ORIGINAL ARTICLE

The Karaman score: A new diagnostic score for acute appendicitis

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ABSTRACT

BACKGROUND: The Karaman score is a novel diagnostic scoring system consisting of 6 parameters. The aim of the present study was to assess the diagnostic performance of the Karaman score in comparison with the Alvarado score.

METHODS: A total of 200 patients who underwent an appendectomy were enrolled in the study (research registry number: 2290).

RESULTS: The cutoff threshold of the Karaman score in distinguishing acute appendicitis from negative appendectomy was ≥9 with 84.3% sensitivity, 64.7% specificity, 92.1% positive predictive value (PPV), and 45.8% negative predictive value (NPV). The cutoff threshold of the Alvarado score in distinguishing acute appendicitis from negative appendectomy was ≥8 with 72.9% sensitivity, 70.6% specificity, 92.4% PPV, and 34.8% NPV. In multivariate logistic regression analysis, an Alvarado ≥8 score (Odds ratio [OR]:6.644, 95% confidence interval [CI]: 2.854–15.466; p<0.001) and a Karaman ≥9 score (OR:10.374, 95% CI: 4.383–24.558; p<0.001) were each individually predictive in distinguishing acute appendicitis from negative appendectomy when correction was made according to age and gender. However, when both scores were evaluated together, the Alvarado score ≥8 lost its efficacy (OR:1.838, 95% CI: 0.517–6.530; p=0.347), whereas the Karaman score ≥9 retained its predictive power (OR:6.586, 95% CI: 1.893–22.917; p=0.003).

CONCLUSION: The Karaman score was more predictive than the Alvarado score in distinguishing acute appendicitis from a negative appendectomy.

Keywords: Acute appendicitis; Alvarado score; Karaman score; negative appendectomy; sensitivity; specificity.

INTRODUCTION

Acute appendicitis is the most common abdominal emergency requiring surgery, and has an estimated life time prevalence of 7%.[1] Despite the development of new technologies in radio-diagnostics and the availability of many laboratory tests and scoring systems, diagnosis of appendicitis remains challenging.[2–4] The Alvarado score is the most well-known and best performing scoring system in validation studies.[5] The Karaman score is a novel diagnostic tool consisting of 6 parameters based on the patient's symptoms and signs supported by laboratory tests, and is easy to perform.

The primary outcome of the present study was to determine the diagnostic performance of the Karaman score in acute appendicitis. The second outcome was to compare the results of the Karaman score with the Alvarado score. Finally, the third outcome was to determine the diagnostic compliance of the Karaman and Alvarado scores with ultrasound (US) and computerized tomography (CT) findings.

MATERIALS AND METHODS

After receiving ethics committee approval, the study was conducted between May 2014 and December 2015 in the

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general surgery department of Sakarya University Training and Research Hospital. Informed consent was obtained from all of the patients. Patients were included if they were ≥18 years of age. A total of 200 patients qualified for the study during the research period. All of the patients were scored using the Alvarado and Karaman scoring systems. The Alvarado score includes 8 parameters, whereas the Karama score uses 6 parameters.

The Karaman Scoring System

The Karaman scoring system consists of 6 parameters. Of these, 2 symptomatic parameters are anorexia and migratory right iliac fossa pain. Rebound tenderness in the right iliac fossa and aggravation of peritoneal irritation in the right iliac fossa with heavy coughing are the 2 positive signs. Additionally, a leukocyte count of >10.000/mm^3 and a left shift of neutrophils of >70% are the positive laboratory parameters. Each positive parameter in the Karaman score generates 2 points, while 1 point is removed for each negative parameter. The maximum number of points for diagnosis is 12 and the minimum is -6 points.

Study Design

A scoring chart with both the Karaman and the Alvarado score criteria was completed by the attending surgeon at the time of presentation prior to radiological examinations (US, CT) (Table 1). The appendectomy decision was based solely on the surgeon's clinical judgment after taking into consideration all of the clinical, laboratory, and radiological findings. The Karaman and Alvarado scores were used only for research purposes.

Patients were monitored following admission, surgery, and through discharge from the hospital. Daily follow-up included monitoring of vitals 3 times a day and systemic examination once a day. Postoperative histopathology findings were collected and correlated with the scoring systems. The study was terminated after 200 consecutive appendectomies.

The diagnostic performance of the Karaman and Alvarado scores was determined according to sensitivity, specificity, and the positive predictive value (PPV) and negative predictive value (NPV). The diagnostic compliance of the Karaman and Alvarado scores with US and CT findings was also analyzed.

Statistical Analysis

Data analysis was performed using SPSS Statistics for Windows, Version 17.0 (SPSS, Inc., Chicago, IL, USA). Normal distribution of continuous variables was determined using the Kolmogorov-Smirnov test. Continuous variables were represented by the median (minimum-maximum), otherwise, the number of cases and percentages were used for categorical data. The Mann-Whitney U test was applied for comparisons of the non-normally distributed data. Categorical variables were analyzed using a chi-square or the McNemar test, as appropriate. The diagnostic performance of the Alvarado and the Karaman scoring systems was evaluated using receiver operating characteristic (ROC) curve analysis. The optimal cutoff point of each scoring system was assumed to provide the maximum sum of sensitivity and specificity. The diagnostic performance of the scoring systems was evaluated, including sensitivity, specificity, PPV, and NPV. The agreement between the Alvarado and Karaman scores was evaluated by calculating the kappa coefficient. Analysis of the best scoring system for diagnosis was determined using multiple logistic regression analysis after adjustment for age and gender. An adjusted odds ratio (OR) and 95% confidence interval (CI) for each independent variable was also calculated. A p value less than 0.05 was considered statistically significant.

Table 1. The Karaman and Alvarado scoring systems

Karaman score	Positive (+)	Negative (–)
Symptoms		
Anorexia	+2	-1
Migratory right iliac fossa pain	+2	
Signs		
Rebound tenderness in right iliac fossa	+2	-1
Peritoneal irritation in right iliac fossa with heavy coughing	+2	-1
Laboratory findings		
WBC >10.000/mm^3	+2	-1
PMNL >70%	+2	-1
Total points	12	-6
Alvarado score		
Symptoms		
Anorexia	+1	
Migratory right iliac fossa pain	+1	
Nausea/vomiting	+1	
Signs		
Tenderness in right iliac fossa	+2	
Rebound tenderness in right iliac fossa	+1	
Elevation of body temperature (≥37.3C°)	+1	
Laboratory findings		
WBC >10.000/mm^3	+1	
PMNL >75%)	+1	
Total points	10	0

PMNL: Polymorphonuclear leukocytes; WBC: White blood cell.

RESULTS

A total of 200 patients underwent appendectomy and were included in the study. Of these, 118 patients were male (59%)

Table 2. Patient demographic data and characteristics

Variables	n=200
Age (years), median (min-max)	32 (18–78)
Gender, n (%)	
Male	118 (59)
Female	82 (41)
Histopathological signs, n (%)	
Appendicitis	166 (83)
Acute appendicitis	136 (68)
Perforated appendicitis	18 (9)
Phlegmonous appendicitis	12 (6)
Non-appendicitis	34 (17)
Lymphoid hyperplasia	20 (10)
Normal appendix	12 (6)
Meckel's diverticulitis	1 (0.5)
Over cyst rupture	1 (0.5)
Localization, n (%)	
Retrocecal	146 (73)
Subcecal	37 (18.5)
Peri-ileal	9 (4.5)
Pelvic	4 (2)
Retroileal	4 (2)
Alvarado score, median (min-max)	8 (2–10)
Karaman score, median (min-max)	9 (-3–12)

and 82 patients were female (41%). The median age was 32 years (min-max: 18–72 years). In all, 166 patients (83%) had histopathologically confirmed acute appendicitis. Of these, 18 patients (9%) had perforated acute appendicitis, whereas 12 patients (6%) had phlegmonous appendicitis. Thirty-four patients (17%) had a negative appendectomy. In that group, 20 patients (10%) had lymphoid hyperplasia, 12 patients (6%) had a normal appendix, 1 patient (0.5%) had Meckel's diverticulitis, and 1 patient (0.5%) had over cyst rupture. The most frequently observed localization of the appendix was retrocecal (146 patient, 73%) followed by subcecal (37 patients, 18.5%), peri-ilieal (9 patients, 4.5%), pelvic (4 patients, 2%), and retroileal (4 patients, 2%), respectively. The median Alvarado score among the patients was 8 (min-max: 2–10), whereas the median Karaman score was 9 (min-max: -3–12) (Table 2).

No significant difference was found according to median age between the patients with acute appendicitis and those with a negative appendectomy (p=0.102). However, the male /female ratio was significantly higher in patients with acute appendicitis and the negative appendectomy rate was significantly higher in females (p=0.02). US could not significantly differentiate acute appendicitis from negative appendectomy (p=0.061). On the other hand, the detection of acute appendicitis by CT was

Table 3. Comparison of patient characteristics and demographic data according to acute appendicitis and negative appendectomy results

Acute appendicitis	Negative (n=34)	Positive (n=166)	p
Age (years), median (min-max)	29 (18–46)	32 (18–78)	0.102†
Gender, n (%)			0.020‡
Male	14 (41.2)	104 (62.7)	
Female	20 (58.8)	62 (37.3)	
US findings, n (%)			0.061‡
No	10 (58.8)	18 (33.3)	
Yes	7 (41.2)	36 (66.7)	
CT findings, n (%)			<0.001‡
No	14 (51.9)	13 (9.0)	
Yes	13 (48.1)	132 (91.0)	
Alvarado score, median (min-max)	6.5 (2–10)	8 (3–10)	<0.001†
Karaman score, median (min-max)	3 (-3–12)	10.5 (-3–12)	<0.001†

†Mann-Whitney U test; ‡Pearson's chi square test.
CT: Computerized tomography; US: Ultrasound (abdominal).

significantly higher (p=0.001). The median Alvarado score in patients with acute appendicitis was 8 (min-max: 3-10) and the median Alvarado score for negative appendectomy patients was 6.5 (min-max: 2–10). The median Alvarado score of 8 (min-max: 3–10) was significantly more frequently observed in patients histopathologically diagnosed as having acute appendicitis than in those with negative appendectomy (p=0.001). The median Karaman score for acute appendicitis was 10.5 (min-max: -3–12), whereas the median Karaman score for negative appendectomy was 3 (min-max: -3–12). The median Karaman score of 10.5 (min-max: -3–12) was significantly more frequent in patients with acute appendicitis than in those with a negative appendectomy (p=0.001), (Table 3).

Receiver operating characteristic (ROC) analysis of the Karaman score revealed that the area under the curve (AUC) was significant in distinguishing acute appendicitis from negative appendectomy (AUC: 0.821, 95% CI: 0.732–0.910; p<0.001), (Fig. 1a). The cutoff threshold of the Karaman score in distinguishing acute appendicitis from negative exploration was ≥9, with 84.3% sensitivity, 64.7% specificity, 92.1% PPV, and 45.8% NPV. ROC analysis of the Alvarado score revealed that the AUC was significant in distinguishing acute appendicitis from negative appendectomy (AUC: 0.782, 95% CI: 0.690–0.874; p=0.001), (Fig. 1b). The cutoff threshold of the Alvarado score in distinguishing acute appendicitis from negative appendectomy was ≥8 with 72.9% sensitivity, 70.6% specificity, 92.4% PPV, and 34.8% NPV (Table 4).

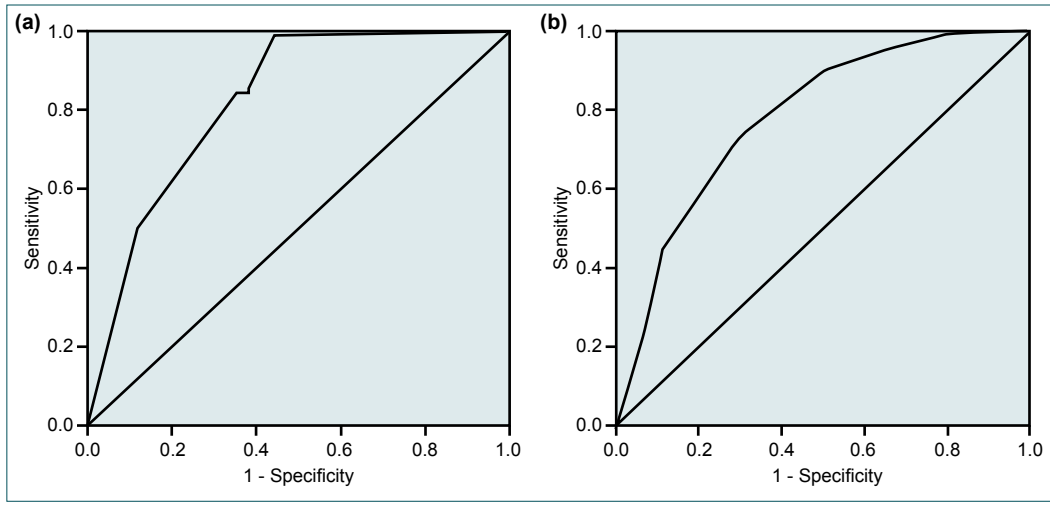

Figure 1. Receiver operating characteristics curve demonstrating the predictive values of the **(a)** Karaman and **(b)** Alvarado scoring systems.

A positive correlation was found according to the distribution of the Alvarado (8</≥8) and Karaman scores (<9/≥9). According to the histopathological findings, the frequency of a Karaman score of ≥9 was in 152 of 200 cases (76%), in 140 of 166 acute appendicitis specimens (84.3%), and in 12 of 34 non-appendicitis specimens (35%). On the other hand, the frequency of an Alvarado score of ≥8 was present in 131 of 200 cases (65.5%), 121 of 166 acute appendicitis specimens (72.9%), and in 10 of 34 non-appendicitis specimens (29.4%). Overall, the frequency of a Karaman score of ≥9 was significantly higher than an Alvarado score of ≥8 (76% vs 65%; p=0.001). A comparison of the 2 scoring systems according to negative appendectomy revealed no significant difference (35.3% vs 29.4%; p=0.625). However, the frequency of a Karaman score of ≥9 was significantly higher in acute appendicitis than an Alvarado score of ≥8 (84.3% vs 72.9%; p=0.001).

Each parameter used in the present study was analyzed according to diagnostic sensitivity, specificity, PPV, NPV, positive and negative likelihood ratio, and accuracy. Right iliac fossa tenderness had the highest sensitivity (100%), with 83% accuracy, followed by peritoneal irritation with heavy coughing (sensitivity: 90%, accuracy: 80.4%) and anorexia (sensitivity: 89.8%, accuracy: 80%).Fever (sensitivity: 29.5%, accuracy: 37%) and a neutrophil ratio of >75% (sensitivity: 62.7%, accuracy: 67%) had the lowest sensitivity and accuracy (Table 5).

Table 4. Diagnostic performance of Alvarado and Karaman scores

	Alvarado	Karaman
The area under the ROC curve	0.782	0.821
95% confidence interval	0.690–0.874	0.732–0.910
P value	<0.001	<0.001
Cutoff point	≥8	≥9
Sensitivity	72.9%	84.3%
Specificity	70.6%	64.7%
Positive predictive value	92.4%	92.1%
Negative predictive value	34.8%	45.8%

ROC: Receiver operating characteristic.

In multivariate logistic regression analysis, both an Alvarado score of ≥8 (OR: 6.644, 95% CI: 2.854–15.466; p<0.001) and a Karaman score of ≥9 (OR: 10.374, 95% CI: 4.383–24.558; p<0.001) were predictive in distinguishing acute appendicitis from negative appendectomy when a correction was made for age and gender. However, when the 2 scores were compared, the Alvarado score lost its efficacy (OR:1.838, 95% CI: 0.517–6.530; p=0.347), whereas the Karaman scoring system maintained its predictive power (OR: 6.586, 95% CI: 1.893–22.917; p=0.003), (Table 6).

DISCUSSION

The Karaman score is a new, practical, cost-effective, and feasible scoring system developed on the basis of clinical symptoms, signs, and laboratory data. In contrast to the Alvarado and other scoring systems, fewer parameters are used. In addition, the validation of the parameters used in the Karaman score is well known from previous studies. Like the Alvarado score, the cutoff for the white blood cell (WBC) count in the Karaman score is >10.000/mm^3, with the aim of improving the diagnosis of acute appendicitis. In a meta-analysis including 14 studies, a WBC of >10.000/mm^3 had a sensitivity and specificity of 83% and 67%, respectively.[6] Similarly, in the study reported by Bates et al.,[7] a WBC count of <9000/mm^3 reduced the negative appendectomy rate. In the present study, the sensitivity and specificity of a WBC of >10.000/mm^3 was 85.5% and 55.9% with an accuracy of 80.5%. A polymorphonuclear leucocyte (PMNL) ratio of >75% has also been determined to be a discriminator of acute appendicitis, but had a limited

Table 5. Diagnostic power of each parameter used in the study

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	+LR	-LR	Accuracy (%)
White blood cell >10.000/mm^3	85.5	55.9	90.4	44.2	1.94	0.26	80.5
Polymorphonuclear leucocytes >%70	77.1	70.6	92.8	38.7	2.62	0.32	76.0
Polymorphonuclear leucocytes >%75	62.7	88.2	96.3	32.6	5.33	0.42	67.0
Fever >37.3°	29.5	73.5	84.5	17.6	1.12	0.96	37.0
Anorexia	89.8	32.4	86.6	39.3	1.33	0.32	80.0
Nausea and vomiting	75.8	24.2	83.3	16.7	1.00	1.00	67.1
Right quadrant tenderness	100.0	0.0	83.0	–	1.00	–	83.0
Peritoneal irritation with coughing	90.0	29.4	86.2	40.0	1.29	0.31	80.4
Ultrasound	66.7	58.8	83.7	35.7	1.62	0.57	64.8
Computerized tomography	91.0	51.8	91.0	51.9	1.89	0.17	84.8

+LR: Positive likelihood ratio; -LR: Negative likelihood ratio; NPV: Negative predictive value; PPV: Positive predictive value.

Table 6. Multivariate logistic regression analysis for distinguishing acute appendicitis from negative appendectomy

	Odds ratio	95% CI	p†
Model I			
Age	1.036	0.995–1.077	0.083
Male factor	2.935	1.285–6.704	0.011
Alvarado ≥8	6.644	2.854–15.466	<0.001
Model II			
Age	1.039	0.998–1.082	0.063
Male factor	2.988	1.255–7.114	0.013
Karaman ≥9	10.374	4.383–24.558	<0.001
Model III			
Age	1.037	0.996–1.080	0.077
Male factor	3.054	1.278–7.299	0.012
Alvarado ≥8	1.838	0.517–6.530	0.347
Karaman ≥9	6.586	1.893–22.917	0.003

†Multivariate logistic regression analysis. CI: Confidence interval.

clinical significance, with a sensitivity ranging from 66% to 87%, and a specificity of 33% to 84%.[8,9] The cutoff value for the PMNL percentage in the Karaman score was >70% due to the high sensitivity reported by Andersson et al.[10] (sensitivity: 93% in 502 patients) and Fergusson et al.[11] (sensitivity: 87% in 1013 patients). Similarly, the sensitivity of a PMNL percentage of >70% in the present study was greater than a PMNL percentage of >75% (77.1% vs 62.7%) with an accuracy of 76%.

In contrast to the Alvarado score, fever is not used as a parameter in the Karaman score as a result of the limited diagnostic significance demonstrated in other studies.[12–14] The diagnostic sensitivity and accuracy of the presence of a fever of 37.3 °C or more in the present study was 29.5% and 37%, respectively, which supported our hypothesis that fever is not a particularly valuable indicator for the diagnosis of acute appendicitis. Furthermore, the presence of nausea and vomiting is also not used in the Karaman score due to low sensitivity (75.8%) and specificity (24.2%), which has also previously been demonstrated in other studies (sensitivity: 40–72% and specificity: 45-69%).[15–17]

In the present study, the cutoff threshold of the Karaman score in distinguishing acute appendicitis from negative appendectomy was ≥9, with an 84.3% sensitivity, 64.7% specificity, a 92.1% PPV, and a 45.8% NPV. A higher sensitivity (96.2%) and sensitivity (90.5%) were found in a study performed by Nanjundaiah et al.[18] with a Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score of >7.5. The sensitivity and specificity of an Alvarado score of >7 was 58.9% and 85.7% in that study. Similarly, Chong et al.[19] conducted a study that included 192 patients and determined that a RIPASA score of >7.5 and an Alvarado score of >7 had a diagnostic sensitivity of 98% and 68.32%, respectively. However, in contrast to the Karaman score, which uses only 6 parameters, the RIPASA score consists of 18 parameters, including urine analysis, which adds a financial burden. The diagnostic sensitivity of the Karaman score appears to be superior when compared with other scoring systems used in the study reported by Erdem et al.[20] Alvarado (cutoff: 6.5, sensitivity: 81.8%) Eskelinen (cutoff: 63.2, sensitivity: 80.5%), RIPASA (cutoff: 10.25, sensitivity: 83.1%), and Ohmann (cutoff: 13.75, sensitivity: 80.5%).

The most crucial element is to determine how a negative appendectomy can be prevented when facilities and equipment are limited. Diagnosis of acute appendicitis based on only 1 or 2 parameters is not reliable. While 1 positive parameter may support the possibility of acute appendicitis, a negative parameter raises doubts. Additional laboratory tests and radiological

images, such as C-reactive protein (CRP), CT, or MRI may help to diagnose acute appendicitis, but increase the cost. One of the advantages of the Karaman scoring system is a greater ability to predict a negative appendectomy compared with the Alvarado score, which becomes very valuable in the absence of devices to perform CT or MRI or laboratory tests to assess calcitonin, CRP level, and other molecular markers.

In the present study, the accuracy of US in detecting acute appendicitis was low (sensitivity: 66.7%, specificity: 58.8%, accuracy: 64.8%). It is well established that interpretation of US images is operator-dependent. The night shift staff members performing US at our emergency clinic are often junior assistants, which may have affected these results. On the other hand, the diagnostic value of CT has been reported in the literature to be high, with a sensitivity of 91% and an accuracy of 84.8%.[21]

In the present study, the negative appendectomy rate was higher in female patients than in males (24.9% vs 11.9%; of total study patients: 17%), which is comparable with the literature.[22] Lymphoid hyperplasia was the most common leading cause of a negative appendectomy. Both the Alvarado and the Karaman scores failed to distinguish lymphoid hyperplasia from acute appendicitis. CT and US may help in determining lymphoid hyperplasia and prevent false-positive misdiagnoses of appendicitis.[23] When there is doubt, while US is operator-dependent, CT is much more helpful in reducing the negative appendectomy rate.

The present study has some limitations. First, the sample size was small. Secondly, a comparison was only made with the Alvarado score.

Conclusion

Diagnosis of acute appendicitis is still mainly based on history, and clinical and laboratory data. The Karaman score is a cost-effective and practical scoring system consisting of 6 parameters that is easy to perform. The Karaman score appears to be more predictive than the Alvarado score in distinguishing acute appendicitis from negative appendectomy.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Karaman skoru: Akut apandisit tanısında yeni bir skorlama sistemi

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AMAÇ: Karaman skorlama sistemi akut apandisit tanısında kullanılan ve 6 parametreden oluşan yeni bir tanısal skorlama sistemidir. Bu çalışmanın amacı Karaman skorunun akut apandisit tanı performansını Alvarado skoru ile karşılaştırmalı olarak ortaya koymaktır.

GEREÇ VE YÖNTEM: Akut apandisit tanısı ile apendektomi yapılan 200 hasta çalışmaya alındı.

BULGULAR: Karaman skorunun akut apandisiti negatif apandektomiden ayırmadaki kestirim değeri ≥9 olup, sensitivitesi %84.3, spesifitesi %64.7, pozitif prediktif değeri %92.1 ve negatif prediktif değeri %45.8 olarak saptandı. Alvarado skorunun akut apandisiti negatif apandektomiden ayırmadaki kestirim değeri ise ≥8 olup, sensitivitesi %72.9, spesifitesi %70.6, pozitif prediktif değeri %92.4 ve negatif prediktif değeri %34.8 olarak saptandı. Multilojistik regreyon analizinde, yaş ve cinsiyete göre düzeltme yapıldığında; hem Alvarado ≥8 (OR=6.644, %95 CI: 2.854–15.466, p<0.001) hem de Karaman ≥9 skoru (OR=10.374, %95 CI: 4.383–24.558, p<0.001) akut apandisiti negatif apandektomiden ayırmada anlamlı olarak etkin saptandı. Ancak, her iki skor bir arada değerlendirildiğinde, Alvarado skoru ≥8 etkinliğini yitirirken (OR=1.838, %95 CI: 0.517–6.530 and p=0.347) Karaman skoru ≥9 prediktif etkinliğini göstermeye devam etmekteydi (OR=6.586, %95 CI: 1.893–22.917, p=0.003).

TARTIŞMA: Karaman skoru akut apandisiti negatif apandektomiden ayırt etmede daha etkin saptanmıştır.

Anahtar sözcükler: Akut apandisit; Alvarado skoru; negatif apandektomi; sensitivite; spesifite.

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