Annals of Clinical and Analytical Medicine
Original Research

Diagnostic value of imaging methods in diagnosing acute appendicitis in comparison with leukocyte counts

Esra Dişçi[1], Rıfat Peksöz[2], Kamber Kaşali[3], Bahattin Bayar[2]
[1]Department of General surgery, Atatürk University Faculty of Medicine, Erzurum
[2]Department of General Surgery, Muş State Hospital, Muş
[3]Department of Biostatistics, Ataturk University Faculty of Medicine, Erzurum, Turkey

Abstract
Aim: Acute appendicitis (AA) is the most common cause of acute abdomen. Early diagnosis and treatment are life-saving, as delay leads to high mortality and morbidity. In this study, we aimed to investigate the diagnostic values of leukocyte count and imaging methods such as CT (Computed tomography) and USG (Ultrasonography) for patients pre-diagnosed with AA.
Material and Methods: A retrospective study included 425 patients who admitted to the emergency room with abdominal pain and operated for pre-diagnosis of AA.
Results: The patients were divided into groups by appendix histopathology: Group I included 53 patients (12.5%) with a normal appendix, Group II included 289 patients (68%) with noncomplicated appendicitis, and Group III included 83 patients (19.5%) with complicated appendicitis. Two hundred sixty-three patients were male (61.8%), 162 (32.8%) were female, and their mean age was 34.7 (18-82) years. In AA diagnosis, the sensitivity and specificity of leukocyte count were 81.45% and 45.2%, respectively, while USG had a sensitivity of 95% and specificity of 84%, and CT had a sensitivity of 86% and specificity of 59%. There was a significant difference between groups I-II and II-III in terms of leukocyte count ($p<0.001$) in determining the severity of AA.
Discussion: When diagnosing AA, radiological methods such as USG and CT are also used along with physical and laboratory examinations. Since CT is an expensive and difficult-to-access method using contrast materials, USG should be the first radiological method as it has acceptable sensitivity and specificity. To render USG accessible, emergency medical or general surgical specialization training should incorporate emergency USG training.

Keywords
Acute Appendicitis; Leukocyte; Ultrasonography; Computed Tomography

DOI: 10.4328/ACAM.20626 Received: 2021-03-31 Accepted: 2021-06-02 Published Online: 2021-06-16
Corresponding Author: Rıfat Peksöz, Department of General Surgery, Muş State Hospital, 49400, Muş,Turkey.
E-mail: rifat-peksoz@hotmail.com P: +90 5349214382
Corresponding Author ORCID ID: https://orcid.org/0000-0003-4658-5254

Introduction

Acute appendicitis (AA) is an acute inflammatory condition that develops in the appendix tissue as a result of obstruction of the appendix lumen for various reasons [1]. It is the most common cause of acute abdomen in surgery clinics, and its lifelong prevalence is 7% [2]. Appendectomy, applied in the treatment of acute appendicitis, is the most common emergency abdominal surgery operation performed in all surgical clinics worldwide [3]. The timing of the surgery is very important. Early surgical decisions result in 15-30% negative laparotomy; however, when the surgical decision is delayed, the appendix becomes perforated, and the delay period increases mortality and morbidity [2].

In addition to physical examination and scoring systems, radiological methods such as ultrasonography (USG), computed tomography (CT), magnetic resonance (MR) and diagnostic laparoscopy can be used in the diagnosis of acute appendicitis [4,5]. Despite the use of methods such as CT, USG, laparoscopy, and scoring systems, the rate of missing acute appendicitis and/or appendix perforation has not changed (15%), and there is still no single and reliable laboratory test or clinical test to be used for these diagnoses [6].

In this study, it was aimed to compare the leukocyte count, which can be easily studied in serum in the diagnosis of AA, with imaging methods such as CT and USG, and to discuss the value of these methods in the diagnosis of acute appendicitis in the light of literature.

Material and Methods

After obtaining approval from the Ethics Committee of Erzurum Atatürk University Faculty of Medicine, patients who were admitted to the Muş State Hospital Emergency Department with a pre-diagnosis of AA between January 2018 and April 2019 were analyzed retrospectively. In addition to taking blood samples from patients in the emergency department, imaging methods such as standing direct abdominal radiography (SDAR), USG, CT, and MRI were used. The gender, age, leukocyte value at the time of application, the surgery performed with the radiological examinations performed, the type of anesthesia applied, and the postoperative pathology information of the patients were recorded. All patients were adults over the age of 18, and patients who were found to have other pathological findings in addition to acute appendicitis during surgery were excluded from the study.

Serum leukocyte levels, the values such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), Likelihood Ratio positive (LR +), and Likelihood Ratio negative (LR) values of patients applying with the diagnosis of acute appendicitis used for the USG and CT among imaging methods were analyzed statistically.

Appendectomy materials of the patients were classified into 3 groups by the histopathological results as follows: Group I: Patients with normal appendix, lymphoid hyperplasia, obliterative appendix were evaluated as normal (Negative appendectomy); Group II: Patients with phlegmonous appendicitis, catarrhal appendicitis, suppurative appendicitis were evaluated as non-complicated appendicitis; Group III: Patients with gangrenous appendicitis, perforated appendicitis were evaluated as complicated appendicitis. Patients with appendix diameter greater than 6 mm on USG and CT were evaluated as acute appendicitis.

Statistical Analysis

Results were presented as numbers for categorical variables, and as mean ± standard deviation for continuous percentage variables. The normality of continuous variables was evaluated using the Shapiro-Wilk-W and Kolmogorov- Smirnov test. Chi-square and Fisher-Freeman-Halton tests were used for comparing categorical variables. ROC analysis was used to determine whether the continuous variable can be used in diagnosis. In addition, the Youden-Index was used to determine the cut-off value. All analyzes were performed at a 95% confidence interval. The p-value <0.05 was considered significant, while p<0.001 was considered extremely significant. IBM SPSS 20 package software was used for statistical analyses.

Results

We examined 463 patients who were operated consecutively with a pre-diagnosis of acute appendicitis in a 1-year period between 2018-2019 were examined. Thirty-eight patients were excluded from the study (13 patients had other diseases in addition to acute appendicitis during surgery, and blood results or imaging methods were not available in 9 patients, 6 patients were reported as malignancy and 10 patients were pregnant). Among the patients, 263 were males (61.8%), 162 were females (38.1%), and the mean age of the patients was 34.65 (18-82) years.

The patients were classified into 3 groups by their pathology results as follows: Group I: those with pathology result as normal appendectomy material 53 (12.47%), Group II: noncomplicated 289 (68%), Group III: complicated 83 (19.52%) (Table 1).

Table 1. Demographic features of patients

	Sex				Chi-Square	P -value
	Male		Female			
	n	n %	n	n %		
Type of Appendicitis						
Group I	30	11.4%	23	14.2%	0,925	,336
Group II	185	70.3%	104	64.2%	22,702	,000
Group III	48	18.3%	35	21.6%	2,036	,154

Table 2. Statistical analysis of WBC values between groups

	Area ± Std. Error	95% CI for Area		Cut-off value	Sensitivity	Specificity	LR+	LR-	P- value
		Lower	Upper						
Group I-II	0.65±0.041	0.575	0.736	11.5	0.734	0.547	1.62	0.49	<0.001
Group II-III	0.767±0.033	0.702	0.831	14.5	0.807	0.675	2.48	0.29	<0.001

WBC: White Blood Cell, LR+: Likelihood Ratio positive, LR-: Likelihood Ratio negative

Table 3. Diagnostic tests for WBC, USG, CT

	Sensitivity %	Specificity %	PPD	NPD	PLR	NLR
WBC	81.45	45.2	091	0.26	1.49	0.41
USG	95	84	0.98	0.70	6.00	0.06
CT	86	59	0.93	0.38	2.10	0.24

WBC: White Blood Cell, LR+: Likelihood Ratio positive, LR-: Likelihood Ratio negative, USG: Ultrasonography, CT: Computed Tomography

Routine hemogram test, especially leukocyte count, is studied in patients with suspected acute appendicitis disease. When we took the upper reference range (11x103) of the device in our hospital as the cut-off value for leukocyte count, the sensitivity for leukocyte values of our patients was found to be 81.45%, specificity 45.2%, PPD 0.91, NPD 0.26, PLR 1.49, NLR 0.41. Leukocyte count was the highest in Group III, a statistically significant difference was found between Group I-II and GroupII-III ($p < 0.001$) (Tables 2, 3).

SDAR (356 patients) and chest radiography (327 patients) are the first imaging methods requested from patients who applied to the emergency department with complaints of abdominal pain. As an advanced imaging method, USG was performed in 153 (36%) patients, CT in 342 (80.5%) patients and MRI in 1 pregnant patient.

The diagnostic values of USG for acute appendicitis were found as sensitivity 95%, specificity 84%, PPD 0.98, NPD 0.7, PLR 6, NLR 0.06. The diagnostic values of CT for acute appendicitis were found as sensitivity 86%, specificity 59%, PPD 0.93, NPD 0.38, PLR 2.1, NLR 0.24. (Table 3).

Discussion

Acute appendicitis is one of the most common causes of acute abdomen. Its diagnosis can be successfully made by using radiological methods together with physical examination and history [7]. Acute appendicitis can be seen at any age; however, it is most common between the ages of 20-40. The most common age that it is seen is 22 years, and the mean age of being seen is 31.3 years [8]. AA is 1.4 times more common in males than in females [9]. Although different percentages of gender ratio are reported for acute appendicitis patients in the literature, 61.8% of our patients were male, 38.1% were female, and the mean age of the patients was 34.65 (16-82) years, the findings are consistent with the literature. Considering the high incidence rate of acute appendicitis, its diagnosis is of great importance. Many markers have been investigated to prevent morbidity and mortality caused by delays in diagnosis. The complete blood count is one of the leading markers that are easily accessible and rapidly evaluated. WBC (Leukocyte), neutrophil, lymphocyte, and subparameters of complete blood count such as neutrophil-lymphocyte ratio, inflammatory markers, and especially leukocyte counts have been investigated in many studies. Leukocytes have been used to define the severity of infectious and inflammatory diseases such as acute appendicitis [10,11].

The higher the leukocyte value, the more likely the cases to be appendicitis. Perforation is more likely to occur in patients with high leukocyte count. Complicated appendicitis (perforation, gangrenous appendicitis, intraabdominal abscess, plastron formation, generalized peritonitis) constitutes 20-30% of all appendicitis cases. The leukocyte value is not found useful in distinguishing complicated and uncomplicated cases at the cut-off value calculated. In the literature, there are a few studies that have found a difference between complicated and uncomplicated groups [12,13].

In a meta-analysis study, the sensitivity of leukocytosis (> 10000/mm3) in the diagnosis of acute appendicitis has been reported as 83% and specificity as 67% [14]. In studies conducted with AA patients, leukocyte levels in the uncomplicated group have been found to be higher than the normal appendix, and the leukocyte levels in the complicated group have been found to be higher than the noncomplicated appendicitis group [12,15]. In a large study group conducted by Sevinç et al. in a group of 3392 patients, when the cut-off value of leukocyte was taken as 11900/mm3, the sensitivity for acute appendicitis has been found to be 71.2%, specificity to be 67.2%, PPD: 0.92, NPD: 0.30, PLR: 2.15, NLR: 0.43 [10].

When we take the upper reference range (11x103) of the device in our hospital as the cut-off value for leukocyte count, the sensitivity for leukocyte values of our patients was found to be 81.45%, specificity 45.2%, PPD 0.91, NPD 0.26, PLR 1.49, NLR 0.41. These values are compatible with the values measured in a wide range in the literature. The low number of patients in the negative appendectomy group contributes to the low specificity value. In determining the severity of acute appendicitis, a statistically significant difference was found between groups I-II and II-III in terms of leukocyte count ($p < 0.001$) (Table 2).

Although high sensitivity rates have been stated for the diagnosis of acute appendicitis, it is seen that additional imaging methods are needed in the diagnosis of AA to prevent negative appendectomies due to low specificity values. It has been reported that negative appendectomy rates of 15-20% can be reduced by using imaging methods, and unnecessary surgeries, perforation rates and hospital stay can be reduced in patients without acute appendicitis [16].

Among the radiological imaging methods, especially USG and CT are the most used methods in the diagnosis of acute appendicitis and its complications [7]. USG is the first preferred imaging method in patients whose clinical findings suggest AA. However, which imaging method to use may vary depending on the physical conditions of that center, the experience of the radiologist and surgeon, and the characteristics of the patient [17]. We can count the advantages of USG as low cost, not giving ionized radiation to the patient, and the possibility of using it in pregnant women because of not using contrast material. However, the disadvantages are that it depends on the person performing it, it cannot be retrospectively examined, it cannot be optimally performed, or the appendix cannot be visualized due to patient-related problems (intestines full of gas, abdominal fat mass, etc.) [18]. In the studies performed, the sensitivity for diagnosing acute appendicitis for USG has been found to be 66-87%, specificity 46-84%, PPD 0.85-0. 90, NPD 0.23-0.47, and accuracy ranged from 73 to 80% [4,25,26]. In our study, the diagnostic values of USG for acute appendicitis were found as sensitivity 95%, specificity 84%, PPD 0.98, NPD 0.7, PLR 6, NLR 0.06, and the results are better to a certain extent than the literature. In suspicious cases, where USG is insufficient, CT should be preferred because its sensitivity, positive predictive

value, and accuracy rates are higher [3]. Although contrast-enhanced CT is recommended, appropriately performed non-contrasted CT examinations are also sufficient [21]. In a review evaluating 23 prospective studies, the sensitivity rate for CT has been reported to be 77-100% and the diagnostic accuracy rate was 83-100% [22]. In another study, sensitivity for CT has been reported to be 94.12%, PPD 88.89%, and accuracy rate was 87.32% [3]. In our study, the diagnostic values of CT for acute appendicitis were found as sensitivity 86%, specificity 59%, PPD 0.93, NPD 0.38, PLR 2.1, NLR 0.24. According to USG and CT report results, there was no statistically significant difference between the results obtained when the patients whose appendix could not be visualized were accepted as acute appendicitis, and the results obtained when these patients were excluded from the study (p> 0.05). We could not find any study with this patient group in the literature, we think more research should be conducted with this patient group. Although CT is superior to USG in the diagnosis of AA, its disadvantages are that it cannot be found everywhere, its cost is high, it contains ionizing radiation, contrast medium reactions, and increases the time until surgery [23]. CT was used significantly more than USG in patients who applied to the emergency department with abdominal pain due to the absence of a radiologist outside of working hours in our hospital (p <0.001). In the literature, the superiority of CT in recognizing acute appendicitis compared to USG has been demonstrated, however, in our study, USG has superiority in contrast to the literature, because in many health centers in our country, CT reports are carried out through the service procurement system. Therefore, communication difficulties are experienced between the physician who carries out the patient's treatment and the physician who reports the CT result, and the radiologist cannot obtain enough information about the patient. We think that that it is necessary to change the working hours of radiology specialists and provide them with sufficient equipment. For such a common disease, USG training programs should be conducted for general surgery or emergency specialists or emergency USG training should be provided within the specialty training program.

Despite physical examination, laboratory findings, and auxiliary radiological methods, negative appendectomies in a ratio of 15-30% are still performed [2,10]. Negative appendectomy is more common in females due to the confusion of gynecological pathologies with acute appendicitis [24]. In our study, the number of patients with negative appendectomy was higher among male patients, contrary to the literature; however, there is no statistically significant difference (p> 0.05). This may be due to the low number of patients. The negative appendectomy rate was 12.5%, with slightly better results compared to the literature.

Conclusion

Leukocyte value, which is a subparameter of complete blood count, is an easily accessible and rapidly evaluated marker in diagnosing acute appendicitis and determining the severity of appendicitis; although its high sensitivity, the specificity is low. Therefore, we use radiological methods such as USG and CT in addition to physical examination and blood parameters when determining the diagnosis of acute appendicitis. Although the sensitivity and specificity values of CT are higher in the literature, the first radiological method to be applied should be USG with acceptable sensitivity and specificity, as it includes a contrast medium and is expensive. In order for USG to be easily accessible, emergency USG training should also be included within the emergency medicine specialty or general surgery specialty education.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

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. No animal or human studies were carried out by the authors for this article.

Funding: *None*

Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

References

1. Young P. Appendicitis and its history. Rev Med Chil. 2014; 142(5):667-72.

2. Shogilev DJ, Duus N, Odom S.R, Shapiro NI. Diagnosing Appendicitis: Evidence-Based Review of the Diagnostic Approach in 2014. West J Emerg Med. 2014; 15(7):859-71.

3. Celep B, Bal A, Özsoy M, Özkeçeci Z, Tunay K, Erşen O, et al. Abdominal Tomography in the Diagnosis of Acute Appendicitis. Bozok Medical Journal. 2014:29-33

4. Behzatoğlu B, Hatipoğlu E, Bayramoğlu S, Yılmaz G, Yirik G, Cimilli T. Comparison of ultrasonographic and computed tomographic findings in the diagnosis of acute apendicitis. Bakırköy Medical Journal. 2006:22-4.

5. Navez B, Navez J. Laparoscopy in the acute abdomen. Best Pract Res Clin Gastroenterol. 2014; 28(1):3-17.

6. Fike FB, Mortellaro VE, Juang D, Sharp SW, Ostlie DJ, St Peter SD. The impact of postoperative abscess formation in perforated appendicitis. J Surg Res. 2011; 170(1):24-6.

7. Atema JJ, van Rossem CC, Leeuwenburgh MM, Stoker J, Boermeester MA. Scoring system to distinguish uncomplicated from complicated acute appendicitis. Br J Surg. 2015, 102(8):979-90.

8. Franz MG, Norman J, Fabri PJ. Increased morbidity of appendicitis with advancing age. Am Surg. 1995; 61(1):40-4.

9. Çitgöz B, Yetkin G, Akgün İ, Uludağ M, Velidedeoğlu M, Akçakaya A. The relationship between negative appendectomy and gynecological pathologies in female patients. Maltepe Medical Journal. 2011; 3:10-2.

10. Sevinç MM, Kınacı E, Çakar E, Bayrak S, Özakay A, Aren A, et al. Diagnostic value of basic laboratory parameters for simple and perforated acute appendicitis: an analysis of 3392 cases. Ulus Travma Acil Cerrahi Derg/Turkish Journal of Trauma and Emergency Surgery. 2016; 22(2):155-62.

11. Schellekens DH, Hulsewé KW, van Acker BA, van Bijnen AA, de Jaegere TM, Sastrowijoto SH, et al. Evaluation of the diagnostic accuracy of plasma markers for early diagnosis in patients suspected for acute appendicitis. Acad Emerg Med. 2013:703-10.

12. Ayrık C, Karaaslan U, Dağ A, Bozkurt S, Toker İ, Demir F. Predictive calue of leucocyte count, neutrophil percent and C-reactive protein concentration "cut-off value" on the diagnosis of appendicitis. Ulusal Travma ve Acil Cerrahi Dergisi/ Turkish journal of trauma and Emergency Surgery. 2016; 22(1):76-83.

13. Moraitis D, Kini SU, Annamaneni RK, Zitsman JL. Laparoscopy in complicated pediatric appendicitis. JSLS. 2004; 8(4):310-3.

14. Andersson RE. Meta-analysis of the clinical and laboratory diagnosis of appendicitis. Br J Surg. 2004; 91(1):28-37.

15. Keskek M, Tez M, Yoldas O, Acar A, Akgul O, Gocmen E, et al. Receiver operating characteristic analysis of leukocyte counts in operations for suspected appendicitis. Am J Emerg Med. 2008; 26(7):769-72.

16. Brogden TG, Streets CG. The management of acute appendicitis. J R Nav Med Serv. 2013; 99(3):106-10.

17. Balthazar EJ, Megibow AJ, Gordon RB, Whelan CA, Hulnick D. Computed tomography of the abnormal appendix. J Comput Assist Tomogr. 1988; 12(4):595-601.

18. Demircan A, Aygencel G, Karamercan M, Ergin M, Yılmaz TU, Karamercan A. Ultrasonographic findings and evaluation of white blood cell counts in patients undergoing laparotomy with the diagnosis of acute appendicitis. Turkish Journal of Trauma and Emergency Surgery. 2010; 16(3):248-52.

19. Dikicier E, Altıntoprak, Çakmak G, Değirmenci B, Akbulut G. The Use of Ultrasound Imaging for Acute Appendicitis. Sakarya MJ. 2011; 64-6.

20. Kapçı M, Türkdoğan KA, Duman A, Avcil M, Gülen B, Uğurlu Y, et al. Biomarkers

in the diagnosis of acute appendicitis. J Clin Exp Invest. 2014; 5:250-5.
21. Schaefer-Prokop C, Jörgensen M. Gastrointestinal Tract. In: Prokop M, Galanski M, editors. Computed Tomography of the Body. Vol.5. Ludwigsburg, Germany: Thieme; 2003. p. 573-5.
22. Neumayer L, Kennedy A. Imaging in appendicitis: a review with special emphasis on the treatment of women. Obstet Gynecol. 2003; 102(6):1404-9.
23. Musunuru S, Chen H, Rikkers LF, Weber SM. Computed tomography in the diagnosis of acute appendicitis: definitive or detrimental? J Gastrointest Surg. 2007; 11(11):1417-21.
24. Stein GY, Rath-Wolfson L, Zeidman A, Atar E, Marcus O, Joubran S, et al. Sex differences in the epidemiology, seasonal variation, and trends in the management of patients with acute appendicitis. Langenbecks Arch Surg. 2012; 397(7):1087-92.

How to cite this article:
Esra Dişçi, Rıfat Peksöz, Kamber Kaşali, Bahattin Bayar. Diagnostic value of imaging methods in diagnosing acute appendicitis in comparison with leukocyte counts. Ann Clin Anal Med 2021; DOI: 10.4328/ACAM.20626