between computed tomography reports and histopathological results in acute appendicitis

Computed tomography and histopathological correlation in acute appendicitis

Fatih Yıldırım[1], Burak Uçaner[1], Oğuz Hançerlioğulları[1]
[1]Department of General Surgery, Gülhane Training and Research Hospital, University of Health Sciences, Ankara, Türkiye

Abstract

Aim: Preoperative correct diagnosis is very important in reducing negative appendectomy rates. In patients with suspected acute appendicitis (AA), computed tomography (CT) is frequently preferred along with other diagnostic methods to reduce diagnostic uncertainty. The aim of this study is to evaluate the diagnostic performance of CT findings in the histological findings of AA.

Methods: In this study, 319 patients who underwent abdominopelvic CT imaging between January 1, 2017 and May 1, 2022 and who were operated due to AA suspicion were evaluated retrospectively. CT imaging findings, such as appendix diameter, presence of appendicolith, appendix wall thickening, heterogeneity in periappendicular fatty tissue, presence of fluid accumulation/abscess and lymphadenopathy in the right lower quadrant were evaluated. Only patients who were operated due to the suspicion of AA in CT findings were included in the study.

Results: The mean age of the patients was 36.1 ± 14.7 years. In the study, the male/female ratio was 1.7/1. In CT imaging, appendix diameter (AUC = 0.997), heterogeneity in fatty tissue (AUC = 0.704), appendicolith (AUC = 0.702) and appendix wall thickening (AUC = 0.671) were found to be determinants in gangrenous appendicitis compared to normal histology.

Conclusion: Appendiceal diameter (over 9 mm) was found to be a determinant in gangrenous appendicitis with 100% sensitivity and 92.9% specificity. Appendicolith (AUC = 0.619) and appendix wall thickening (AUC = 0.593) had high sensitivity in appendix neoplasms, but their specificity was quite low (23.7% and 18.5%, respectively). Histologically, preoperative CT findings may be useful indicators in the diagnosis of gangrenous appendicitis.

Keywords

acute appendicitis, computed tomography imaging, histopathological correlation, gangrenous appendicitis

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Corresponding Author: Burak Uçaner, Department of General Surgery, Gülhane Training and Research Hospital, University of Health Sciences, Ankara, Türkiye.
E-mail: burakucaner@hotmail.com **P.:** +90 312 304 51 50
Corresponding Author ORCID: https://orcid.org/0000-0002-5420-3810

Introduction

Acute appendicitis (AA), which is the most common surgical emergency worldwide, is an important cause of morbidity and mortality, especially in developing countries. AA symptoms and findings are not always specific and may mimic other surgical pathologies, making accurate diagnosis difficult. AA management has become more up-to-date and more precise with imaging, scoring methods, and wide treatment options.[1]

Various physical examination methods can be used in the diagnosis of AA, but due to their insufficient diagnostic performance for AA, imaging methods are frequently used in diagnosis.[1,2] Today, computed tomography (CT) imaging is the most preferred imaging method in cases with suspected AA in adolescents and adult patients. A significant decrease in negative appendectomy rates was achieved with CT imaging, and the high sensitivity of CT imaging in differential diagnoses, such as appendix neoplasms, is an important advantage.[3,4]

In CT imaging, other than the appendix diameter, findings such as periappendicular inflammatory changes, abscess, free fluid, inflammation in adjacent structures, the presence of appendicolith, and appendix wall thickening are used in the diagnosis of AA. Although it has a high sensitivity in the diagnosis of appendicitis, the correlation of CT findings with histopathological findings of the removed appendix tissue is not known completely.[5,6]

Materials and Methods

This study was approved by University of Health Sciences Gülhane Training and Research Hospital Ethics Committee on December 15, 2021 with decision number 2021/104. The study was carried out in accordance with the World Medical Association Helsinki Declaration and Good Clinical Practice.

Patients who were admitted to our clinic between January 1, 2017 and May 1, 2022 due to abdominal pain and evaluated by our clinic and operated by confirming the diagnosis of AA with CT imaging were planned to be included in this study. Among the specified descriptions, 412 patients over the age of 18 were operated with the suspicion of AA. CT scans of 73 of these patients could not be reached. CT results of 20 patients were not explanatory. Therefore, this study was conducted with 319 patients.

Demographic information, comorbidities, body mass index (BMI), preoperative WBC, neutrophil, lymphocyte and platelet counts, CRP levels, and symptom duration of 319 patients included in the retrospectively designed study were recorded from the hospital patient records. The surgical method used in patients operated with the suspicion of AA, whether additional surgery was required, the duration of surgery, the presence of surgical complications, the presence of reoperation during follow-up, and the time between hospital admission and surgery were recorded. CT reports were examined one by one and the presence of six main findings was examined: appendix diameter, presence of appendicolith, appendix wall thickening, heterogeneity in fatty tissue around the appendix, periappendicular free fluid and abscess, lymphadenopathy in the right lower quadrant.

The normal histopathological examination was evaluated as a negative appendectomy. The distribution of CT findings according to the histopathological evaluation results of the removed appendix was examined. The sensitivity and specificity of CT findings in gangrenous and normal histology were analyzed. The determinants of CT findings in histopathological results were evaluated.

Ethical Approval

This study was approved by the Ethics Committee of University of Health Sciences Gülhane Training and Research Hospital (Date: 15.12.2021, Decision No: 2021/104).

Statistical Analysis

Statistical analyses were performed using the SPSS version 21.0 (Chicago, USA) software. After examining the distribution of the variables, t-test and the Mann-Whitney U test were used in the group comparison. Categorical data were analyzed with Pearson's Chi-square and Fisher's Exact test. The predictiveness of CT findings in histopathological findings was evaluated by the Receiver Operating Characteristic (ROC) analysis. The results of the ROC analysis were expressed in the area under the curve (AUC) and 95% confidence interval. By evaluating the diagnostic performance of CT methods, sensitivity, specificity, positive predictive value (PPV) and negative predictive values were determined for their predictiveness in histopathological findings. In the statistical analyses in the study, values below $P < .05$ were considered statistically significant.

Reporting Guidelines

This study was reported in accordance with the STROBE guideline.

Results

The mean age of 319 patients included in the study was 36.1 ± 14.7 years (18-84 years). In the study, the male/female ratio was 1.7/1. One hundred seventy patients (53.3%) underwent open appendectomy and 149 patients (46.7%) underwent laparoscopic appendectomy. Thirteen (4.1%) patients had at least one complication requiring surgical or interventional procedures (Clavien-Dindo Classification System Grade>3). In this study, 3 patients (0.9%) were re-operated due to complications.

CT imaging findings were appendix wall thickening (82.1%), increased heterogeneity in fatty tissue around the appendix (78.4%), appendicolith (22.9%), lymphadenopathy in the right lower quadrant (21.6%) and periappendicular free fluid/abscess (19.4%), respectively. On CT imaging, the median appendix diameter was 10.2 mm (between 5.5-22 mm). In the histopathological examination of patients operated with the preliminary diagnosis of AA, the most common pathologies were acute focal appendicitis (50.2%), acute suppurative appendicitis (36.1%), and acute gangrenous/perforated appendicitis (5.3%), respectively. However, histopathological examination of 15 patients (4.7%) was normal. Therefore, the negative appendectomy rate of this study was found to be 4.7%. Histopathological examination revealed tumoral lesions in 3.4% of the patients, were detected: 6 patients had sessile serrated adenoma, 3 patients had mucinous neoplasia, 1 patient had adenocarcinoma and 1 patient had a hyperplastic polyp. In addition, a parasite (Enterobius vermicularis) was the cause of appendicitis in one patient.

Patients with and without acute gangrenous appendicitis were compared in terms of demographic and clinical features. Patients with acute gangrenous appendicitis had higher age ($P < .001$), lower lymphocyte count ($P = .004$), higher CRP ($P < .001$) and ASA score ($P = .023$), longer symptom duration ($P < .001$) and longer hospital stay ($P < .001$). Additional surgery ($P < .001$) and complication rate ($P = .001$) were higher in patients with acute gangrenous appendicitis (Table 1).

CT findings were compared between patients with and without acute gangrenous/perforated appendicitis as a result of histopathological examination. In patients with acute gangrenous

appendicitis, appendix diameter ($P < .001$) was larger, the presence of appendicolith ($P = .032$) and periappendicular free fluid ($P < .001$) were more frequent. No significant difference was observed in other CT findings. The appendiceal diameter was smaller ($P < .001$), appendix wall thickening ($P = .034$) and heterogeneity in periappendicular fatty tissue ($P = .024$) were lower in patients with normal histopathology. No significant difference was observed in other CT findings (Table 2).

The role of CT findings in differentiating patients with acute gangrenous appendicitis from patients with normal histopathology was evaluated with ROC analysis. In the ROC analysis, appendix diameter (AUC = 0.997, $P < .001$), heterogeneity in periappendicular

Table 1. Comparison of Demographic and Clinical Features in Patients with and without Acute Gangrenous Appendicitis as a Result of Histopathological Examination

Features		Acute gangrenous/perforated appendicitis (+) (*n* = 17)	Acute gangrenous/perforated appendicitis (-) (*n* = 302)	*P* value
Age	Mean ± SD	46.2 ± 9.3	35.5 ± 14.8	<.001†
Gender				
Female	n (%)	6 (35.3)	112 (37.1)	.882††
Male		11 (64.7)	190 (62.9)	
Comorbidity	n (%)	6 (35.3)	79 (26.2)	.406TT
BMI, kg/m²	Mean ± SD	25.8 ± 5.5	25.3 ± 3.7	.751†
WBC, 10³/µL	Mean ± SD	13.7 ± 4.9	14.2 ± 4.3	.633†
Neutrophil, 10³/µL	Mean ± SD	10.9 ± 5.2	11.2 ± 4.2	.764†
Lymphocyte, 10³/µL	Median (min-max)	1.3 (0.2-2.5)	1.8 (0.6-5.3)	.004T
Platelets, 10³/µL	Mean ± SD	288 ± 82	258 ± 71	.095†
CRP, mg/dL	Median (min-max)	132 (0-397)	18 (0-397)	<.001T
Symptom duration	Median (min-max)	3 (1-10)	1 (1-10)	<.001T
Acute appendicitis on USG	*n* (%)	7 (41.2)	113 (37.5)	.764††
Surgical technique				
Open appendectomy	*n* (%)	11 (64.7)	159 (52.6)	.332††
Laparoscopic appendectomy		6 (35.3)	143 (47.4)	
Additional surgery during appendectomy	*n* (%)	5 (29.4)	8 (2.6)	<.001TT
Operation time, min	Median (min-max)	60 (35-240)	60 (15-120)	.078T
Length of stay, d	Median (min-max)	5 (1-14)	2 (1-17)	<.001T
Drain use	*n* (%)	14 (82.4)	77 (25.5)	<.001TT
ASA score	Mean ± SD	2.00 ± 0.61	1.62 ± 0.57	.023†
Hospitalization-surgery time, ho	Median (min-max)	8 (1-31)	6 (1-36)	.177T
Complication (Clavien-Dindo Grade>3)	*n* (%)	4 (23.5)	7 (2.3)	.001TT
Presence of reoperation	*n* (%)	0	3 (1.0)	.848TT

*†, Independent samples t-test; ††, Chi-square test; T, Mann-Whitney U test; TT, Fisher's exact test; **, ASA, American Society of Anesthesiologists; BMI, Body mass index; WBC, white blood cell count; CRP, C reactive protein; SD, standard deviation.*

Table 2. Comparison of CT Findings in Patients with And without Acute Gangrenous Appendicitis as a Result of Histopathological Examination

CT findings	Acute gangrenous (+) (*n* = 17)	Acute gangrenous (-) (*n* = 302)	*P*	Normal pathology (+) (*n* = 15)	Normal pathology (-) (*n* = 304)	*P*
Appendix diameter, mm*	14.5 (10-21)	10 (5.5-22)	<.001†	7.5 (6.3-10)	11 (5.5-22)	<.001†
Appendicolith	8 (47.1)	65 (21.5)	.032††	1 (6.7)	72 (23.7)	.205††
Wall thickening	16 (94.1)	246 (81.5)	.326††	9 (60)	253 (83.2)	.034††
Heterogeneity in fatty tissue	16 (84.1)	234 (77.5)	.135††	8 (53.3)	242 (79.6)	.024††
Free fluid/abscess	11 (64.7)	51 (16.9)	<.001††	5 (33.3)	57 (18.8)	.181††
LAP in the right lower quadrant	7 (41.2)	62 (20.5)	.064††	6 (40)	63 (20.7)	.103††

*†, Mann-Whitny U test; ††, Fisher's Exact test; *, CT, Computed tomography.*

Table 3. The role of CT Findings in Differentiating Patients with Histopathology of Acute Gangrenous Appendicitis from Patients with Normal Histopathology

CT findings	AUC	95% CI	*P*	Sen. (%)	Spe. (%)	PPD (%)	NPD (%)
Patients with acute gangrenous appendicitis/perforated appendicitis (*n* = 17) versus patients with normal histopathology (*n* = 15)							
Appendix diameter	0.997*	0.867-1.000	<.001	100	92.9	92.9	100
Appendicolith	0.702	0.515-0.850	.004	47.1	93.3	88.9	60.9
Wall Thickening	0.671	0.483-0.826	.017	94.1	40	64	85.7
Heterogeneity in fatty tissue	0.704	0.517-0.851	.005	94.1	46.7	66.7	87.5
Free fluid/abscess	0.657	0.469-0.815	.071	64.7	66.7	68.7	62.5
LAP in the right lower quadrant	0.506	0.324-0.686	.948	41.2	60	53.8	47.4
Patients with negative appendectomy (*n* = 15) versus patients with AA (*n* = 304)							
Appendix diameter	0.877**	0.843-0.912	<.001	92.9	71.2	13.5	99.5
Appendicolith	0.585	0.529-0.640	.017	93.3	23.7	5.7	98.6
Wall Thickening	0.616	0.560-0.670	.080	40	83.2	10.5	96.6
Heterogeneity in fatty tissue	0.631	0.576-0.684	.052	46.7	79.6	10.1	96.8
Free fluid/abscess	0.573	0.517-0.628	.254	33.3	81.2	8.1	96.1
LAP in the right lower quadrant	0.596	0.540-0.651	.147	40	79.3	8.7	96.4
Patients with neoplasm (*n* = 11) versus patients without neoplasm (*n* = 308)							
Appendix diameter	0.579***	0.521-0.635	.375	54.5	63.9	5.4	97.4
Appendicolith	0.619	0.563-0.672	<.001	100	23.7	4.5	100
Wall Thickening	0.593	0.536-0.647	<.001	100	18.5	4.2	100
Heterogeneity in fatty tissue	0.565	0.509-0.620	.167	90.9	22.1	4.0	98.6
Free fluid/abscess	0.635	0.579-0.688	.090	45.5	81.5	8.1	97.7
LAP in the abdominal right lower quadrant	0.518	0.462-0.574	.774	81.8	21.8	3.6	97.1

, Cut-off ≥ 9 mm; **, Cut-off < 9 mm; *, Cut-off ≥ 11 mm.*

fatty tissue (AUC = 0.704, *P* = .005), presence of appendicolith (AUC = 0.702, *P* = .004) and appendix wall thickening (AUC = 0.671, *P* = .017) were found to be determinant in acute gangrenous appendicitis in patients with acute gangrenous appendicitis, respectively. The diameter of appendix more than 9 mm was the determining factor in acute gangrenous appendicitis with 100% sensitivity and 92.9% specificity in acute gangrenous appendicitis, 94.1% sensitivity and 46.7% specificity in heterogeneity in periappendicular fatty tissue, 47.1% sensitivity and 93.3% specificity in the presence of appendicolith, 94.1% sensitivity and 40% specificity in appendix wall thickening. Appendiceal diameter (AUC = 0.877, *P* < .001) and the presence of appendicolith (AUC = 0.585, *P* = .017) were found to be determinants in negative appendectomy patients with normal histopathology, respectively The appendix diameter less than 9 mm was determinant for negative appendectomy with 92.9% sensitivity, and 71.2% specificity, and the absence of appendicolith was determinant with 93.3% sensitivity and 23.7% specificity. In patients with histopathology of neoplasia, the presence of appendicolith, appendix diameter (AUC = 0.619, *P* < .001) and wall thickening (AUC = 0.593, *P* < .001) were found to be determinants, respectively. The sensitivity of the presence of appendicolith for neoplasia was 100%, the specificity was 23.7%, the sensitivity of wall thickening was 100%, and the specificity was 18.5% (Table 3).

Discussion

AA is an important surgical emergency pathology that should be considered in the differential diagnosis of all acute abdominal patients, so it is important that AA can be differentiated from other pathologies. In addition to physical examination findings, laboratory findings and scoring systems based on these findings have been used in the diagnosis of AA for a long time. However, imaging methods are frequently used when there is doubt about the diagnosis.[7]

Although the diagnostic importance of CT imaging for AA has been demonstrated in many studies,[8-11] the relationship of CT imaging findings with the histopathological features of patients operated for AA has been examined in a very limited number of studies.[12-14]

In this study, the efficacy of CT imaging findings was evaluated in patients with acute gangrenous appendicitis due to its clinical significance. According to the CT findings, the diameter of the appendix (over 9 mm) had a very high diagnostic performance for perforation. However, among the CT findings, it was seen that increased heterogeneity in periappendicular fatty tissue and appendix wall thickening could be used in the diagnosis of perforation, but the diagnostic performance of the findings except for the appendix diameter was low for acute gangrenous appendicitis. The predictiveness of CT findings in acute perforated appendicitis has been evaluated in many studies, but in these studies, perforation has often been defined surgically.[15,16]

In the study by Ali et al., contrast defects in the appendix wall, extraluminal air, appendicolith, and abscess image were used for perforation diagnosis among CT findings in 236 patients.[13] The sensitivity of CT for perforated appendicitis was 71.4% and the specificity was 90.7%. However, contrary to our findings, the diagnostic performance of CT findings was not evaluated separately in this study and routine imaging protocol was not used in CT imaging. Failure to use the routine CT protocol may make

it difficult to evaluate patients with suspected AA, especially in the emergency service environment. Hansen et al. evaluated the association of CT imaging findings with histological AA severity in 105 patients, and the histological severity was ranked from mild to severe, including acute mucosal appendicitis, acute suppurative appendicitis, and gangrenous appendicitis.[14] Among the CT findings, it was stated that the diameter of the appendix, heterogeneity in periappendicular fatty tissue, and the intensity of CT imaging formed using fluid, appendicolith, and free air correlated with the severity of histological appendicitis. However, as in this study, the relationship of CT imaging findings with individual histological diagnoses was not evaluated.

In a recent study by Naya et al., CT findings that may be determinant in gangrenous histology were evaluated in 146 patients operated with the suspicion of AA.[17] In the study, it was reported that the appendix diameter was larger in the gangrenous group, and the presence of appendicolith and heterogeneity in periappendicular fatty tissue were higher. In the study, the diagnostic performance of CT findings in gangrenous appendicitis was not evaluated separately, instead, CT findings were evaluated by combining them with total bilirubin level, but contrary to our findings, sufficient specificity could not be reached for gangrenous appendicitis.

Contrary to our findings, there were also studies reporting that CT findings could not be used in the diagnosis of perforated AA. In the study of Gaskill et al., 89 patients who were operated due to suspected AA with CT imaging were examined and it was stated that none of the CT findings such as appendicolith, cecal wall thickening, and fluid accumulation were determinant in pathologically demonstrated perforation.[18] However, it is noteworthy that only 89 patients were evaluated in this study and the perforation rate was approximately 50%.

Several studies have evaluated the sensitivity of CT findings in perforated appendicitis. In these studies, 34-62% sensitivity and 81-99% specificity were reported for CT imaging.[15,16,19] In these studies, which frequently reported high perforation rates and were performed with a limited number of patients, perforation was evaluated surgically, and the perforation diagnosis evaluated by radiologists in the light of CT findings was generally taken into consideration in the perforation decision. In this study, the histopathological method, which is the gold standard in the diagnosis of perforation, was preferred and the predictiveness of CT findings in histology compatible with perforation was evaluated separately. In addition, the number of patients included in this study is greater than in the previous studies.[15,16,19] Therefore, it can be said that this study yielded more objective findings.

In this study, it was observed that appendix diameter (less than 9 mm) and absence of appendicolith could be used among CT findings in patients with negative appendectomy. Particularly, the appendix diameter being 9 mm below the diameter of the appendix had high sensitivity (92.9%) and specificity (71.2%) for negative appendectomy. Similar results have been reported before. In this study, it was observed that the value showing the best sensitivity and specificity in differentiating the appendix diameter from normal histology was above 9 mm. It has been stated in some studies that 6-7 mm threshold values can be used in the diagnosis of AA.[20] The high appendix diameter value reported in this study was an important reason for the fact that all the patients included in this study were patients who were operated due to suspected AA. In studies in which appendix diameter was reported to be lower, the inclusion of patients who were not operated may have resulted in smaller appendix diameter values.

In this study, the predictiveness of CT findings in patients with neoplasia was not sufficient. It was observed that appendicolith and wall thickening could be used in the diagnosis of neoplasia, but the specificities were quite low (18.5-23.7%). Previous studies have also reported that CT findings were not specific to appendix neoplasms.[21,22]

Limitations

This study has some limitations. In this study, patients who were operated with suspected AA as a result of clinical evaluation and CT imaging were evaluated. Therefore, the diagnostic performance of CT imaging in the diagnosis of AA could not be evaluated. In addition, common findings used in the diagnosis of AA among CT imaging findings were evaluated. However, apart from these findings, there are also CT findings such as the general opinion of the radiologist and suspected mass consistent with appendix malignancies. In addition, the diagnostic performance of CT findings in gangrenous appendicitis was obtained by comparing patients with normal histology. However, comparing gangrenous histology with other AA-compatible histologies will reduce the diagnostic performance of CT findings for perforation.

Conclusion

According to the data of this study, the increase in the diameter of the appendix, the presence of appendicolith and the presence of periappendicular free fluid among the preoperative CT findings were found to be determinants in histologically demonstrated perforated appendicitis. Especially the appendix diameter greater than 9 mm has high sensitivity and specificity for perforated appendicitis. In this study, appendix neoplasia was observed in 3.4% of the patients who were operated with the suspicion of AA as a result of CT imaging. The sensitivity and specificity of CT findings in appendix neoplasms are not at the desired level. As the number of homogeneous studies conducted with larger patient series will increase in the future, a question on this subject will also be answered.

Declarations

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was waived due to the retrospective nature of the study.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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None.

Abbreviations

AA: Acute appendicitis
ASA: American society of anesthesiologists
AUC: Area under the curve
BMI: Body mass index
CRP: C-reactive protein
CT: Computed tomography
PPV: Positive predictive value
ROC: Receiver operating characteristic

SD: Standard deviation
SPSS: Statistical package for the social sciences
WBC: White blood cell count

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