



Impact of the alvarado score on the diagnosis of acute appendicitis: comparing clinical judgment, alvarado score, and a new modified score in suspected appendicitis: a prospective, randomized clinical trial

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Abstract

Background The Alvarado score is a clinical scoring system used in the diagnosis of acute appendicitis. This study aimed to compare the reliability of the Alvarado score and clinical judgment and to refine the score to make it easier to use.

Methods In this prospective, randomized study, patients presenting at the authors' outpatient department with suspected appendicitis during a 1-year period were assigned in weekly alternation to either group A or group B. The group A patients were treated on the basis of their Alvarado score, and the group B patients underwent treatment based on clinical judgment. The correctness of the methods was assessed by evaluation of the final histology. Statistical comparison of the data was performed using SPSS 20.

Results The study investigated 269 patients (131 in group A and 138 in group B). The groups were homogeneous in terms of mean age, gender, body mass index, and American Society of Anesthesiologists score. The number of negative appendectomies was 12 (9.16 %) in group A versus 5 (3.6 %) in group B ($p = 0.063$). The clinical judgment had better specificity and sensitivity than the Alvarado score. For that reason, the specificity of the Alvarado score was refined using statistical methods, with weighting of certain

clinical data and inclusion of new ones (e.g., ultrasound investigation). Consequently, the area under the curve by receiver operating characteristic analysis gradually increased, and the Alvarado score became more accurate.

Conclusion The study findings showed clinical judgment to be more reliable in the diagnosis of acute appendicitis than the Alvarado score, but the score is a useful diagnostic aid, especially for young colleagues. The use of the new scoring system has become easier. It includes fewer criteria as well as an important and sensitive predictor: the ultrasound investigation.

Keywords Appendix · Statistical · Technical · Abdominal · Ultrasonography

Acute appendicitis is the most common urgent surgical condition, with 9 % of the population affected [1]. Its differential diagnosis is extremely difficult, especially for the elderly, children, and fertile-age women, in whom it can mimic numerous gynecologic and urogenital conditions [2]. The lethality of the condition is about 0.7 %, which means that it causes the death of almost 100 patients in Hungary each year [3]. Furthermore, the number of negative appendectomies remains in the approximate range of 5–10 %, although the negative appendectomy rate (NAR) has decreased in recent decades due to better diagnostic techniques (i.e., ultrasound and preoperative computed tomography [CT]) [4].

The diagnosis of acute appendicitis is based on the medical history, the physical examination, and the laboratory analysis, but imaging techniques (ultrasound and CT scan) also may be helpful. The ultrasound scan is easy to perform and inexpensive, but its result is examiner- and patient-dependent. With its help, however, the number of negative appendectomies can be decreased by 10 % [5]. The CT scan

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Table 1 Alvarado score

| | Value |
|---------------------------------|-------|
| Symptoms | |
| Pain migration | 1 |
| Anorexia | 1 |
| Nausea-vomiting | 1 |
| Signs | |
| Tenderness in RLQ | 1 |
| Rebound pain | 2 |
| Evaluation of temperature >37.3 | 1 |
| Laboratory | |
| Leukocytosis | 2 |
| Shift to the left | 1 |
| Total | 10 |

1–4 points (discharge), 5–6 points (observation), 7–10 points (emergency surgery)
RLQ right lower quadrant

is expensive and exposes the patient to radiation, although with the help of this sensitive diagnostic tool, NAR has decreased significantly in the last decade [6].

In the past, numerous clinical scoring systems have been created to make the diagnosis of acute appendicitis easier. The best known is the Alvarado score, created in 1986 by Alvarado, who processed the data of appendectomy patients retrospectively. It includes eight diagnostic criteria (historical data, physical examination, and laboratory values) [7] (Table 1).

Since 1986, the reliability of the Alvarado scoring system has been assessed by many studies, including numerous prospective ones, but the number of randomized studies is low. According to these studies, the score is useful for adults but less reliable for children and the elderly [8, 9]. As a diagnostic aid, it can help young surgeons and emergency physicians, but it is inferior compared with the diagnostic accuracy of experienced specialist surgeons [10, 11].

Hungary has a growing number of emergency care centers [accident and emergency (A&E) units], in which specialist surgeons work only as consultants. Therefore, patients with suspected appendicitis are assessed primarily by young resident internists, surgeons, and emergency physicians. Our study aimed to compare the reliability of the Alvarado score and that of conventional clinical judgment and to refine the score with the use of statistical methods, the inclusion of new criteria, and the exclusion of old criteria to make easier to use in our practice, especially for young colleagues.

Methods

Between 1 September 2011 and 31 September 2012, our prospective, randomized study enrolled 269 patients presenting with right lower abdominal complaints at the outpatient clinic of the Department of Surgery at the University of Szeged. After signing a consent form, the

Table 2 Patient characteristics

| | Group A (<i>n</i> = 131) | Group B (<i>n</i> = 138) | <i>p</i> value |
|----------------------|------------------------------|------------------------------|----------------|
| Age: years (range) | 33.3 (17–87) | 35.52 (18–82) | 0.690 |
| Gender | | | |
| Female: <i>n</i> (%) | 92 (70.2) | 88 (63.7) | 0.326 |
| Male: <i>n</i> (%) | 39 (29.7) | 50 (36.3) | 0.264 |
| BMI | 23.7 | 25.8 | 0.241 |
| Mean ASA score | 1.7 | 1.5 | 0.580 |

BMI body mass index, *ASA* American Society of Anesthesiology

Table 3 Surgery–pathology cross-tabulation in group A (*n* = 131)

| | Surgery | |
|-----------|---------|----|
| | – | + |
| Pathology | – | 86 |
| | + | 10 |

Sensitivity (69 %), specificity (87.8 %)

Pathology: –, no pathologic investigation or no inflammation; +, inflammation of the appendix. Surgery: –, discharge, no operation; +, appendectomy

Table 4 Surgery–pathology cross-tabulation in group A after overriding of the score by the chief surgeon (*n* = 95)

| | Surgery | |
|-----------|---------|----|
| | – | + |
| Pathology | – | 64 |
| | + | 0 |

Sensitivity (100 %), specificity (88.9 %)

Pathology: –, no pathologic investigation or no inflammation; +, inflammation of the appendix. Surgery: –, discharge, no operation; +, appendectomy

patients were divided into two groups. The groups altered weekly. In group A, the treatment decision was based on the Alvarado score as follows: 1–4 points (discharge), 5–6 points (observation, with scoring repeated in 12 h), 7–10 points (urgent surgery).

Further treatment of the patients in group B was based on the decision made by the head surgeon on duty, who did not know the Alvarado score of the patient. At week A, the head surgeon on duty had the opportunity to override the score based on the physical examination, laboratory findings, and abdominal ultrasound. After a laparoscopic appendectomy, the accuracy of the methods was assessed by evaluating the final histologic results.

We then assessed the value of the ultrasound scan (in terms of specificity and sensitivity) performed routinely in

the diagnosis of appendicitis at our clinic to determine the reliability of the imaging technique in our practice.

With the help of a statistical method using logistic regression, we first tried to refine the score by weighting certain data. Then after analyzing our own experience and the efficiency of the ultrasound scan, we amended the score with new aspects and discarded older ones. The data were analyzed with SPSS 20 (SPSS, Chicago, IL, USA). The

Table 5 Surgery–pathology cross-tabulation in group B ($n = 138$)

| | Surgery | |
|-----------|---------|----|
| | – | + |
| Pathology | – | 92 |
| | + | 0 |

Sensitivity (100 %), specificity (94.8 %)

Pathology: –, no pathologic investigation or no inflammation; +, inflammation of the appendix. Surgery: –, discharge, no operation; +, appendectomy

Table 6 Value of ultrasound investigation

| | Pathology | |
|------------|-----------|-----|
| | – | + |
| Ultrasound | – | 164 |
| | + | 29 |

Specificity (84.9 %), sensitivity (73.3 %), predictive value (65.4 %)

Pathology: –, no pathologic investigation or no inflammation; +, inflammation of the appendix. Ultrasound: –, no sign of appendicitis; +, appendicitis

Table 7 Score–pathology rank correlation in both groups A and B

| Correlations | Pathology | Score |
|--------------------------|--------------------|--------------------|
| Spearman's rho | | |
| Pathology | | |
| Correlation coefficient | 1.000 | 0.523 ^a |
| Significant (two-tailed) | 0.000 | 0.000 |
| n | 233 | 232 |
| Score | | |
| Correlation coefficient | 0.523 ^a | 1.000 |
| Significant (two-tailed) | 0.000 | 0.000 |
| n | 232 | 232 |

^a Correlation is significant at the 0.01 level (two-tailed)

Table 8 Receiver operating characteristic (ROC) analysis of group A before overriding of the score, group A after overriding of the score, and group B

| AUC | SE | Asympt. sig. | AUC | SE | Asympt. sig. | AUC | SE | Asympt. sig. |
|-------|-------|--------------|-------|-------|--------------|-------|-------|--------------|
| 0.749 | 0.044 | 0.000 | 0.869 | 0.033 | 0.000 | 0.933 | 0.027 | 0.000 |

AUC, area under the curve, SE standard error

significance level was determined to be a p value lower than 0.05.

The study was approved by the Ethics Committee of the University of Szeged and registered at Current Controlled Trials under number ISRCTN56471.

Results

During a period of 1 year, 269 patients were enrolled in our study (131 in group A and 138 in group B). Their mean age was 34.6 years (range, 17–87 years; group A, 33.3 years; group B, 35.52 years; $p = 0.069$). Only 13 patients were older than 65 years. Most of the patients were 30–40 years of age. In terms of gender distribution, group A had 92 women and 39 men, whereas group B had 88 women and 50 men ($p = 0.326$). The mean body mass index (BMI) was 24.6 kg/m² (23.7 kg/m² in group A and 25.8 kg/m² in group B; $p = 0.241$), and the mean American Society of Anesthesiology (ASA) score of 1.6 (1.7 in group A and 1.5 in group B; $p = 0.580$). Based on these data, the demographics of the two groups was considered to be homogeneous (Table 2). We also investigated the duration of symptoms and found that 99 patients had symptoms for less than 48 h, and 170 patients had symptoms for more than 48 h.

After surgery, the histologic results were evaluated in both group A and group B. Based on cross-tabulation of the postsurgery histologic results, the specificity of the Alvarado score and that of the conventional clinical judgment were calculated. We also investigated the 36 cases in which the chief surgeon overrode the therapy suggested by the Alvarado score. These cases were not excluded from group A, but we calculated the specificity and sensitivity of the Alvarado score without these patients.

In the original group A, the sensitivity was 69 %, and the specificity was 87.8 versus 100 % and 88.9 %, respectively, in group A without the overridden cases. In group B, the sensitivity was 100 %, and the specificity was 94.8 %. We found a significant difference only when we compared the sensitivity between the original group A and the overridden group A (69 vs 100 %; $p < 0.05$). In group A, 12 negative appendectomies (9.16 %) were performed compared with 5 (3.6 %) in group B ($p = 0.063$) (Tables 3, 4, 5).

Table 9 New score made by logistic regression, receiver operating characteristic (ROC) analysis

| Symptoms | Modified score |
|---|----------------|
| RLQ pain | 1 |
| Nausea-vomiting | 1 |
| Anorexia | 1 |
| Tenderness in right iliac fossa | 1 |
| Indirect sign of positivity (1–2) | 1 |
| Indirect sign of positivity (≥ 2) | 2 |
| Elevated temperature | 1 |
| Rectal-axillar temperature difference >1 °C | 1 |
| Leucocytosis >10 g/l | 1 |
| Leucocytosis >15 g/l | 2 |

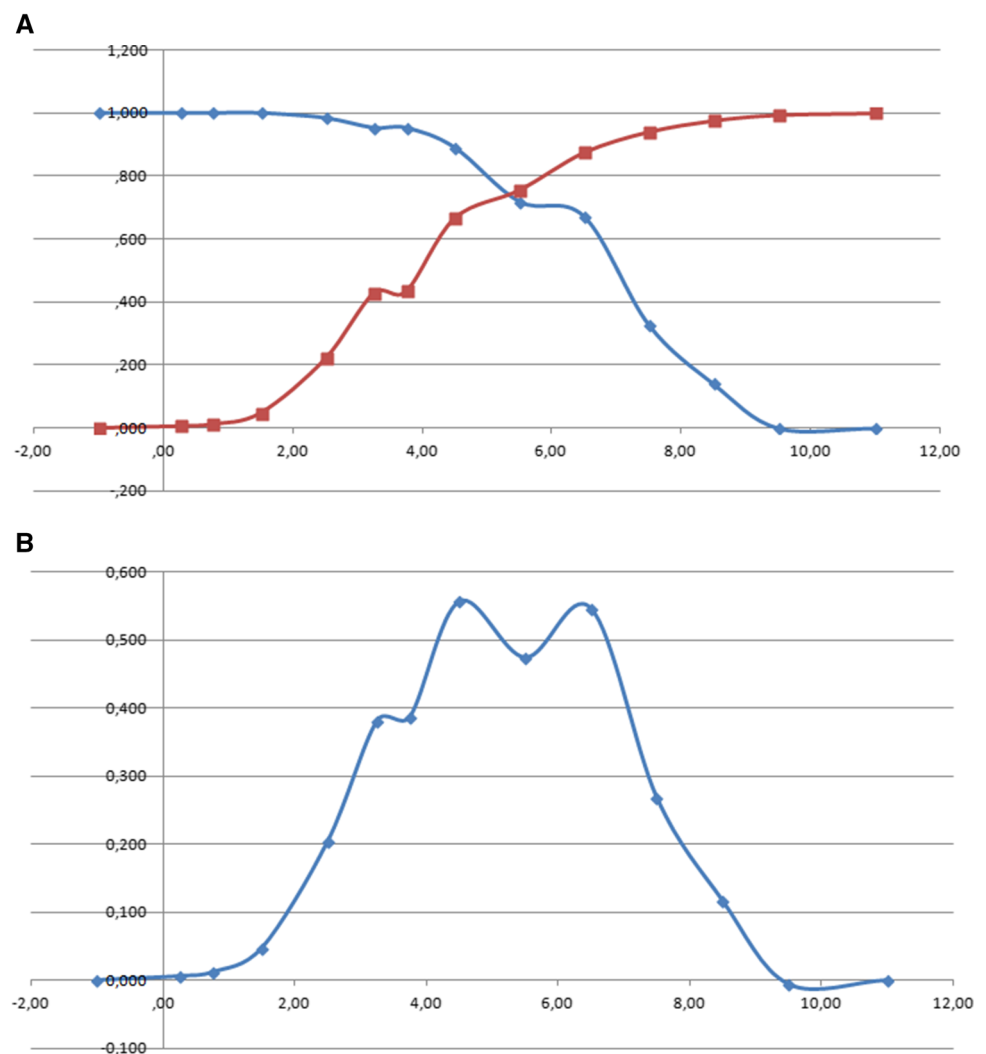
| AUC | SE | Asympt. sig. |
|-------|-------|--------------|
| 0.830 | 0.027 | 0.000 |

RLQ right lower quadrant, AUC area under the curve, SE standard error

We compared the diagnostic values of the scores between the genders. We found that the score overpredicted for the women (area under the curve [AUC], 0.868) compared with the men (AUC, 0.785). We also investigated the effect of age (older vs younger than 65 years) and duration of symptoms (shorter or longer than 48 h) on prediction of the degree of appendiceal inflammation. The two groups did not differ significantly. The patients older than 65 years had an AUC of 0.833 compared with an AUC of 0.875 for the patients younger than 65 years. The duration of symptoms was longer than 48 h for those with an AUC of 0.843 and shorter than 48 h for those with an AUC of 0.826. This means that the Alvarado score is a good predictive factor for older patients as well and that it is reliable when the duration of symptoms is longer than 48 h.

An ultrasound scan was performed for every patient, and the results were compared with the final histologic result. The specificity (73.3 %), sensitivity (84.9 %), and positive

Fig. 1 A, B Specificity, sensitivity, and Youden Index of the Alvarado score



predictive value (65.4 %) of the imaging procedure were calculated (Table 6).

Spearman's rank correlation was used to assess whether a higher score was accompanied by more severe inflammation. Assessment of this in both groups showed a borderline correlation point (i.e., the correlation was not very close in this regard) (Table 7). Based on the receiver

operating characteristic (ROC) analysis, the clinical judgment showed a better discriminating capacity than the Alvarado scoring system (AUC of 0.933 in group B vs AUC of 0.749 in original group A and 0.869 in modified group A) (Table 8).

By estimating Youden's Index ($Y = \text{sensitivity} + \text{specificity} - 1$), it can be established that the cutoff

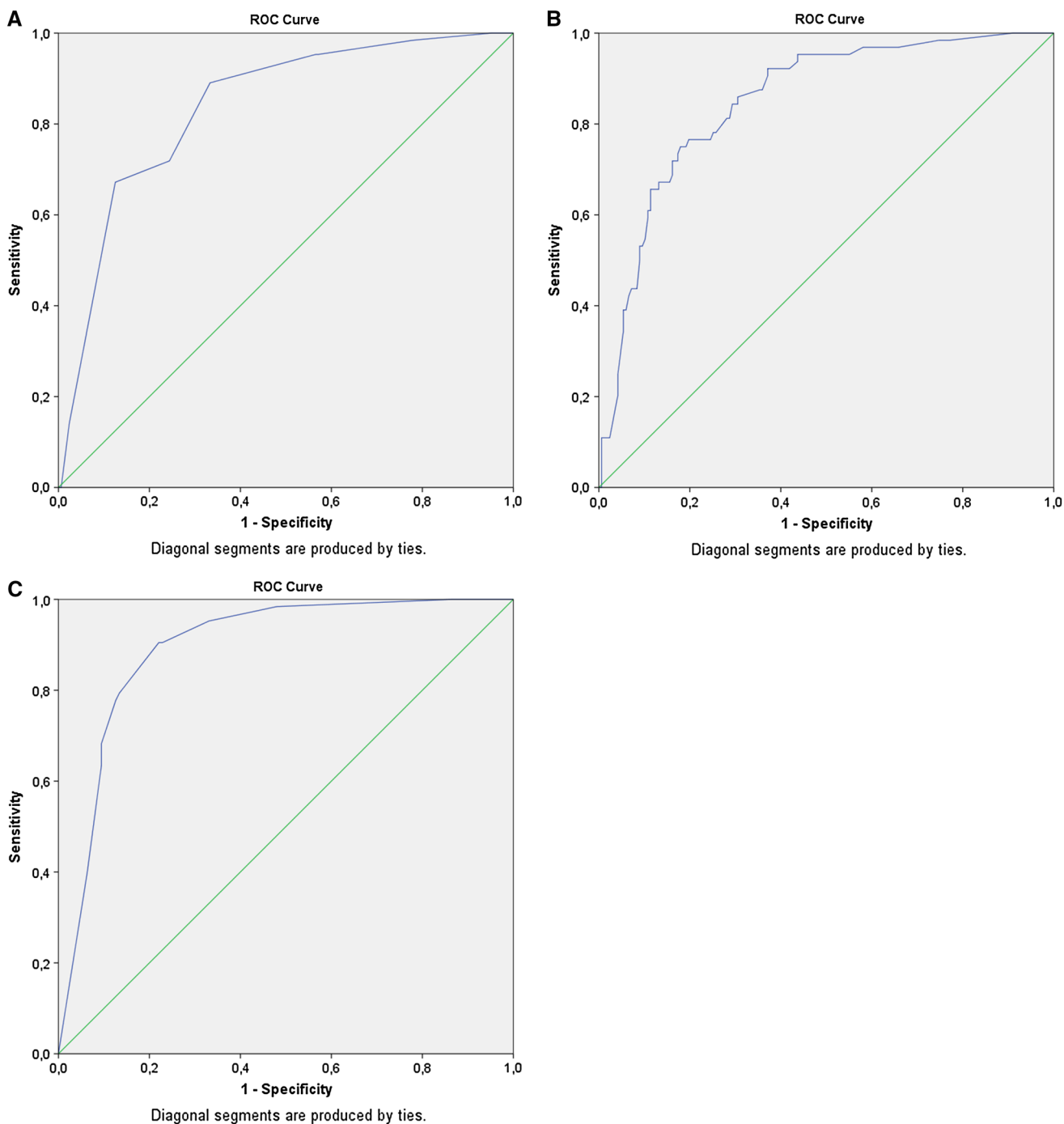


Fig. 2 The changing receiver operating characteristic (ROC) curves after modification of the Alvarado score. **A** Original score. **B** Score made by logistic regression. **C** Modified score containing ultrasound investigation

values of 5–6 given by the Alvarado scoring system are correct. In case of a score below 4, appendicitis is unlikely in the patient, whereas if the score is above 7, inflammation is highly probable. Therefore, observation of the patients and possibly another imaging procedure (urgent CT scan) are necessary in cases showing the so-called “gray zone” between scores 5 and 6 (Fig. 1).

We tried to create a new score with the help of multiple logistic regression by weighting certain parameters. Parameters that had not been part of the score before but are important based on our clinical experience (rectal-axillary temperature difference, indirect signs) were included in the criteria system. The AUC by ROC analysis increased (0.849). Therefore, the original scoring system was successfully refined (Table 9).

To refine the score further, certain predictors that had proved to be less significant were removed from the scoring system, and the result of the ultrasound scan was included instead because it showed good specificity and sensitivity. This further increased the AUC, and the score was successfully refined even further (Fig. 2).

The new modified scoring system is shown in Table 10. Due to the modification of the Alvarado score, the AUC increased. With the original Alvarado score, it was 0.749. When we weighted each criteria, the AUC of the new score was 0.830, and it increased finally to 0.899 when we included the ultrasound in the score (Table 11).

Discussion

Despite the advances in imaging procedures and laboratory analyses, diagnosing appendicitis still is a very difficult task, especially for candidate consultants and young colleagues. In addition, patients with right lower abdominal

complaints, suspected to have appendicitis, are first assessed primarily by nonsurgical residents or specialists in a growing number of emergency care centers (A&E units). Although several studies have found no significant difference in the accuracy of diagnosis between surgical and nonsurgical residents, these young colleagues need help to know when they should ask for consultation from a specialist surgeon for patients with suspected appendicitis [12, 13].

Of course, imaging procedures also may help us. Ultrasound scanning is an inexpensive, quick, repeatable procedure. It is excellent for the differential diagnosis of gynecologic conditions, but this method is examiner dependent [14]. An abdominal ultrasound scan is routinely performed at our clinic in cases of suspected appendicitis. With the addition of the abdominal ultrasound scan result, the Alvarado score could be refined, thus increasing its reliability (AUC increased from 0.749 to 0.899). Currently, we cannot imagine the diagnosis of abdominal pain without imaging techniques.

Cost effectiveness and avoidance of redundant examinations are important not only in developing countries but also in countries with a higher health budget as well. A CT scan compared with ultrasound provides an even more accurate picture of the lesion and reduces the number of negative appendectomies, but it is expensive and involves exposure to radiation [15, 16].

A recent American metaanalysis compared the costs of an ultrasound-CT protocol (on-demand CT) and a CT-only protocol for an appendicitis evaluation. They found that an ultrasound-CT protocol for appendicitis evaluation offers potentially large savings over the standard CT-only protocol [17]. In their analysis, the positive predictive value of ultrasound was 91 % compared with 92.5 % for CT scan (nonsignificant difference). Urgent surgery was performed without a CT scan when ultrasound (\$88) confirmed acute appendicitis. In problematic cases, they asked for a CT scan (\$547). The cost saving for the total U.S. population was \$24.9 million per year, and the ultrasound resulted in significantly less radiation exposure for the patients.

Numerous studies have confirmed the reliability of the Alvarado score and the modified Alvarado score (MAS) in the diagnosis of appendicitis [18–20]. According to a recent review, the cutoff score of 5 points is an excellent tool for determining whether the patient should be discharged or provided with further treatment (observation, surgery). In case of a higher score, consultation with a surgeon is required for making the decision about further therapy [21].

When our sensitivity–specificity values were plotted with the help of the Youden Index, a similar result was reached. The so-called gray zone was between 5 and 6 points. In these cases, further observation or an imaging

Table 10 New modified score containing ultrasound examination and receive operating characteristic (ROC) analysis

| Symptoms | Modified score | |
|--|----------------|--------------|
| Nausea-vomiting | 2 | |
| RLQ tenderness | 2 | |
| Indirect sign of positivity (1–2) | 1 | |
| Indirect sign of positivity (≥ 2) | 2 | |
| Leucocytosis >10 g/l | 1 | |
| Leucocytosis >15 g/l | 2 | |
| Ultrasound examination | 2 | |
| AUC | SE | Asympt. sig. |
| 0.899 | 0.020 | 0.000 |

RLQ right lower quadrant, AUC area under the curve, SE standard error

Table 11 Increasing the area under the curve (AUC) by modifying the Alvarado score

| I | | | II | | | III | | |
|-------|-------|--------------|-------|-------|--------------|-------|-------|--------------|
| AUC | SE | Asympt. sig. | AUC | SE | Asympt. sig. | AUC | SE | Asympt. sig. |
| 0.749 | 0.044 | 0.000 | 0.830 | 0.027 | 0.000 | 0.899 | 0.020 | 0.000 |

I, original score; II, new score made by logistic regression; III, score containing ultrasound examination

SE, standard error

procedure (CT) is needed to confirm the diagnosis. According to some studies, a value above 7 points is the diagnostic criterion that calls for urgent surgery, and the negative appendectomies decrease to a rate lower than 16 % [22–25]. Other studies have shown that the conventional clinical judgment is more reliable with regard to the indication for surgery and that the number of negative appendectomies in these cases is about 12 % [26–28].

In our study, the specificity and sensitivity of the conventional clinical judgment were higher than those of the Alvarado scoring system, but the difference was not significant (94.8 vs 87.8 %; $p = 0.32$). However, we did find a significant difference when we compared the sensitivity in group A before ($n = 131$) and after ($n = 95$) the chief surgeon on duty overrode the score's decision (69 vs 100 %; $p < 0.05$). In 12 cases, the Alvarado score suggested surgery, but the chief surgeon discharged the patient home. None of these patients returned to our outpatient department in the following period with abdominal pain. In 14 cases, the Alvarado score was lower than 7 points, but the surgeon suggested surgery. In 10 of these cases, the patient had appendicitis proved by histologic examination, but in 4 cases, the appendectomy was negative. In group A, 12 negative appendectomies (9.16 %) were performed, whereas this number was 5 (3.6 %) in group B ($p = 0.063$). According to the most recent systematic review, the Alvarado score overpredicts for women [20]. Our investigation found the same result: the AUC was 0.868 in the women's group and 0.785 in the men's group.

We found the Alvarado score to be reliable in the diagnosis of acute appendicitis, helping the staff at the emergency outpatient clinic, primarily in the decision regarding admission/discharge and about consulting a specialist. The use of the new scoring system has become easier. It includes fewer criteria as well as the addition of an important and sensitive predictor: the result of the ultrasound scan. With the help of this new score, decision making is more reliable because it contains the most sensitive predictors from the original Alvarado score and the result of a routine imaging technique available in every A&E unit in Hungary. As a result, CT investigation is needed only in problematic cases when the diagnosis is equivocal. It means less radiation exposure for the patient and cost saving for the hospital.

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