ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/medsci.2021-85007

Computed Tomography Trend in Acute Appendicitis: Retrospective Cross-Sectional Analysis

Akut Apandisitte Bilgisayarlı Tomografi Eğilimi: Retrospektif Kesitsel Analiz

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This study was presented as an oral presentation at the 12th National Trauma and Emergency Surgery Congress, October 9-13, 2019, Antalya, Türkiye.

ABSTRACT Objective: Acute appendicitis (AA) is one of the abdominal pain pathologies that often requires emergency surgery. It was aimed to reveal the flaws in our radiological examination request algorithm by looking at the diagnostic activities of abdominal ultrasonography (USG) and computed tomography (CT). **Material and Methods:** Hospital records of 299 patients who were operated between January and July 2019 in Ankara Training and Research Hospital, General Surgery Clinic were retrospectively reviewed. Patients' age, gender, comorbid disease, body mass index, preoperative white blood leukocyte levels, length of hospital stay and CT and USG requests were recorded. Findings were correlated with postoperative pathology results and the efficacy of radiological examinations in diagnosis were evaluated. **Results:** The patients were classified as those who underwent USG only (85), CT only (43), CT after USG (162) and those who did not undergo imaging (9). Pathology results were reported as apendicitis in 257 patients (86%) and normal in 42 (%14). When radiological imaging examinations and pathology results were compared, positive predictive values/occuracy rates for USG alone, only CT and CT after USG were 89.02%/89.41%, 94.12%/76.74% and 87.97%/78.40% respectively. Although the positive predictive value of CT was higher than USG, the occuracy rate was lower. No statistically significant difference was found between the groups in terms of pathological correlation. **Conclusion:** In patients with AA, it is appropriate to make CT requests with the recommendation of a radiologist and surgeon after the first examination and sonographic examination. Thus, we believe that CT will be used effectively and there will be no unnecessary X-ray burden for patients.

Keywords: Appendicitis; tomography; ultrasonography

ÖZET Amaç: Akut apandisit (AA), sıklıkla acil cerrahi gerektiren karın ağrısı patolojilerinden biridir. Karın ultrasonografisi (USG) ve bilgisayarlı tomografinin (BT) tanısal aktivitelerine bakılarak, radyolojik tetkik istem algoritmamızdaki aksaklıkların ortaya çıkarılması amaçlandı. **Gereç ve Yöntemler:** Ocak-Temmuz 2019 tarihleri arasında Ankara Eğitim ve Araştırma Hastanesi Genel Cerrahi Kliniğinde ameliyat edilen 299 hastanın hastane kayıtları geriye dönük olarak incelendi. Hastaların yaş, cinsiyet, komorbid hastalığı, beden kitle indeksi, ameliyat öncesi lökosit düzeyleri, hastanede kalış süreleri, BT ve USG istekleri kaydedildi. Bulgular, postoperatif patoloji sonuçları ile korele edildi ve radyolojik incelemelerin tanıdaki etkinlikleri değerlendirildi. **Bulgular:** Hastalar; sadece USG (85), sadece BT (43), USG sonrası BT (162) yapılanlar ve görüntüleme yapılmayanlar (9) olarak klasifiye edildi. Patoloji sonuçları, hastaların 257'sinde (%86) apandisit, 42'sinde (%14) normal olarak rapor edildi. Radyolojik görüntüleme incelemeleri ve patoloji sonuçları karşılaştırıldığında; USG, BT ve USG sonrası BT yapılan hastalarda pozitif prediktif değerler/geçerlilik oranları sırasıyla %89,02/%89,41; %94,12/%76,74 ve %87,97/%78,40 idi. BT'nin pozitif prediktif değeri, USG'ye göre daha yüksek olmasına rağmen geçerlilik oranı daha düşüktü. Patolojik korelasyon açısından gruplar arasında istatistiksel olarak anlamlı fark bulunmadı. **Sonuç:** AA hastalarında ilk muayene ve sonografik inceleme sonrasında BT istemlerinin radyolog ve cerrah önerisi ile yapılması uygundur. Böylece BT'nin etkin kullanılacağı ve hastalar için gereksiz X-ışını yükü olmayacağı kanaatindeyiz.

Anahtar Kelimeler: Apandisit; tomografi; ultrasonografi

Acute appendicitis (AA) is one of the pathologies frequently encountered in emergency departments due to abdominal pain and often requires urgent surgical intervention.[1,2] The diagnosis of appendicitis can mostly be made with anamnesis, physical examination findings and laboratory data, but some of the patients (20-33%) go to hospitals with atypical examination findings and laboratory values which do not support the diagnosis.[3,4]

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Peer review under responsibility of Turkiye Klinikleri Journal of Medical Sciences.

Received: 17 Jun 2021 ***Received in revised form:*** 23 Mar 2022 ***Accepted:*** 28 Mar 2022 ***Available online:*** 06 Apr 2022

While negative appendectomy rates are high in surgeries performed as a result of history, physical examination and laboratory findings, serious complications such as abscess, perforation, peritonitis and plastron may develop in delayed atypical cases (4-15%). The imaging methods frequently used in the diagnosis of appendicitis are ultrasonography (USG) and computed tomography (CT). Although USG has high sensitivity and specificity in the diagnosis of appendicitis, it may be insufficient in cases with retrocecal location. In atypical cases which cannot be diagnosed by USG and especially in differential diagnosis, CT is very effective and has high accuracy rates.[5]

We aimed to evaluate the diagnostic contribution of using USG and CT alone or together by reviewing our radiological examination request algorithm applied in AA cases. In addition, we tried to reveal the measures to be taken to detect and eliminate the problems in this algorithm.

MATERIAL AND METHODS

In this study, files of 299 patients who were operated with a pre-diagnosis of AA were retrospectively reviewed. History, physical examination, laboratory findings and/or radiological findings were obtained for clinical diagnosis, and postoperative histopathological examination results for definitive diagnosis.

The records of 299 patients who were hospitalized and operated in the General Surgery Clinic of Ankara Training and Research Hospital with a pre-diagnosis of AA from the emergency department between January and July 2019 were retrospectively analysed. Age, gender, comorbid disease, body mass index, initial leukocyte value, length of hospital stay, USG and CT requests and pathology reports of the patients were recorded.

Almost all USG requests were made by emergency physicians. All USGs were performed by radiologists working in the emergency room radiology unit. On USG, uncompressible and blind-ended tubular structure with 6 mm↑ diameter, appendicolitis in the lumen of the appendix, and the presence of periapendicular free fluid were recorded as findings contributing to the diagnosis and were interpreted in favor of appendicitis.

The CT requests were made by emergency physicians before the surgical consultation, and then by general surgeons. All CTs were performed using a standard dose protocol, with intravenous contrast. On CT, findings of thickening of the appendix wall, pericecal free fluid, appendicolitis appearance, heterogeneity around the cecum were recorded and interpreted in favor of appendicitis.

It was recorded by which unit physicians (emergency or general surgery) the radiological imaging requests were made. In addition, the timing between USG and CT requests and general surgery consultation was examined. We tried to find the effectiveness of performing radiological examinations separately or together by calculating the sensitivity, specificity, positive/negative likelihood ratio, positive/negative predictive value and accuracy rate for USG and CT in the diagnosis of AA.

For statistical analysis, SPSS [IBM (International Business Machines Corporation), United States of America] program and two-sample chi-square test were used.

Our study was carried out in accordance with the principles of the Declaration of Helsinki. Ethics committee permission for the study was obtained from the Ethics Committee of Ankara Training and Research Hospital with the number E-93471371-514.10, dated 18.02.2021.

RESULTS

The overall mean age of 299 patients was 34.41 (±14.24), and it was 29.27 (±11.32) in men and 37.52 (±10.44) in women. One hundred and seventy seven (59.20%) of the patients were male and 122 (40.80%) were female. The male/female ratio was found to be 1.55. There were 32 (10.70%) hypertension, 14 (4.68%) diabetes mellitus and 4 (1.33%) random pregnancies in the patients. Body mass index was greater than 35 in 69 (23.07%) patients.

The demographic data of the patients and presence of comorbid disease, body mass index, white blood cell count on admission to the hospital, length of hospitalization are shown in Table 1. A white blood leukocyte value being 10,000 mm^3↑ was sta-

TABLE 1: Analysis of descriptive data.

		n	%
Age	Men	177	29.27 (±11.32)
	Women	122	37.52 (±10.44)
	Total	299	34.41 (±14.24)
Gender	Male	177	59.2
	Female	122	40.8
*Comorbid diseases	Hypertension	32	10.7
	Diabetes mellitus	14	4.6
	Pregnancy	4	1.3
Body mass index	28-35	230	77.0
	35-40	55	18.4
	40↑	14	4.6
Leukocyte values	10,000↓	73	24.4
	10,000-20,000	196	65.6
	20,000↑	30	10.0
Length of hospitalization	1-3 days	281	94.0
	3-5 days	15	5.0
	5 days↑	3	1.0

*Hypertension, diabetes mellitus and pregnancy have been questioned.

tistically significant in terms of appendicitis positivity ($p<0.05$).

A total of 247 USGs and 205 CTs were performed on the patients. Of these radiological views, 85 (28.42%) were in the form of USG alone, 43 (14.38%) were only in the form of CT and 162 (54.18%) were in the form of CT after USG. No imaging was performed in 9 (3.01%) patients. Sensitivity, specificity, positive and negative likelihood ratio, positive and negative predictive value, occuracy rate and p value were calculated for the groups in which USG and CT were performed separately and together. There was no statistically significant difference between the groups ($p>0.05$). Diagnostic efficiency analysis of imaging methods is shown in Table 2.

In the pathological examination results, 257 (85.95%) patients were diagnosed with positive appendicitis, while the number of negative appendectomies was found to be 42 (14.04%). Twenty four (9.33%) of 257 patients had microperforation (gangrenous appendicites), 8 (3.11%) had perforation and/or periappendicular abscess. All recovered without any additional complications, but eighteen patients had a hospital stay of more than 3 days.

Dual imaging and non-imaging were compared. There was no statistically significant difference between the groups in terms of the contribution of CT after USG (dual imaging) and no radiological imaging on postoperative pathological results ($p=1.00$). The effect of CT requests performed after USG by emergency physicians or general surgeons on pathology results was examined. The rate of pathological appendicitis diagnosis was higher in the emergency physician group. However, there was no statistically significant difference between the groups when compared with general surgeons ($p=0.06$). Of the 43 CTs made as the first choice, 7 were requested by general surgeons and 36 by emergency physicians. The pathology results were negative in 3 patients from whom CTs were requested by emergency physicians, and all of the results were positive in patients from whom CTs were requested by general surgeons. There was no statistically significant difference in terms of the contribution of the physician requesting CT to pathological diagnosis ($p=0.55$), but it was a

TABLE 2: Comparison of diagnostic efficiency of imaging methods.

	n	Sensitivity analysis (%)	Specificity analysis (%)	PPV (%)	NPV (%)	Positive likelihood ratio (%)	Negative likelihood ratio (%)	Accuracy[a] (%)	p (chi-square)*
USG (alone)	85	100.00	25.00	89.02	100.00	1.33	0.00	89.41	0.812
CT (alone)	43	80.00	33.33	94.12	11.11	1.20	0.60	76.74	0.136
CT after USG	162	86.03	38.46	87.27	34.48	1.40	0.36	78.40	0.279
USG (total)	247	90.91	34.21	88.37	40.62	1.38	0.27	82.19	0.147
CT (total)	205	84.66	37.93	89.22	28.95	1.36	0.40	78.05	0.942

[a]The ratio of true positive and true negative results to all results; *$p<0.05$ significant; PPV: Positive predictive value; NPV: Negative predictive value; USG: Ultrasonography; CT: Computed tomography.

TABLE 3: Correlation of CT with pathology results.

		*CT (after USG) request (dual imaging)		**CT (after USG) request		**CT (alone) request	
		Yes	No	Emergency physician	Generally surgeon	Emergency physician	Generally surgeon
AA	Positive, n (%)	136 (84)	8 (89)	113 (86)	23 (74)	33 (92)	7 (100)
	Negative, n (%)	26 (16)	1 (11)	18 (14)	8 (26)	3 (8)	0 (0)
Total, n (%)		162 (100)	9 (100)	131 (100)	31 (100)	36 (100)	7 (100)
p (chi-square)***		1.00		0.06		0.55	

*Pathological correlation with dual imaging/no imaging; **The effect of the physician requesting CT (alone) or CT after USG on pathological correlation; ***p<0.05 significant; USG: Ultrasonography; CT: Computed tomography, AA: Acute appendicitis.

remarkable finding that the pathology result was appendicitis in all the patients from whom CTs were requested by general surgeons. The reason for this may be that surgeons can diagnose appendicitis in most cases with anamnesis and physical examination, and they only request CTs in difficult cases rather than from patients who have undergone USG before (Table 3).

DISCUSSION

Advances in medical technology in recent years have led to a better understanding of the pathophysiology of diseases and to a change in clinical approaches in emergency departments. With the increase in knowledge, experience and technical facilities, emergency radiological examinations become more effective and are placed at the centre of decision-making mechanisms in emergency departments. It is very important to use appropriate diagnostic methods together with cost-effective protocols.[6,7]

Ultrasonographic examination performed by applying graded compression with the probe for the right lower quadrant is the first choice in the diagnosis of AA. The inflamed appendix is seen as a tubular structure with increased diameter and cannot be compressed. Increased blood supply in the appendix wall can also be observed with Doppler USG support. In addition, USG may guide percutaneous drainage procedures in pathologies such as abscess which may develop in the appendix and periapendicular area.[7,8]

In a study, the diagnostic efficiency of CT performed by applying compression to the right lower quadrant and USG performed under gradual compression in the study and control groups were compared. It was reported that the compression CT technique applied to the right lower quadrant had high diagnostic accuracy in cases of AA and might be the equivalent of the graded compression USG technique.[9]

CT protocol with intravenous and oral contrast is often used for AA. However, in the literature, there are only intravenous, only oral contrast and combined use (including rectal contrast) protocols. Since CT is an imaging method which includes ionizing radiation, its use in children and pregnant women is limited and intravenous contrast images especially cannot be performed in cases of renal failure. In the presence of high clinical suspicion after USG, CT should be performed with a low dose initially, but if it is insufficient in terms of diagnosis, it should be performed with standard doses.[10]

In a meta-analysis evaluating 64 studies, the specificity and sensitivity rate for CT was found to be 95% regardless of the protocol (intravenous, oral or intravenous+oral contrast administration). It was reported that CT protocols with low dose, standard dose or unspecified dose range have similar sensitivity and specificity rates, and there is no significant difference between them.[11]

CT is used to reduce diagnostic uncertainty in people with suspected AA and is often helpful in diagnosing other causes of abdominal pain, such as cholecystitis, diverticulitis, kidney stones, epiploic appendicitis, bowel obstruction, and gynecological conditions. With its contribution in differential diagnosis and diagnosis of AA, CT can play an important

role in reducing both unnecessary surgery and delay in surgery.[12,13]

CT is an advanced radiological examination tool which may induce several important complications such as allergic reactions against contrast agent or acute tubular necrosis. It should be used in the appropriate indication and in sufficient dosage range.

A recent meta-analysis states that low-dose CT (effective dose around 2 mSv) used in many studies is the right choice as standard CT in the diagnosis of appendicitis.[14] In contrast, many studies report the accuracy of CT in distinguishing simple appendicitis between 0.28-0.95 and 0.88-1.0, respectively, with more heterogeneous estimates of sensitivity and specificity.[15-17] Sippola et al. in a study showed that the diagnostic accuracy of contrast-enhanced low-dose CT was not inferior to standard CT (79% accurate diagnosis at low dose and 80% on standard CT by a primary radiologist). However, the mean radiation dose of low-dose CT was found to be significantly lower compared to the standard CT (3.33 and 4.44 mSv respectively).[18] In some cases, the use of CT may be limited. This restriction is valid for pregnant, elderly and pediatric patient groups in terms of AA cases.

In pregnant women, especially in the last trimester, the uterus grows and the anatomical locations of many organs including the appendix change. It should be examined with USG initially and if it is insufficient, magnetic resonance imaging should be performed instead of CT. In children, it should be started with USG first, and CT can be performed starting from low doses if necessary, but it should always be decided by weighing the advantages and disadvantages.[19,20] In addition, there are studies reporting that the efficiency of blood leukocyte values in the diagnosis is in the range of 20-60% in children, pregnant women and confused elderly patients.[21-23]

Celep et al. retrospectively analyzed 338 patients who underwent appendectomy, calculated the positive diagnostic value for USG (0.85) and CT (0.89) and emphasized that CT has high accuracy, sensitivity and positive diagnostic value. They concluded that if USG is insufficient for diagnosis, CT should be preferred.[1] Balcı and Onur recommended that USG should be performed first in patients with suspected AA, but CT should be requested if the clinical suspicion persists and the appendix is non-visualized on USG.[24] Yazıcı et al. retrospectively analyzed 811 patients. CT was performed in 208 (25%) patients, most of whom were USG negative. Forty two % of CT requests were made by emergency physicians and 57% by surgeons. As a result, they concluded that CT was used effectively in the diagnosis of appendicitis.[25] In our study, positive predictive values in 299 patients were 89.02%, 94.12% and 87.97% for USG alone, CT only and CT after USG groups, respectively. However, our accuracy rates for the same groups were 89.41%, 76.74% and 78.40%. It was concluded that the positive predictive value of CT was high, but its contribution (accuracy rate) was lower in determining true positive and true negative results. The fact that approximately two-thirds of the CT scans were requested before surgical consultation mostly by emergency department physicians may explain the low diagnostic contribution.

There are different factors which affect the CT request decisions of emergency physicians, the most important of which is the rapid decision-making mechanism that develops due to the intense workload in the emergency department.

Fersahoğlu et al. retrospectively analyzed the surgical, CT and pathology records of 1,891 patients who underwent appendectomy for AA. They studied the pathology results of 1,478 (78.8%) patients who underwent CT through the re-evaluation reports of the radiologist who interpreted the examination and the surgeon who performed the operation. Despite the normal CT results of 145 patients reported by the radiologist, 105 of these patients were found to be compatible with AA as a result of the re-evaluation by surgeons. They found that the CT evaluation performed by the operating surgeon had higher accuracy rates than the reports of radiologists, and stated that the CT interpretation ability gained during general surgery training would increase the chance of accurate diagnosis.[26] A comparison could not be made, as we did not have recorded data on whether surgeons re-evaluated or not. Increasing the experience of radiological examination evaluation in general surgery residency training and perhaps including it in intern-

ship programs will contribute positively to diagnostic accuracy rates.

Erkoç et al. retrospectively analyzed 32 cases of appendectomy. They looked at the USG, CT reports and blood leukocyte values of the patients. USG findings in 18 (55.25%) patients, CT findings in 28 (87.55%) patients, and blood leukocyte values (↑10,000/mm^3) in 30 (93.75%) patients were found to be significant in terms of AA. When blood leukocyte values were compared with USG and CT findings, it was statistically significant ($p<0.05$).[27] Similarly, we examined the blood leukocyte values of the patients in 3 groups as 0-10,000/mm^3, 10,000-20,000/mm^3 and ↑20,000/mm^3, and we found that 10,000/mm^3↑ was statistically significant for AA ($p<0.05$).

In the literature, there are studies showing that negative appendectomy rates decreased from 16% to 4% after the effective use of CT in appropriate cases.[28-30] In one study, negative appendectomy rate was reported below 2% after CT examination.[31] Despite the high rate of CT requests, our negative appendectomy rate (14.04%) was found to be close to the literature data (15-20%).

In one study, chest X-rays and thoracic tomographies were examined for 1,012 patients in 2 groups, trauma and non-traumatic, who came to the emergency department. More than 75% of patients in both groups could be treated without requiring thoracic tomography. It was stated that the radiologist's recommendation in the trauma group and both the radiologist's recommendation and the patient's age should be decisive in the non-traumatic group for the tomography examination.[32] In our study, it was observed that CT examinations performed after sonographic imaging in patients with suspected AA were high and its contribution to the diagnosis was low. It is obvious that radiologist advice is important, especially in CT requests after USG, in order to reduce both unnecessary CT costs and X-ray burden on patients.

The Alvarado Scoring has been used for years in the diagnosis of AA in emergency departments. In a series of 254 patients with suspected AA, appendicitis was found to be positive in 25% when the Alvarado score was </=4, while it was found to be positive in 96% when the appendicitis was >/=9. In addition, the USG report determined the rate of appendicitis as 32% in patients with normal appendix and 95% in patients with AA. Again, it was observed that the rate of appendicitis increased as the serum C-reactive protein level increased.[33] Since sufficient data could not be obtained for these scoring parameters in our series in our study, a comparison could not be made. However, there is no doubt that making the decision of the additional imaging method by making the Alvarado score will contribute to the reduction of unnecessary CT requests.

As a result of the regional socio-economic situation, the number of green field examination applications in our emergency department is high. The increasing workload adversely affects the working order in the emergency department, causing time and labor loss. Thus, the fact that emergency patients are not allocated sufficient time during the examination and consultation phase may explain that CT is often requested without surgical consultation. Although our CT requests were high especially after USG, we found that it did not provide additional diagnostic contribution in terms of AA. The nightmare of all clinicians is a malpractice situation that can occur with the interruption of diagnosis and treatment.

The increasing workload of emergency physicians prevents them from establishing effective dialogue with radiologists and surgeons, and CT requests are mostly made without the recommendation of a radiologist. CT should be performed in selected cases within the framework of emergency radiological imaging protocols and with the recommendation of a general surgeon and a radiologist.

STUDY LIMITATIONS

The important factor limiting our study is its retrospective nature.

CONCLUSION

USG should be the first choice for imaging for AA in emergency departments. If the diagnosis cannot be made by USG, it would be appropriate to request a CT with the recommendation of a radiologist and sur-

geon. Thus, with the effective use of CT, it will contribute to diagnosis and differential diagnosis, and additional X-ray burden and time losses will be prevented.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Salih Tuncal;* ***Design:*** *Yılmaz Ünal;* ***Control/Supervision:*** *Salih Tuncal;* ***Data Collection and/or Processing:*** *Yılmaz Ünal;* ***Analysis and/or Interpretation:*** *Salih Tuncal;* ***Literature Review:*** *Salih Tuncal;* ***Writing the Article:*** *Salih Tuncal;* ***Critical Review:*** *Yılmaz Ünal;* ***References and Fundings:*** *Yılmaz Ünal;* ***Materials:*** *Yılmaz Ünal.*

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