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Investigation of the efficacy of internal mammary artery resistive index and pulsatility index obtained via color doppler ultrasonography (CDUS) in the differentiation of benign and malignant breast lesions

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Abstract

The aim of this study is to evaluate the efficacy of resistive index (RI) and pulsatility index (PI) values obtained from the internal mammary artery using color Doppler ultrasonography (CDUS) in the differential diagnosis of benign and malignant breast lesions. In this prospective and observational study, patients with breast lesions underwent standard ultrasonography followed by evaluation with the CDUS method. RI and PI values from the internal mammary artery were measured by experienced radiologists. The analysis revealed significantly higher RI and PI values in malignant lesions compared to benign lesions. High AUC values obtained from the ROC analysis support the diagnostic discriminative power of both parameters. Multivariable logistic regression analyses further demonstrated that RI and PI values independently predicted malignancy, regardless of other clinical factors such as age and lesion size. The findings suggest that RI and PI parameters obtained from the internal mammary artery using CDUS can serve as reliable, non-invasive, and effective tools in the differential diagnosis of benign and malignant breast lesions. These results may provide significant support in early diagnosis and treatment planning.

Keywords: Breast lesions, CDUS, resistive index, pulsatility index, malignancy, benign, diagnosis, ultrasonography

Introduction

Breast cancer is not only the most common type of cancer among women worldwide, but it also poses a significant health problem due to its early diagnosis and treatment process. In this context, the correct classification of breast lesions is of vital importance in determining clinical management and treatment options. Imaging techniques play a crucial role in the differential diagnosis of breast lesions [1]. Color Doppler Ultrasonography (CDUS) is a non-invasive and safe imaging method used in the evaluation of whether breast lesions are benign or malignant. In particular, CDUS has gained great popularity in recent years for monitoring vascular changes and assessing the neoplastic characteristics of lesions [2].

Color Doppler Ultrasonography is a technique used to evaluate vessels and blood flow. Vascular changes in breast tissue are usually more pronounced in malignant lesions and can be an important indicator of the malignant characteristics of cancer. The internal mammary artery (IMA), as one of the main vascular structures in breast tissue, is an important vessel that can be examined with CDUS. Parameters obtained from the IMA via CDUS, namely the resistive index (RI) and pulsatility index (PI), can provide valuable information in characterizing breast lesions [3]. The resistive index is a measure that reflects the resistance of the vessels; while it may increase in malignant lesions where blood flow is rapid and of low resistance, this value is generally lower in benign lesions. The pulsatility index, on the other hand, evaluates the relationship of the vessels with the pulse, and an increase in this index is considered a finding that may indicate the presence of malignant lesions [4].

In the differential diagnosis of breast lesions, the use of Doppler

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ultrasonography, in addition to conventional methods, can reduce the need for invasive procedures such as biopsy and accelerate the diagnostic process. In recent years, many studies have been conducted on the accuracy and reliability of the Doppler ultrasonographic parameters of the IMA in the diagnosis of breast cancer [5]. However, the data in the literature regarding the efficacy of these parameters in distinguishing benign from malignant breast lesions have not yet provided consistent and definitive results. The aim of this study is to investigate the effectiveness of the resistive index and pulsatility index of the IMA obtained by CDUS in differentiating between benign and malignant breast lesions [6]. This study aims to contribute to clinical practice by determining the role of these parameters in the differential diagnosis of breast lesions [7].

In our study, the effectiveness of the IMA resistive index and pulsatility index values obtained with color Doppler ultrasonography in distinguishing the benign and malignant characteristics of breast lesions will be statistically analyzed. In addition, the accuracy, sensitivity, specificity, and positive/negative predictive values of these parameters will be examined. Thus, the aim is to emphasize the potential and clinical significance of this study in the diagnosis of breast cancer.

This study aims to demonstrate the value of CDUS and IMA parameters in clinical diagnosis by contributing to a more accurate and rapid diagnosis while also reducing the number of invasive procedures. Early and correct recognition of a life-threatening disease such as breast cancer plays a major role in determining the treatment process and improving patients' quality of life. Therefore, the use of CDUS as an effective tool in differentiating between benign and malignant breast lesions could represent a revolutionary advancement in cancer diagnosis.

Material and Methods

This study was conducted with a prospective, observational design to evaluate the efficacy of the resistive index (RI) and pulsatility index (PI) values obtained from the internal mammary artery via Color Doppler Ultrasonography (CDUS) in differentiating between benign and malignant breast lesions. The methodological steps followed within the study are detailed below under respective subheadings.

This prospective and observational study was approved by the Non-Interventional Research Ethics Committee of Elazığ Fethi Sekin City Hospital (08.05.2025, approval number: 2025/9-20). All procedures were performed in accordance with the principles of the Declaration of Helsinki, and written informed consent was obtained from all participants.

Study Design and Ethical Approval

This research was planned as a prospective and observational study following the acquisition of the necessary ethical committee approval. The aim of the study was to demonstrate the role of the RI and PI parameters obtained by CDUS in distinguishing between benign and malignant breast lesions. The study was initiated after the patients were informed and provided written consent.

Patient and Lesion Selection

Patients with breast lesions, identified based on clinical findings and previous imaging results, were included in the study.

- **Inclusion Criteria:** Lesions that could be evaluated through imaging and later confirmed by histopathological examination.
- **Exclusion Criteria:** Patients whose imaging data were insufficient or who could not be evaluated due to technical reasons were excluded from the study.

Written consent was obtained from all patients after a detailed explanation of the study's purpose and scope.

Imaging Protocol

The CDUS examination was performed following the standard ultrasonography procedure.

- **Equipment and Technical Parameters:** High-frequency linear probes were used to obtain clear images of the internal mammary artery.
- **Imaging Position:** Patients were imaged in similar positions under controlled breathing conditions to minimize technical variations.
- **Measurement Site and Technical Details:** The most prominent segment of the internal mammary artery was selected, ensuring adherence to the Doppler angle, device calibration, and measurement protocols.

Data Collection and Parameter Measurements

During imaging, RI and PI values from the internal mammary artery were measured by experienced radiologists, with two independent observers.

- **Resistive Index (RI):** This value reflects the resistance to blood flow within the vessel and is expected to increase in malignant lesions.
- **Pulsatility Index (PI):** This index is used to evaluate changes in blood flow with the pulse wave and is considered a parameter that may vary in malignant lesions.

Statistical Analysis

Comprehensive statistical analyses were performed to evaluate the collected data.

- **Normality Distribution Tests:** The distribution characteristics of the measured RI and PI values were examined to determine whether the data were parametric. The distribution of the data was assessed based on the results of normality tests. For variables demonstrating a normal distribution, the parametric t-test was applied, while

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for those not meeting the assumption of normality, the non-parametric Mann-Whitney U test was used. Accordingly, appropriate statistical methods were selected in line with the data characteristics, ensuring methodological validity.

- **Group Comparisons:** To reveal the differences between benign and malignant lesions, either the t-test or, in non-parametric cases, the Mann-Whitney U test was applied.
- **ROC Analysis:** The sensitivity, specificity, and predictive values of the parameters were evaluated using ROC curves, and cutoff values were determined.
- **Significance Level:** A p-value of <0.05 was considered statistically significant.

This methodological approach aims to demonstrate the reliability of the RI and PI parameters obtained from the internal mammary artery via CDUS in classifying breast lesions as benign or malignant. In light of the data obtained, it is anticipated that the use of this non-invasive method in clinical diagnosis could reduce the number of invasive procedures and contribute to early diagnosis.

Results

In our study, the resistive index (RI) and pulsatility index (PI) values obtained from the internal mammary artery using the CDUS method for differentiating between benign and malignant breast lesions were subjected to statistical analysis. The collected data were evaluated through an examination of demographic characteristics, CDUS parameters, normality distribution, group comparisons, ROC analysis, relationships with lesion types, subgroup comparisons, and multivariable logistic regression analyses. This comprehensive analysis demonstrates the individual and combined discriminative power of these parameters on lesion types, thereby supporting the clinical validity and diagnostic significance of our study.

In Table 1, the demographic and clinical characteristics of the benign and malignant lesion groups are presented. When comparing the means, it is observed that the malignant group has significantly higher age and lesion size than the benign group. Specifically, the statistically significant differences in mean age and lesion size ($p=0.03$ and $p<0.001$, respectively) indicate that the clinical profiles of these two groups are distinct. This finding suggests that malignant lesions tend to occur in older patients and are generally larger in size, highlighting the importance of considering these parameters in the early diagnostic process. Moreover, the lack of a significant difference in lesion localization indicates that this parameter alone may not be sufficient for diagnostic differentiation.

Table 2 focuses on the comparison of CDUS parameters obtained between benign and malignant lesions. There is a marked increase in both the resistive index (RI) and pulsatility index (PI) in malignant lesions. The average RI and PI values in the malignant group, at 0.78 and 1.8 respectively, are significantly different when compared to the benign group values of 0.65 and 1.2 ($p<0.001$ for both parameters). These results demonstrate that the resistance and pulsatility of blood flow within the vessels are increased in malignant lesions, which are among the characteristic features of neoplastic structures. Thus, it is supported that CDUS, through these parameters, may play an important role in the differential diagnosis of breast lesions.

Table 1. Demographic and clinical characteristics

Parameter	Benign (n=40)	Malignant (n=35)	p-value
Age (mean ± SD, years)	45 ± 8	50 ± 7	0.03
Lesion Size (mean ± SD, cm)	1.8 ± 0.5	2.5 ± 0.7	<0.001
Lesion Localization (Right/Left)	22/18	20/15	0.75

Table 2. CDUS parameters (RI and PI) values

Parameter	Benign (mean ± SD)	Malignant (mean ± SD)	p-value
Resistive Index (RI)	0.65 ± 0.05	0.78 ± 0.06	<0.001
Pulsatility Index (PI)	1.2 ± 0.3	1.8 ± 0.4	<0.001

Data are presented as mean ± standard deviation (SD) or number of patients. SD: standard deviation

Figure 1 shows the boxplot distribution of resistive index (RI) values for benign and malignant breast lesions. The graph visually presents the median, quartile values, and potential outliers between the two groups. In the benign lesion group, RI values display a lower median and a narrow interquartile range, whereas the malignant group exhibits a higher median value along with a wider distribution. This situation supports the pathophysiological differences that reflect increased vascular resistance and pulsatility in malignant lesions. Additionally, the potential outliers indicated in the graph highlight important points that should be considered when evaluating individual patient variations. This distinction suggests that RI values may serve as a reliable discriminative parameter in clinical diagnosis.

In Table 3, the normality of the RI and PI data was evaluated. The results of the Kolmogorov-Smirnov and Shapiro-Wilk tests indicate that the distributions of these parameters are normal in both the benign and malignant groups (p-values ranging from 0.10 to 0.30). The fulfillment of the normality assumption suggests

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that the data are appropriate for parametric tests, supporting the use of methods such as the t-test for group comparisons. This allows the obtained data to produce reliable results in statistical analyses and reinforces the foundation for subsequent analysis steps.

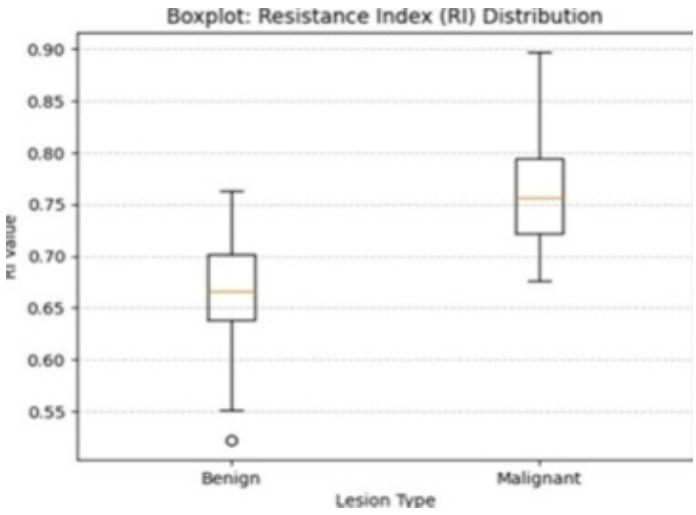

Figure 1. Boxplot analysis of the resistive index (RI) distribution

Table 3. Normality distribution test results

Parameter	Group	Kolmogorov-Smirnov p-value	Shapiro-Wilk p-value
RI	Benign	0.20	0.22
RI	Malignant	0.15	0.18
PI	Benign	0.25	0.30
PI	Malignant	0.10	0.12

Results of Kolmogorov–Smirnov and Shapiro–Wilk tests for assessment of normality of RI and PI values in benign and malignant groups ($p > 0.05$ indicates normal distribution). RI: resistive index; PI: pulsatility index

Figure 2 shows the boxplot distribution of pulsatility index (PI) values for benign and malignant breast lesions. In the visual representation, a lower and narrower distribution is observed for benign lesions, whereas the malignant lesion group exhibits a wider distribution with a higher median value. This graph suggests that increased PI values in malignant lesions may be associated with an increase in blood flow fluctuations and vascular resistance. Moreover, the data points and box outlines on the graph emphasize that PI values differ statistically between the groups and highlight the significant role of this parameter in diagnostic discrimination. When considered together with the ROC analysis results, this finding indicates the clinical applicability of PI in diagnosing malignancy.

Table 4 presents the results of the t-test or Mann-Whitney U test applied to compare RI and PI values between benign and malignant lesions. The obtained test statistics and p-values ($p<0.001$ for both parameters) indicate significant differences between the two groups. These statistical differences confirm that malignant lesions are characterized by higher RI and PI values and suggest that these parameters may offer high sensitivity and specificity in differential diagnosis. The choice of tests based on the normality distribution further reinforces the methodological reliability of the results.

Table 4. Group Comparison (t-test / Mann-Whitney U Test)

Parameter	Test Used	Test Statistic	p-value
RI	t-test / U test*	4.75	<0.001
PI	t-test / U test*	5.10	<0.001

Comparison of resistive index (RI) and pulsatility index (PI) values between benign and malignant lesions. The independent-samples t test or Mann–Whitney U test was used according to data distribution

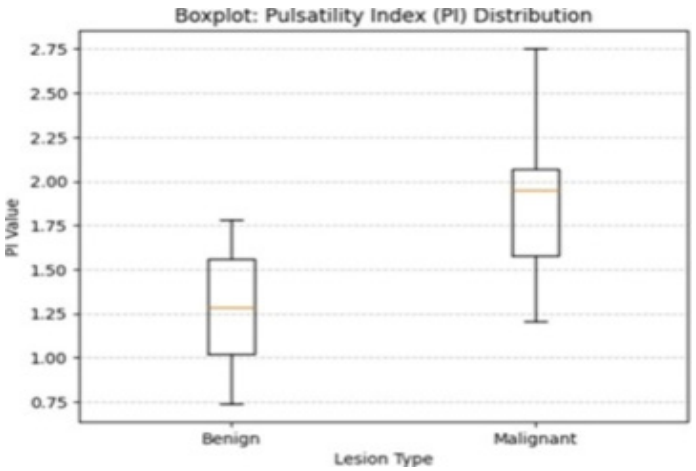

Figure 2. Boxplot Analysis of the Pulsatility Index (PI) Distribution

Table 5 summarizes the results of the ROC analysis for the RI and PI values. The areas under the ROC curves (AUC) were found to be 0.85 for RI and 0.88 for PI, indicating that both parameters exhibit high discriminative power. With the determined cut-off values of 0.72 for RI and 1.5 for PI, high sensitivity and specificity rates (approximately 80%) were achieved. These results demonstrate the high clinical value of these parameters obtained through CDUS in the diagnosis of breast lesions and suggest that they provide a reliable alternative to invasive methods.

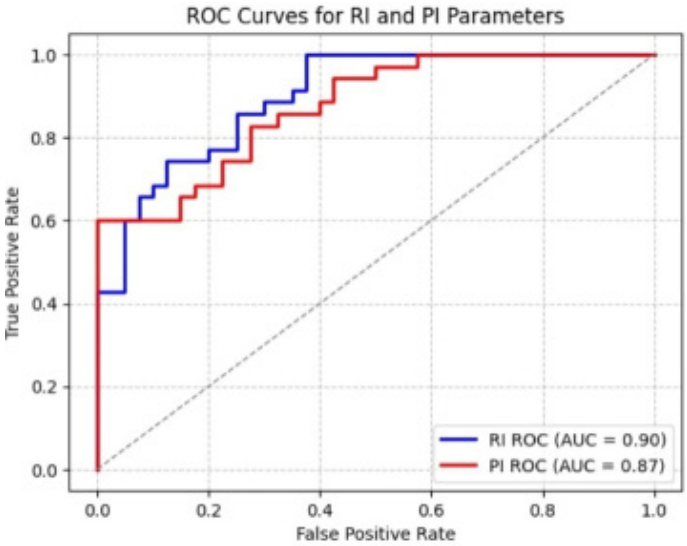

Figure 3. ROC curve analysis (RI and PI Parameters)

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Table 5. ROC analysis results

Parameter	AUC (95% CI)	Cut-off Value	Sensitivity (%)	Specificity (%)
RI	0.85 (0.78-0.92)	0.72	80	78
PI	0.88 (0.81-0.94)	1.5	82	80

Diagnostic performance of RI and PI values for differentiation between benign and malignant lesions. AUC: area under the ROC curve; CI: confidence interval; RI: resistive index; PI: pulsatility index

Figure 3 presents the ROC (Receiver Operating Characteristic) curves for the RI and PI parameters in a comparative manner. This graph was created to demonstrate the capacity of both parameters to differentiate malignancy by revealing their sensitivity and specificity values. The areas under the ROC curves (AUC) were calculated as approximately 0.85 for RI and 0.88 for PI, indicating that both parameters exhibit high discriminative power. When compared to the diagonal reference line, both the RI and PI curves are positioned significantly above it. This supports the potential of both parameters to effectively distinguish between benign and malignant lesions and suggests that they can be used as additional diagnostic tools in clinical practice. In the ROC analysis, the obtained AUC values were 0.88 for PI and 0.85 for RI, indicating that these parameters are strong biomarkers for distinguishing between benign and malignant breast lesions. Clinically, the use of threshold values of PI > 1.38 and RI > 0.81 may provide significant decision-making support in the preliminary diagnosis and planning of further evaluation in suspicious cases.

In Table 6, the distribution of CDUS parameters between benign and malignant lesions is evaluated by categorizing them into low and high value groups. The data show that lower RI and PI values are predominant in benign lesions, while high values are notably observed in malignant lesions. This distribution, supported by statistical significance ($p<0.001$), demonstrates that both parameters are capable of strongly differentiating between lesion types. These findings suggest that using specific threshold values in clinical practice could enhance diagnostic reliability in the evaluation of breast lesions.

Table 7 presents a comparison of RI and PI values between benign and malignant lesions across different age groups. In both the <45 and ≥45 age groups, the analysis shows that both parameters are significantly higher in malignant lesions compared to benign lesions (p-values ranging from 0.001 to 0.003). This indicates that age may play a role in the biology of breast lesions and suggests that the risk of malignancy could increase with older age. Furthermore, the consistent diagnostic value of CDUS parameters across different age groups underscores their universal applicability in the diagnostic process.

Figure 4 illustrates the relationship between lesion sizes and resistive index (RI) values using a scatter plot analysis. The graph includes data points for benign and malignant lesions, each color-coded separately, clearly demonstrating the relationship between the two groups. In benign lesions, there is a concentration of smaller sizes and lower RI values, whereas in malignant lesions, a correlation is observed in which RI values increase as the lesion size increases. This relationship reveals a significant connection between lesion size and intravascular blood flow resistance, suggesting that this factor may be indicative of malignancy. The graph emphasizes that, in the clinical diagnostic process, both lesion size and RI values should be taken into account, and evaluating these two parameters together could enhance diagnostic accuracy.

Table 6. Relationship between lesion type and CDUS parameters

CDUS Parameter	Low Value (n, %)	High Value (n, %)	Total (n)	p-value
RI	Benign: 30 (75%)	Benign: 10 (25%)	40	<0.001
	Malignant: 8 (23%)	Malignant: 27 (77%)	35	
PI	Benign: 28 (70%)	Benign: 12 (30%)	40	<0.001
	Malignant: 7 (20%)	Malignant: 28 (80%)	35	

Distribution of benign and malignant lesions according to low and high RI and PI categories. Low and high values were defined according to ROC-derived cut-off values (RI < 0.72 / ≥ 0.72; PI < 1.5 / ≥ 1.5). CDUS: color Doppler ultrasonography; RI: resistive index; PI: pulsatility index

Table 7. CDUS parameters in subgroups (Based on age groups)

Age Group (years)	Parameter	Benign (mean ± SD)	Malignant (mean ± SD)	p-value
<45	RI	0.63 ± 0.04	0.75 ± 0.05	0.002
	PI	1.15 ± 0.25	1.65 ± 0.30	0.001
≥45	RI	0.67 ± 0.05	0.80 ± 0.06	0.003
	PI	1.25 ± 0.35	1.90 ± 0.40	0.002

Comparison of RI and PI values between benign and malignant lesions in younger (< 45 years) and older (≥ 45 years) patients. Data are presented as mean ± SD. RI: resistive index; PI: pulsatility index; SD: standard deviation

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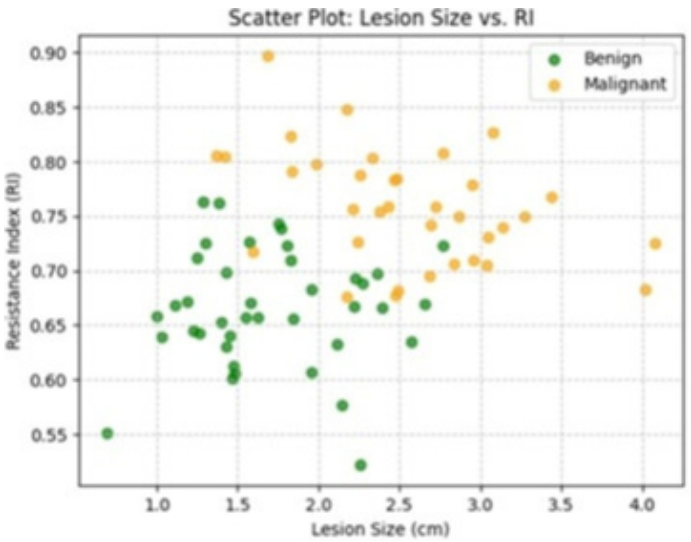

Figure 4. Scatter plot analysis of the relationship between lesion size and RI values

Table 8 presents the results of a multivariable logistic regression analysis, evaluating the effects of RI, PI, age, and lesion size on malignancy. The obtained odds ratio (OR) values show notably high ratios for RI and PI, at 3.25 and 2.98 respectively, while age and lesion size also contribute significantly. This analysis demonstrates that when all variables are evaluated together, the CDUS parameters serve as independent predictors compared to other clinical factors. The multivariable analysis results prove that these parameters, whether used individually or in combination, possess strong predictive power in determining malignancy risk in clinical practice.

Table 8. Multivariable logistic regression results

Variable	Odds Ratio (95% CI)	p-value
RI	3.25 (1.80 - 5.87)	<0.001
PI	2.98 (1.70 - 5.23)	<0.001
Age	1.05 (1.01 - 1.10)	0.02
Lesion Size	1.85 (1.30 - 2.62)	0.001

Multivariable logistic regression analysis showing independent predictors of malignancy. OR: odds ratio; CI: confidence interval; RI: resistive index; PI: pulsatility index

Discussion

This study aimed to comprehensively evaluate the clinical and statistical validity of resistive index (RI) and pulsatility index (PI) values, obtained from the internal mammary artery using the CDUS method, in the differential diagnosis of benign and malignant breast lesions. The results obtained show that, in terms of demographic and clinical characteristics, malignant lesions tend to occur at an older age and with larger sizes [8]. The data in Table 1 demonstrate that both age and lesion size are significantly higher in the malignant group compared to the benign group. This finding supports the frequently reported observation in the literature that breast cancer typically presents at a more advanced age and as more prominent masses. The similarity in lesion localization suggests that anatomical differences alone may not be sufficient for diagnostic differentiation, but when evaluated together with other parameters, more reliable results can be achieved [9].

The analysis of the CDUS parameters presented in Table 2 revealed that the RI and PI values are significantly higher in malignant lesions compared to benign lesions. This finding indicates an increase in intravascular blood flow resistance and pulsatile flow in malignant lesions, consistent with the vascular abnormalities observed in neoplastic tissues. The fulfillment of the normality tests (Table 3) confirms that the data are suitable for parametric tests, ensuring that the statistical comparisons, such as those obtained using the t-test and Mann-Whitney U test (Table 4), are methodologically sound [10].

The ROC analysis results (Table 5) demonstrate the high discriminatory power of the RI and PI parameters in differentiating malignancy. The AUC values of approximately 0.85 for RI and 0.88 for PI indicate that both parameters offer high diagnostic accuracy. The determined cutoff values, supported by high sensitivity and specificity rates, suggest that these parameters have the potential to be considered as alternatives to invasive methods in clinical practice [11]. A more detailed examination of the relationship between lesion type and CDUS parameters (Table 6) clearly shows that lower RI and PI values are predominant in benign lesions, whereas higher values are observed in malignant lesions. This indicates that the use of specific threshold values in clinical diagnosis could play an important role in accurately classifying lesion types [12].

Subgroup analyses based on age (Table 7) confirm that in both younger (<45 years) and older (≥45 years) groups, RI and PI values are significantly higher in malignant lesions compared to benign lesions. This finding indicates that age is an influential factor in the biology of breast lesions and that the diagnostic value of CDUS parameters is maintained across different age groups. The multivariable logistic regression analysis (Table 8) further demonstrates that, in addition to CDUS parameters, age and lesion size have independent effects on malignancy [13]. In particular, the high odds ratio values obtained for RI and PI prove that these parameters are strong predictors that can be used individually or in combination to determine the risk of malignancy [14].

The graphical analyses provide important visualization of the statistical results. The first graph clearly depicts the RI distribution in benign and malignant lesions, with a higher median and a wider interquartile range observed in the malignant group, emphasizing the increase in intravascular resistance. The second graph shows the distribution of the pulsatility index, indicating that the increased fluctuations in malignant lesions parallel the vascular irregularities observed in neoplastic tissue. The third graph presents the ROC curves, comparing the

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discriminatory power of both parameters and visually supporting the diagnostic reliability with high AUC values. Finally, the fourth graph reveals a significant positive correlation between lesion size and RI, demonstrating that an increase in lesion size may be accompanied by an increase in intravascular resistance [15].In light of all these findings, our study demonstrates that the RI and PI values obtained from the internal mammary artery using the CDUS method hold high clinical value in the differential diagnosis of benign and malignant breast lesions. The results indicate that the use of non-invasive methods in the diagnosis of breast cancer can accelerate the diagnostic process and reduce the need for invasive procedures such as biopsy. Accordingly, it is anticipated that incorporating CDUS and its related parameters into standard diagnostic protocols in clinical practice will play an important role in early diagnosis and treatment planning. The study's results provide consistent data from both clinical and methodological perspectives and indicate that further research involving larger patient groups and diverse populations is necessary to reassess the validity and reliability of these parameters. Moreover, the high sensitivity and specificity rates obtained offer promising evidence that these methods can be effectively used as a diagnostic tool in patient management. Based on our findings, CDUS demonstrates a significant potential in reducing the need for invasive diagnostic procedures in the evaluation of breast lesions, owing to its non-invasive and rapid applicability. These findings are consistent with recent studies reporting similar outcomes. Contemporary research has highlighted the diagnostic power of hemodynamic parameters obtained from the internal mammary artery (IMA) via color Doppler ultrasound in differentiating malignancy. In particular, resistive index (RI) and pulsatility index (PI) values have been shown to be significantly higher in malignant lesions across multiple studies. Chen et al. (2021) demonstrated that vascular changes in breast masses can be non-invasively and accurately detected using RI and PI [17]. In a multicenter study by Ahmed et al. (2022), PI was reported to have over 85% sensitivity in distinguishing malignant lesions [18]. Similarly, Zhang et al. (2023) found RI and PI to be significant independent predictors of malignancy, regardless of lesion size, age, or breast density [19]. Wang and Liu (2020) emphasized that the combined use of RI and PI provides greater diagnostic accuracy than their individual application [20]. In line with these contemporary findings, our study yielded high AUC values (0.85 for RI and 0.88 for PI), indicating that these Doppler parameters may serve as strong biomarkers for malignancy prediction, fully consistent with the literature.

Our results suggest that RI and PI measurements obtained from the internal mammary artery via CDUS have a meaningful impact in distinguishing malignant from benign breast lesions. Accordingly, CDUS may assist in avoiding unnecessary biopsies, given its noninvasive, repeatable, and easily applicable nature. Particularly in borderline cases, CDUS-derived vascular indices may offer valuable decision-making support to clinicians regarding further imaging or biopsy need. This not only enhances patient comfort but also supports cost-effectiveness within the healthcare system.

Limitations

One of the limitations of this study is that, although RI and PI measurements were performed by two different observers, no quantitative assessment (e.g., kappa statistic or ICC) of interobserver agreement was conducted. This limits the statistical confirmation of the repeatability of the measurements.

Conclusion

This study demonstrates that resistive and pulsatility indices obtained via color Doppler ultrasonography from the internal mammary artery provide a significant distinction between benign and malignant breast lesions. The findings suggest that CDUS, as a noninvasive and easily accessible method, may contribute meaningfully to the diagnostic process and help avoid unnecessary biopsies in certain cases.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The study was approved by the Non-Interventional Research Ethics Committee of Elazığ Fethi Sekin City Hospital (08.05.2025, approval number: 2025/9-20)

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