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# Diagnostic value of the pregnancy index for acute appendicitis in pregnant women

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**Acute appendicitis is one of the most common non-gynecological and non-obstetric causes of acute abdominal conditions requiring urgent surgery during pregnancy. Due to the similarity between the symptoms of the disease and those of pregnancy, laboratory findings become particularly important in diagnosis. This study aimed to evaluate these parameters for the first time using a new index definition. Between 2015 and 2021, a total of 120 patients were included in the study, divided into the four groups: healthy pregnant woman (HPW), healthy woman (HW), unhealthy pregnant woman (UPW, pregnant patient with acute appendicitis), and unhealthy woman (UW, non-pregnant patient with acute appendicitis). Laboratory parameters, including white blood cell count (WBC), C-reactive protein (CRP), neutrophil-lymphocyte ratio (NLR), ischemia-modified albumin (iMA), and platelet-lymphocyte ratio (PLR), were assessed. In this study, significant differences were observed in various laboratory parameters between groups, such as WBC, CRP, NLR, and PLR, indicating potential markers for differentiating between pregnant women with and without appendicitis. An index was created for the diagnosis of acute appendicitis in pregnant women and was named the Pregnant Index. The Pregnant Index (PGIndex) values of pregnant women without appendicitis were compared with those of pregnant women with appendicitis. It was found that the PGIndex value was significantly higher in pregnant women with appendicitis ($p < 0.001$). Using the ROC curve and Youden index, the PGIndex cut-off value to best differentiate between the two groups was 10.62. This value provided a sensitivity of 73.3%, specificity of 96.7%, positive predictive value of 95.7%, negative predictive value of 78.7%, and test accuracy of 85% for identifying pregnant women with appendicitis. Compared to other markers, the PGIndex had the highest accuracy value, and it was observed that patients with a PGIndex value above 10.62 had a significantly increased likelihood of having appendicitis. These results indicate that the PGIndex is a significant marker for detecting appendicitis in pregnant women. Laboratory parameters, particularly NLR and PLR, show promise as diagnostic tools for appendicitis in pregnant women. Incorporating these markers, the Pregnant Index (PGIndex) demonstrated high sensitivity and specificity in distinguishing between pregnant women with and without appendicitis. This is the first study using the Pregnant Index in pregnant women to diagnose appendicitis. Early diagnosis is crucial for preventing maternal and fetal morbidity and mortality associated with appendicitis during pregnancy.**

**Keywords** Appendicitis, Pregnancy, Diagnosis

Acute appendicitis in pregnancy is one of the most common non-gynecological and non-obstetric causes of acute abdomen among clinics requiring emergency surgery[1,2]. Similarly, acute appendicitis is the most common surgical condition requiring non-obstetric abdominal surgery during pregnancy, and its incidence is reported to be between 1:1250 and 1:1500 in pregnancies, and 50% of the cases occur in the second trimester[3]. Due to the high prevalence of nausea, vomiting, and abdominal pain in the normal obstetric patient population, surgical intervention is delayed.

There is a common defensive attitude among healthcare professionals against unnecessary surgery in a woman with a prediagnosis of acute appendicitis. However, right-sided abdominal pain associated with defense and rebound and accompanied by fever in any pregnant woman should be considered acute appendicitis unless proven otherwise.

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Pregnancy-related localization changes of the appendix vermiformis according to gestational age may mask or change the symptoms and physical examination findings. As a result, there is a significant risk of delay in diagnosis. In addition to the usual complications of appendicitis, additional comorbidities for mother and fetus should be kept in mind in these patients. Therefore, early diagnosis and treatment are very important in terms of prevention of both maternal and fetal morbidity and mortality[4]. Here, laboratory parameters are as important as clinical and imaging studies regarding diagnosis in pregnant women. Especially in cases such as nausea, vomiting, and abdominal pain in masked pregnancy, it becomes an important instrument in making a distinctive diagnosis.

Although there is no specific laboratory marker for the diagnosis of appendicitis, various parameters, including white blood cell (WBC) count, C-reactive protein (CRP), neutrophil-to-lymphocyte ratio (NLR), ischemia-modified albumin (iMA) and platelet-to-lymphocyte ratio (PLR) are used in the diagnosis of acute appendicitis[5,6]. Pregnant Index (PGIndex) was defined as PGIndex = NE*CRP/MPV according to the positive correlation of pregnant appendicitis and blood values.

The aim of this study was to determine a specific index for the diagnosis of pregnancy appendicitis by using laboratory parameters used in the diagnosis of acute appendicitis. Four groups were evaluated: the healthy woman group (HW), the normal (non-pregnant) appendicitis group (UW), the normal (non-appendicitis) pregnant group (HPW), and the pregnant appendicitis (UPW) group. It was aimed to determine a parameter defined as the Pregnant Index (PGIndex) with the results obtained by evaluating laboratory parameters between these groups in order to help in cases that pose difficulties in terms of diagnosis in pregnant appendicitis.

## Materials and methods

This study was approved by the Clinical Research Ethics Committee of Hitit University Faculty of Medicine (2023/71) and was designed retrospectively. Patients diagnosed with appendicitis who presented to the Emergency Clinic of Hitit University Faculty of Medicine Erol Olçok Training and Research Hospital and were consulted by the Departments of General Surgery and Obstetrics and Gynecology between 2015 and 2021 were included in the evaluation. Subsequently, the records of patients who underwent surgery were reviewed, and a total of 30 patients were identified. The patient groups were categorized into four distinct groups: Healthy Pregnant Women (HPW) Healthy pregnant women are pregnant patients who do not have any chronic disease, acute or chronic inflammatory condition, or acute appendicitis. Healthy Women (HW): Healthy women are non-pregnant female individuals who do not have any chronic disease, acute or chronic inflammatory condition, or acute appendicitis. Unhealthy Pregnant Women (UPW): Unhealthy pregnant women are pregnant patients with acute appendicitis who do not have any chronic disease or acute or chronic inflammatory condition. Unhealthy Women (UW): Unhealthy women are female patients with acute appendicitis who do not have any chronic disease or acute or chronic inflammatory condition.

In a retrospective study conducted in the General Surgery clinic, 30 pregnant patients with acute appendicitis and no chronic diseases or chronic/active inflammation, as well as 30 healthy women with acute appendicitis, were identified. Similarly, in the Obstetrics and Gynecology clinic, 30 healthy women and 30 healthy pregnant women who met the inclusion criteria were enrolled through a retrospective screening. Exclusion criteria included patients under 18 years of age, those with known hematologic or oncologic diseases, perforated appendicitis, periappendicular abscess, phlegmonous appendicitis, and conditions other than appendicitis. In total, 120 patients who met the inclusion criteria were recorded.

The age and serum values at admission, including WBC, NE, LY, MO, Hb, Plt, MPV, Alb, and CRP, were retrospectively obtained from the archive system. The neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), C-reactive protein-to-albumine ratio(CAR), platelet-to monocyte ratio (PMR), and monocyte-to-lymphocyte(MLR) values were calculated from the admission data and included in the study. The diagnoses of appendicitis in patients who had undergone appendectomy were confirmed by reviewing postoperative pathology reports.

Statistical analyses were performed using IBM SPSS Statistics for Windows (version 26). Continuous variables were tested for normality using the Shapiro-Wilk test. For normally distributed data, independent sample t-tests were used to compare means between groups. For non-normally distributed data, the Mann-Whitney U test was employed. Categorical variables were analyzed using chi-square or Fisher's exact tests, as appropriate. Multivariate logistic regression was applied to identify predictors of acute appendicitis in pregnant women. Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the diagnostic performance of the Pregnant Index and to determine optimal cut-off values using the Youden index. Statistical significance was accepted at $p < 0.05$.

For numerical measurements between research groups, independent sample t-tests were used for WBC, hemoglobin, neutrophil count, MPV, and albumin levels in non-pregnant patients, while age, lymphocyte count, platelet count, CRP, monocyte count, NLR, PLR, CAR, PMR, and MLR were assessed using the Mann-Whitney U test. Similarly, independent sample t-tests were used for pregnant patients' WBC, hemoglobin, lymphocyte count, MPV, and monocyte count. In contrast, the Mann-Whitney U test evaluated age, gestational week, neutrophil count, platelet count, albumin, CRP, NLR, PLR, CAR, PMR, and MLR. Binomial logistic regression analysis, including NE, LY, Alb, MPV, and CRP, was performed for multivariate statistical analysis between the two groups, revealing that NE, CRP, and MPV were significant in multivariate analysis. The Pregnant Index (PGIndex) was defined as PGIndex = NE * CRP / MPV based on the positive significance of these criteria for appendicitis. The ROC curve was used to demonstrate the discriminative ability of statistically significant variables and cut-off values for the markers were determined using the area under the curve (AUC) and the Youden index. Sensitivity, specificity, PPV, NPV, and accuracy values were calculated for these cut-off values. Odds ratios were also calculated based on these cut-offs. Statistical significance was accepted as $p < 0.05$.

## Results

The entire group's mean age was 30.2 ± 7.39 (29.5) years, as detailed in Table 1, which comprehensively evaluates demographic data. The groups were examined in two parts: a comparison of non-pregnant normal patients and patients with appendicitis and a comparison of pregnant normal patients and pregnant patients with appendicitis.

### Evaluation of non-pregnant patients (HW and UHW)

The mean age of the healthy female group was calculated as 29.53 ± 6.97 (31.00) years, while the mean age of the appendicitis female group was 27.73 ± 7.05 (25.50) years, with no statistically significant difference observed ($p = 0.245$). The mean WBC count was 7.19 ± 1.56 (7.15) in the healthy female group, whereas it was 13.01 ± 4.83 (13.28) in the appendicitis female group, showing a statistically significant increase ($p < 0.001$). The mean neutrophil count was 5.72 ± 0.95 (5.52) in the healthy female group and 10.05 ± 4.66 (9.92) in the appendicitis group, with a statistically significant difference observed ($p < 0.001$). When examined in terms of lymphocyte count, the mean lymphocyte count was 2.21 ± 0.53 (2.33) in the healthy female group, and 2.05 ± 1.07 (1.75) in the patient female group, with no statistically significant difference observed ($p = 0.067$).

No statistically significant difference was observed in the mean hemoglobin levels between the healthy and appendicitis female groups ($p = 0.596$). Similarly, the two groups had no significant difference in platelet counts ($p = 0.069$). No significant difference was observed in the mean MPV and albumin levels between the two groups ($p = 0.242$ and $p = 0.949$, respectively). The median CRP was 3.14 (3.02–6.38) in the healthy female group, while it was 24.9 (3.02–152) in the appendicitis female group, indicating a statistically significant increase in CRP levels ($p < 0.001$). No statistically significant difference was observed in mean monocyte counts between the two groups ($p = 0.178$).

When the NLR values of both groups were examined, the median NLR was 2.52 (1.69–8.48) in the healthy female group and 4.59 (1.33–28.06) in the appendicitis female group, showing a statistically significant difference

| Variables | All Patients | Non-Pregnant Patients | Pregnant Patients | Normal | Appendicitis | Statistical Significance | Pregnant | Pregnant Appendicitis | Statistical Significance |
|---|---|---|---|---|---|---|---|---|---|
| Age | 30.20 ± 7.39 (29.5) | 28.63 ± 7.00 (29.50) | 28.77 ± 6.49 (28.00) | 29.53 ± 6.97 (31.00) | 27,73 ± 7,05 (25,50) | 0,245* | 30,00 ± 5,53 (29,50) | 27,53 ± 7,21 (25,50) | 0,094* |
| Gestational Weeks | 19.02 ± 8.75 (20) | | 19.02 ± 8.75 (20.00) | | | | 21,23 ± 10,05 (24,50) | 16,80 ± 6,68 (17,50) | 0,035* |
| WBC | 10.59 ± 4.37 (9.52) | 10.10 ± 4.61 (8.52) | 11.08 ± 4.09 (9.74) | 7.19 ± 1.56 (7.15) | 13,01 ± 4,83 (13,28) | < 0,001* | 9,43 ± 1,89 (9,62) | 12,73 ± 4,97 (12,61) | 0,002* |
| HGB | 12.03 ± 1.35 (12) | 12.31 ± 1.47 (12.50) | 11.75 ± 1.16 (11.85) | 12.41 ± 1.60 (12.60) | 12,21 ± 1,35 (12,40) | 0,596* | 12,01 ± 0,94 (12,00) | 11,49 ± 1,31 (11,80) | 0,085* |
| NE | 8.23 ± 3.94 (6.96) | 7.88 ± 3.99 (6.66) | 8.58 ± 3.90 (7.19) | 5.72 ± 0.95 (5.52) | 10,05 ± 4,66 (9,92) | < 0,001* | 6,86 ± 1,60 (6,78) | 10,30 ± 4,71 (9,78) | 0,005* |
| LY | 1.87 ± 0.77 (1.83) | 2.13 ± 0.84 (2.17) | 1.61 ± 0.60 (1.72) | 2.21 ± 0.53 (2.33) | 2,05 ± 1,07 (1,75) | 0,067* | 1,79 ± 0,42 (1,76) | 1,43 ± 0,70 (1,44) | 0,020* |
| PLT | 250.41 ± 71.69 (244.5) | 270.48 ± 65.49 (268.00) | 230.33 ± 72.50 (217.00) | 286.07 ± 68.31 (280.00) | 254,90 ± 59,64 (255,50) | 0,069* | 232,93 ± 71,61 (233,00) | 227,73 ± 74,51 (207,00) | 0,589* |
| MPV | 10.04 ± 1.28 (10.05) | 10.15 ± 1.25 (10.15) | 9.93 ± 1.31 (9.85) | 10.40 ± 1.43 (10.30) | 9,90 ± 0,98 (9,95) | 0,242* | 10,44 ± 0,99 (10,40) | 9,42 ± 1,40 (9,25) | 0,002* |
| Alb | 3.82 ± 0.61 (3.85) | 4.23 ± 0.34 (4.20) | 3.42 ± 0.54 (3.50) | 4.23 ± 0.30 (4.20) | 4,22 ± 0,38 (4,20) | 0,949* | 3,15 ± 0,57 (3,05) | 3,68 ± 0,36 (3,70) | < 0,001* |
| CRP | 6.84 (3.02–183) | 3.23 (3.02–152) | 10.1 (3.02–183) | 3.14 (3.02–6.38) | 24,9 (3,02-152) | < 0,001† | 8,31 (3,3–21,1) | 22,45 (3,02-183) | < 0,001† |
| MO | 0.58 ± 0.24 (0.54) | 0.59 ± 0.27 (0.52) | 0.58 ± 0.21 (0.59) | 0.55 ± 0.25 (0.47) | 0,63 ± 0,28 (0,58) | 0,178* | 0,60 ± 0,16 (0,63) | 0,56 ± 0,25 (0,55) | 0,482* |
| NLR | 3.73 (1.33–56.13) | 2.91 (1.33–28.06) | 4.44 (2.04–56.13) | 2.52 (1.69–8.48) | 4,59 (1,33 – 28,06) | 0,001† | 3,91 (2,09 – 7,07) | 7 (2,04–56,13) | 0,001† |
| PLR | 132.36 (43.66-803.85) | 125.05 (52.21–575) | 148.12 (43.66-803.85) | 120.7 (67.5–575) | 130,66 (52,21–487,1) | 0,745† | 126,62 (67,3-232,63) | 168,78 (43,66–803,85) | 0,011† |
| CAR | 2.24 (0.64–54.85) | 0.8 (0.64–33.78) | 3.3 (0.7-54.85) | 0.76 (0.64–1.56) | 5,3 (0,66 – 33,78) | < 0,001† | 2,38 (0,79 – 6,39) | 6,08 (0,7–54,85) | 0,001† |
| PMR | 24.24 (8.54–59.34) | 25.53 (8.54–59.3) | 22.34 (9.83–59.34) | 25.83 (12.35–59.3) | 24,97 (8,54 – 51,15) | 0,274† | 22,3 (9,83 – 43,3) | 22,45 (12,19–59,34) | 0,574† |
| MLR | 0.3 (0.13–2.75) | 0.24 (0.13–0.9) | 0.36 (0.15–2.75) | 0.22 (0.13–0.65) | 0,33 (0,13 – 0,9) | 0,040† | 0,36 (0,16 – 0,53) | 0,35 (0,15 – 2,75) | 0,425† |
| | | | | | | PGIndex | 5.22 (1.57–20.62) | 18.71 (1.74–438.3) | < 0.001† |

**Table 1**. All patients and groups data and comparison of variables between groups. WBC: White blood cell count, HGB: Hemoglobin, NE: Neutrophil count, LY: Lymphocyte count, PLT: Platelet count, MPV: Mean platelet volume, Alb: Albumin, CRP: C-reactive peptide, MO: Monocyte count, NLR: Neutrophil-lymphocyte ratio, PLR: Platelet-lymphocyte ratio, CAR: CRP-Albumin ratio, PMR: Platelet-monocyte ratio, MLR: Monocyte-lymphocyte ratio, PGIndex: Pregnant Index †: Results of Mann-Whitney U test, *: Results of student t-test.

| Variables | Cut-Off | Diagnostic Values | | | | | ROC Curve | | | Odds Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sensitivity | Specificity | PPV | NPV | Accuracy | Area (SE) | %95 CI | *p* | Odds Ratio | %95 CI | *p* |
| NLR | 3.33 | 66.7% | 90.0% | 87.0% | 73.0% | 78.3% | 0.751 (0.070) | 0.613–0.889 | 0.001 | 18 | 4.378–74.012 | <0.001 |
| CAR | 1.08 | 73.3% | 96.7% | 95.7% | 78.4% | 85.0% | 0.834 (0.058) | 0.722–0.947 | <0.001 | 79.75 | 9.276-685.633 | <0.001 |
| MLR | 0.33 | 50.0% | 80.0% | 71.4% | 61.5% | 65.0% | 0.654 (0.072) | 0.514–0.795 | 0.040 | 4 | 1.272–12.578 | 0.029 |

**Table 2**. Cut-off points and diagnostic values of variables for the distinction between normal and appendicitis patients. *ROC: Receiver operating curve, PPV: Positive predictive value, NPV: negative predictive value, SE: Standard error, CI: Confidence interval, p: Statistical significance, NLR: neutrophil-lymphocyte ratio, CAR: CRP-albumin ratio, MLR: Monocyte-lymphocyte ratio.*

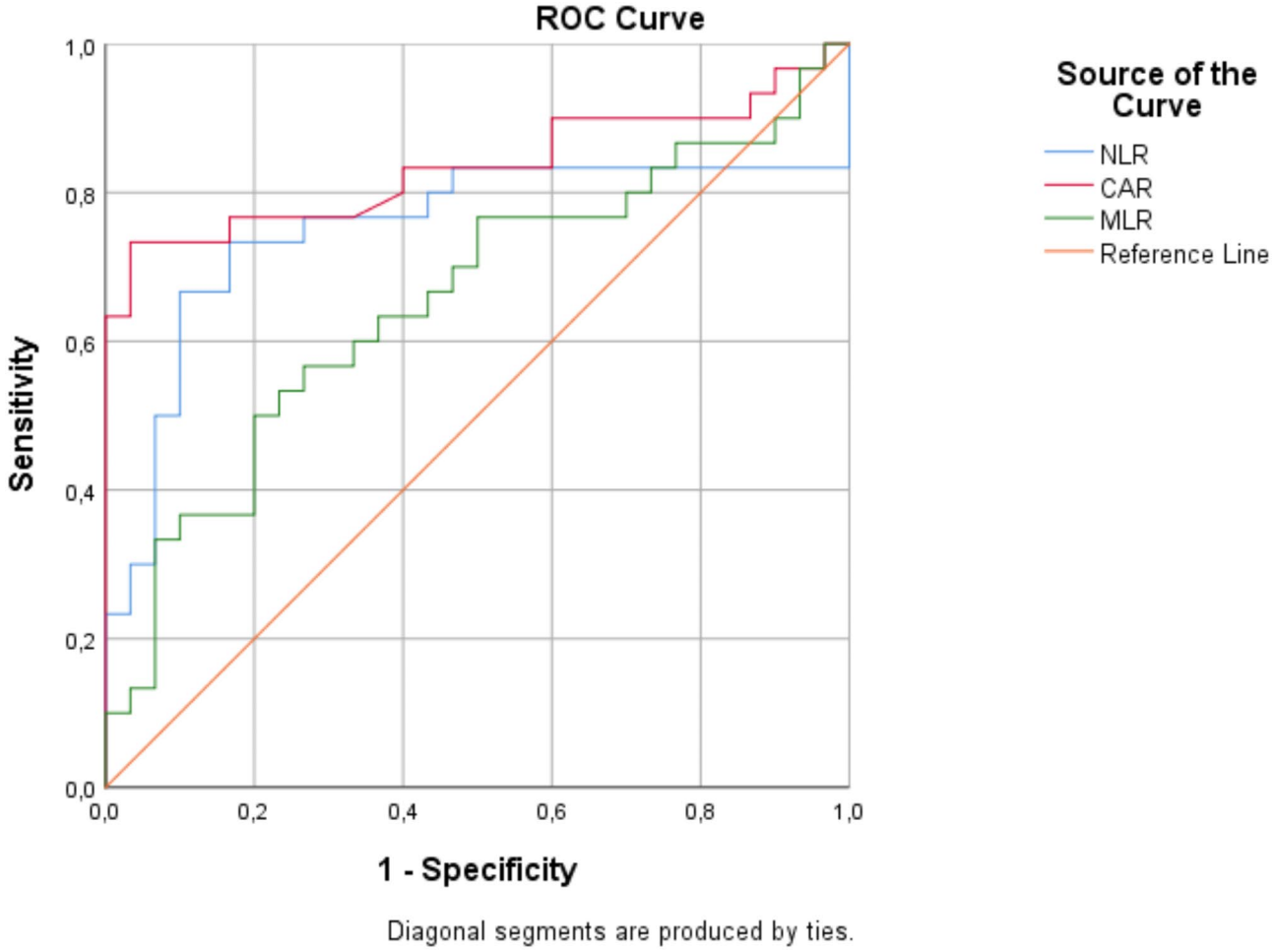


**Fig. 1**. ROC curve for the diagnosis of appendicitis by NLR, CAR, MLR in non-pregnant participants.

($p = 0.001$). The median CAR in the healthy female group was 0.76 (0.64–1.56), whereas it was 5.3 (0.66–33.78) in the appendicitis female group, indicating a significantly higher level, with a statistically significant difference observed ($p < 0.001$). Regarding MLR, the median MLR was 0.22 (0.13–0.65) in the healthy female group and 0.33 (0.13–0.9) in the appendicitis female group, showing a statistically significant difference ($p = 0.04$).

When comparing the mean PLR and PMR of non-pregnant women groups, no statistically significant difference was observed ($p = 0.745$ and $p = 0.274$, respectively) (Table 1).

## Diagnostic evaluation of discriminating markers in the non-pregnant group (HW vs. UHW)

NLR, CAR, and MLR markers, showing significant differences between the non-pregnant normal (HW) and appendicitis (UHW) groups, were evaluated for their ability to distinguish between these groups using the area under the ROC curve and the Youden index. For NLR, a cut-off value of 3.33 (OR 18, 95% CI 4.378–74.012, $p < 0.001$) was found with 66.7% sensitivity and 90% specificity. For CAR, a cut-off value of 1.08 (OR 79.75, 95% CI 9.276-685.633, $p < 0.001$) was found with 73.3% sensitivity and 96.7% specificity. For MLR, a cut-off value of 0.33 (OR 4, 95% CI 1.272–12.578, $p = 0.029$) was found with 50% sensitivity and 80% specificity (Table 2) (Fig. 1).

## Evaluation of pregnant patients (HPW and UPW)

The mean age of healthy pregnant women (HPW) was calculated as 30.00 ± 5.53 (29.50) years, while the mean age of pregnant patients with appendicitis (UPW) was 27.53 ± 7.21 (25.50) years. Although the mean age of the appendicitis group appeared slightly younger, no statistically significant difference was observed ($p = 0.094$). The mean gestational week was 21.23 ± 10.05 (24.50) weeks for healthy pregnant women (HPW) and 16.80 ± 6.68 (17.50) weeks for pregnant patients with appendicitis (UPW), showing a significant difference ($p = 0.035$).

When examining the mean WBC count, it was significantly higher in pregnant patients with appendicitis (UPW) with a mean of 12.73 ± 4.97 (12.61), compared to 9.43 ± 1.89 (9.62) in healthy pregnant women (HPW) ($p = 0.002$). The mean neutrophil count was 10.30 ± 4.71 (9.78) in pregnant patients with appendicitis (UPW) and 6.86 ± 1.60 (6.78) in healthy pregnant women (HPW), showing a significant increase in neutrophil count in pregnant patients ($p = 0.005$). The mean lymphocyte count was 1.79 ± 0.42 (1.76) in healthy pregnant women (HPW) and 1.43 ± 0.70 (1.44) in pregnant patients with appendicitis (UPW), indicating a statistically significant decrease in lymphocyte count in the presence of inflammation ($p = 0.02$). No statistically significant difference was observed in the mean monocyte count between the two groups ($p = 0.482$).

No significant difference was observed in the mean hemoglobin and platelet values between non-appendicitis pregnant women and the appendicitis group ($p = 0.085$ and $p = 0.589$, respectively). The mean MPV was 10.44 ± 0.99 (10.40) in healthy pregnant women (HPW) and 9.42 ± 1.40 (9.25) in pregnant patients with appendicitis (UPW), showing a statistically significant decrease in the appendicitis group ($p = 0.002$).

When examining the mean albumin, it was 3.15 ± 0.57 (3.05) in healthy pregnant women (HPW) and 3.68 ± 0.36 (3.70) in pregnant patients with appendicitis (UPW), indicating a statistically significant difference ($p < 0.001$). The median CRP was 8.31 (3.3–21.1) in healthy pregnant women (HPW) and 22.45 (3.02–183) in pregnant patients with appendicitis (UPW), showing a significantly higher value in the appendicitis group ($p < 0.001$).

When comparing the mean NLR values, the median NLR was 3.91 (2.09–7.07) in non-appendicitis pregnant women and 7.00 (2.04–56.13) in pregnant patients with appendicitis, showing a significantly higher value in the appendicitis group ($p = 0.001$). Evaluation of PLR medians revealed 126.62 (67.3-232.63) in the normal pregnant group and 168.78 (43.66-803.85) in the pregnant appendicitis group, indicating a statistically significant difference ($p = 0.011$). The mean CAR was 2.38 (0.79–6.39) in the normal pregnant group and 6.08 (0.7-54.85) in the pregnant appendicitis group, significantly higher in the appendicitis group ($p = 0.001$).

No statistically significant difference was observed between the two groups regarding PMR and MLR mean comparisons ($p = 0.574$, $p = 0.425$, respectively) (Table 1).

## Diagnostic evaluation of markers with differences in the pregnancy group

To differentiate between non-appendicitis (HPW) and appendicitis (UPW) groups in pregnant individuals, the significant differences in NLR, PLR, and CAR markers were evaluated using the area under the ROC curve and the Youden index. It is noteworthy that MLR, which was found to be significant in the distinction of appendicitis in non-pregnant patients, loses its significance in pregnant patients, while the PLR value becomes significant. In pregnant women, the cut-off values were determined as follows: 53.3% sensitivity and 96.7% specificity for NLR at 6.51 (OR 33, 95% CI 3.984-275.727, $p < 0.001$), 50% sensitivity and 86.7% specificity for PLR at 170.04 (OR 6.5, 95% CI 1.820-23.213, $p = 0.005$), and 60% sensitivity and 90% specificity for CAR at 4.87 (OR 13.5, 95% CI 3.333–54.673, $p < 0.001$). It is noteworthy that NLR and CAR cut-off values in pregnant appendicitis patients (UPW) have higher threshold values compared to non-pregnant appendicitis patients (UW), which should be considered as an important point (Table 3) (Fig. 2).

## Diagnostic power of PGindex in distinguishing appendicitis in pregnant women

To better assess the differences between pregnant women without appendicitis (HPW) and pregnant women with appendicitis (UPW), a binomial logistic regression analysis was conducted, including neutrophil count, lymphocyte count, albumin level, mean platelet volume (MPV), and C-reactive protein (CRP), which showed significant differences in comparisons between the two groups. Neutrophil count, CRP level, and MPV did not lose their significance in multivariable regression analysis, but lymphocyte count, and albumin level individually lost their determinative value ($p = 0.046$, $p = 0.016$, $p = 0.005$, $p = 0.514$, and $p = 0.151$, respectively).

| | | Diagnostic Values | | | | | ROC Curve | | | Odds Ratio | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variables | Cut-Off | Sensitivity | Specificity | PPV | NPV | Accuracy | Area (SE) | %95 CI | *p* | Odds Ratio | %95 CI | *p* |
| NLR | 6.51 | 53.3% | 96.7% | 94.1% | 67.4% | 75.0% | 0.751 (0.066) | 0.622–0.880 | 0.001 | 33 | 3.984-275.727 | < 0.001 |
| PLR | 170.04 | 50.0% | 86.7% | 78.9% | 63.4% | 68.3% | 0.691 (0.070) | 0.553–0.829 | 0.011 | 6.5 | 1.820-23.213 | 0.005 |
| CAR | 4.87 | 60.0% | 90.0% | 85.7% | 69.2% | 75.0% | 0.749 (0.067) | 0.617–0.881 | 0.001 | 13.5 | 3.333–54.673 | < 0.001 |
| PGIndex | 10.62 | 73.3% | 96.7% | 95.7% | 78.4% | 85.0% | 0.842 (0.056) | 0.733–0.952 | < 0.001 | 79.75 | 9.276-685.633 | < 0.001 |

**Table 3**. Cut-off points and diagnostic values of variables for the distinction between pregnant non-appendicitis and pregnant appendicitis patients PGIndex: NE*CRP/MPV. *ROC: Receiver operating curve*, *PPV: Positive predictive value*, *NPV: negative predictive value*, *SE: Standard error*, *CI: Confidence interval*, *p: Statistical significance*, *NLR: neutrophil-lymphocyte ratio*, *PLR: Platelet-lymphocyte ratio*, *CAR: CRP-albumin ratio*, *PGIndex: Pregnant Index*.

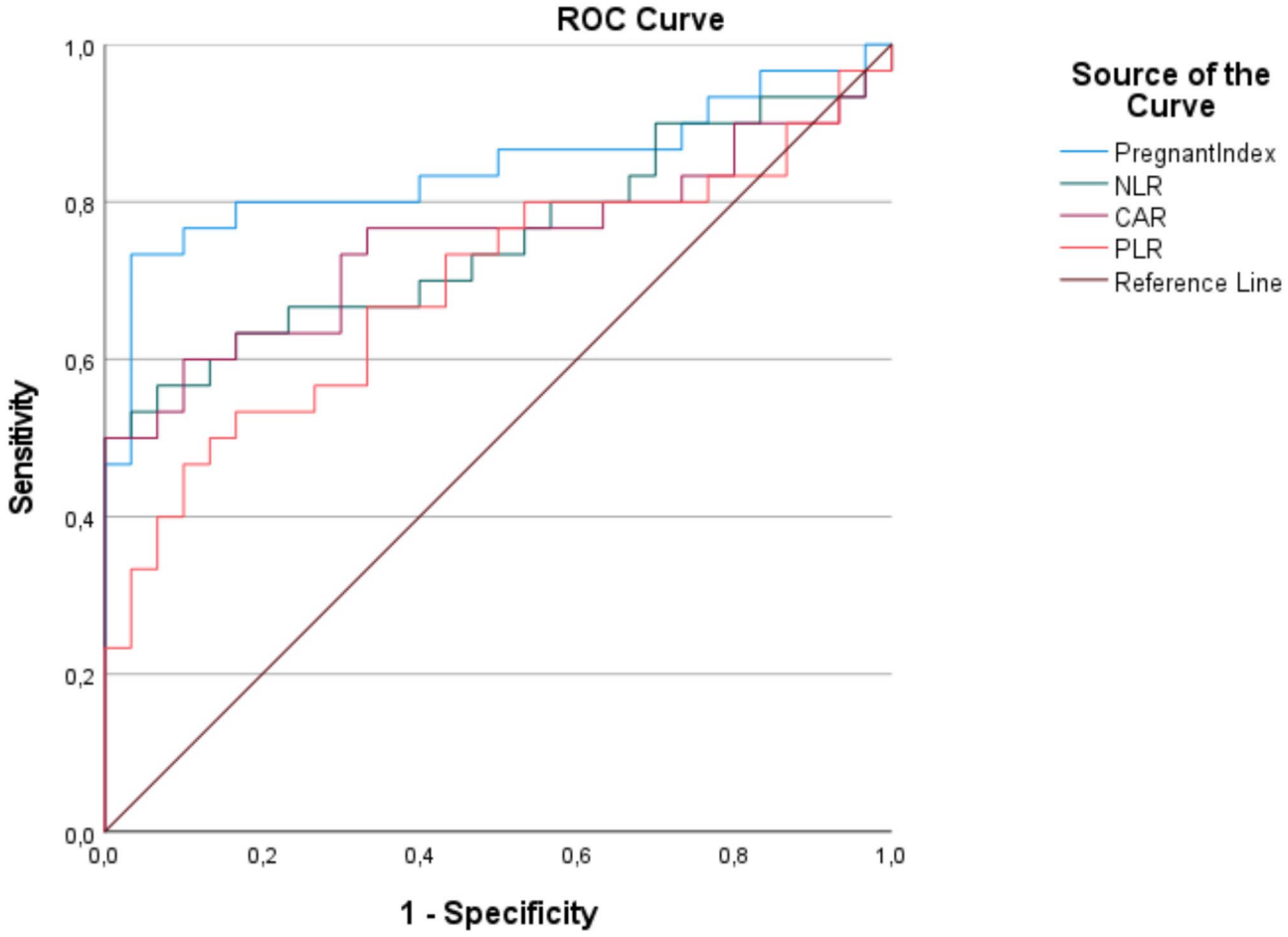


**Fig. 2**. ROC curve for the diagnosis of appendicitis by NLR, PLR, CAR and PGIndex in pregnant participants.

An attempt was made to establish a new evaluation criterion based on the relationship of the values maintaining significance in multivariable analysis with the groups. The Pregnant Index (PGIndex) was defined as PGIndex = NE*CRP/MPV based on the positive significance of blood values in pregnant appendicitis cases.

In pregnant women without appendicitis (HPW), the median PGIndex was found to be 5.22 (1.57–20.62), whereas, in pregnant women with appendicitis (UPW), this value was 18.71 (1.74–438.3), significantly higher than the other group ($p < 0.001$).

When the PGIndex value that best distinguished between the two groups was calculated using the ROC curve and the Youden index, the cut-off value was found to be 10.62 with 73.3% sensitivity, 96.7% specificity, 95.7% positive predictive value, 78.4% negative predictive value, and 85% test accuracy (OR 79.75; 9.276-685.633; $p < 0.001$). Compared to other markers, PGIndex had the highest accuracy value, and it was observed that the likelihood of belonging to the appendicitis group in patients with a PGIndex above 10.62 was 78.75 times higher than in a patient below this threshold (Table 3) (Fig. 2).

## Discussion

The difficulty in diagnosing acute appendicitis generally arises from the need to synthesize clinical, laboratory, and radiological findings. In pregnant women, this becomes even more challenging because the similarities between acute appendicitis symptoms and pregnancy physiology make diagnosis difficult[7]. Consequently, pregnant women with acute appendicitis often present to obstetrics and gynecology clinics, as abdominal pain is primarily attributed to pregnancy-related issues[8]. Accurate and timely diagnosis is critically important to reduce complications and negative appendectomy rates and often requires collaboration between obstetrics-gynecology and general surgery clinics. Delays in diagnosis can increase maternal and fetal morbidity and mortality rates. Several studies have shown that diagnostic challenges lead to higher complication rates and increased rates of fetal and maternal death[9–11]. Therefore, early diagnosis during the early stages of the disease, followed by surgical intervention alongside obstetric care, leads to recovery. Consequently, imaging and laboratory values have gained significant importance as early diagnostic tools. Recent studies have highlighted the importance of inflammatory markers and indices in obstetrics and gynecology for diagnosing and managing various conditions. In particular, the utility of markers such as NLR, PLR, and other derived indices has been explored for their predictive and diagnostic value in pregnancy-related complications. A recent study discusses the role of these markers in identifying inflammatory conditions in pregnant women, demonstrating their potential to

enhance early diagnosis and improve outcomes. These findings align with our study's emphasis on the Pregnant Index (PGIndex) as a novel marker for diagnosing acute appendicitis in pregnant women. By incorporating these markers into routine evaluations, clinicians can achieve better diagnostic accuracy, particularly in challenging cases where clinical symptoms overlap with physiological changes during pregnancy. Our study further contributes to the literature by demonstrating the superior diagnostic performance of PGIndex compared to traditional inflammatory markers, thus reinforcing the importance of tailored indices in obstetric care[12].

Imaging modalities, especially in pregnant women, are paramount during the preoperative period. While computed tomography (CT) has significant prognostic value in diagnosing acute appendicitis, alternatives such as ultrasound (USG) and magnetic resonance imaging (MRI) may be used in pregnant women due to the risks of ionizing radiation associated with CT. A meta-analysis reported that ultrasound has high specificity but moderate sensitivity in diagnosing acute appendicitis in pregnant women[13]. MRI imaging, on the other hand, is an excellent method for excluding acute appendicitis in pregnant patients presenting with right lower quadrant pain[14]. However, it is not preferred in emergency settings due to longer examination times and prolonged duration for making a diagnosis.

The challenges in imaging underscore the importance of laboratory findings. Unlike the difficulties in accessing imaging, laboratory findings' ease of access and cost-effectiveness make them a readily available and convenient tool. In this context, additional evaluations such as NLR and PLR, which were evaluated in the literature alongside existing laboratory findings, have become important for us. In a study by Akın et al.[15], the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) were not found to be significant in distinguishing appendicitis. However, most studies in the literature have reported the success of NLR and PLR in diagnosing appendicitis[16,17]. In this study, NLR and PLR were observed to be successful in diagnosing appendicitis in pregnant women as well. A notable point in our study is that while MLR was found to be successful in diagnosing appendicitis in non-pregnant patients, it lost its power in pregnant patients, and PLR became significant. This indicates that the threshold values used in non-pregnant patients change in pregnant patients due to the effects of pregnancy-related physiological changes[15]. While the optimal cut-off for NLR in non-pregnant patients was observed to be 3.33, this threshold value increased to 6.51 in pregnant patients. The change in threshold values for non-pregnant patients due to physiological changes inherent in pregnancy, observed in our study, has also been noted in similar studies in the literature[15].

In our study, the most successful parameter in diagnosing appendicitis was determined to be the Pregnant Index, which includes neutrophils, CRP, and MPV. This index has higher sensitivity, specificity, and odds ratio compared to other parameters. An elevation of CRP above 4.87 increases the likelihood of a pregnant patient having appendicitis by 12.5 times, while an NLR exceeding 6.51 results in a 32-fold increase in the likelihood of appendicitis. Moreover, exceeding a PGIndex of 10.62 increases the likelihood of appendicitis by 78.75 times.

## Limitations

Our study has some limitations. The discrepancy in gestational weeks between the healthy pregnant group and the appendicitis group is a limitation of this study. Gestational age-related changes in laboratory parameters, particularly WBC, may have impacted the results. Future prospective studies with more precisely matched gestational weeks are warranted to validate these findings. The retrospective design and multivariable analysis may pose limitations in terms of sensitivity and specificity of PGIndex by making it difficult to control potential factors fully. Additionally, being a single-center study restricts the generalizability of the results. Therefore, validating the study with larger and multicenter prospective studies is important. In this way, stronger evidence can be obtained for integrating PGIndex into clinical practice.

## Conclusion

Despite some weaknesses in the study, it holds the distinction of being the first study in the literature to evaluate the potential benefits of PGIndex in diagnosing appendicitis in pregnant women. PGIndex's utilization of routine clinical parameters such as neutrophil count, C-reactive protein level, and mean platelet volume ensures that it is easily applicable and does not incur additional costs, making it a readily available diagnostic tool. Consequently, the potential for PGIndex to rapidly and effectively determine the diagnosis of appendicitis in pregnant women has been demonstrated in clinical practice. The ease of calculation, simple usability, straightforward formulation, lack of additional cost, and, most importantly, its measurable quality are believed to provide significant advantages in clinical use. We are of the opinion that our findings should be evaluated through prospective studies involving a larger patient population.

## Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and privacy are available from the corresponding author upon reasonable request. Data are located in controlled access data storage at Hitit University Faculty of Medicine Department of General Surgery.

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## Author contributions

RT: Writing – review & editing, Supervision, Methodology, Conceptualization MBT: Data curation Formal analysis Software Writing–original draft.İS: Funding acquisition Investigation Project administration. MAY: Investigation Resources Validation. OA: Investigation Project administration Software Visualization All authors approved the final version of the manuscript to be published.

## Declarations

## Competing interests

The authors declare no competing interests.

## Ethics approval and consent to participate

This exploratory, retrospective, single-center cohort study was conducted in accordance with the most recent version of the Declaration of Helsinki. The study received approval from the local ethics committee of the Hitit University Faculty of Medicine (2023/71). Given the retrospective design of the study, the ethics committee granted a waiver for written informed consent. The informed consent was waived by IRB (Clinical Research Ethics Committee of Hitit University Faculty of Medicine) The data collection and manuscript preparation processes were conducted in accordance with the guidelines set forth by the Committee on Publication Ethics (COPE) and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) initiative.

## Additional information

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-90931-2.

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