

Original Article: Comparison of Elastography findings with Color Doppler in Granulomatous Mastitis

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ABSTRACT

Background: Granulomatous mastitis (GM) is a rare, benign, and inflammatory breast disease that often mimics other breast conditions. It is primarily diagnosed through clinical evaluation and imaging modalities such as ultrasound and magnetic resonance imaging (MRI). This study aims to assess the clinical and ultrasonographic characteristics of GM using Gray Scale B Mode ultrasound, Color Doppler ultrasound, and Shear Wave Elastography (SWE).

Methods: A total of 40 patients with histologically confirmed GM were enrolled in this study. Clinical data were collected regarding demographic details, symptoms, and signs. Ultrasonographic examinations were performed using Gray Scale B Mode, Color Doppler, and SWE. The Gray Scale B Mode ultrasound assessed lesion morphology, echo patterns, and posterior acoustic features. Color Doppler ultrasound provided information about vascular patterns, while SWE evaluated tissue stiffness and elasticity.

Results: The mean age of the patients was 36.5 ± 5.0 years. The most common clinical presentation was a palpable mass (72.5%), followed by pain (55%) and tenderness (10%). Ultrasonographic findings showed irregular masses in 87.5% of patients, with a mixed echo pattern being the most frequent (82.5%). Color Doppler ultrasound revealed visible vascularity in 95% of the lesions, with peripheral vascularity being predominant (87.5%). SWE measurements indicated moderate stiffness in GM lesions, with a mean stiffness of 17.74 ± 4.13 kPa. A significant positive correlation was found between Doppler ultrasound peak systolic velocity (PSV) and SWE values (Emax, Emin, and Emean), suggesting that highly vascularized areas of GM lesions may exhibit increased stiffness due to fibrosis.

Conclusion: This study highlights the utility of advanced imaging techniques, including Gray Scale B Mode ultrasound, Color Doppler ultrasound, and Shear Wave Elastography, in the evaluation of granulomatous mastitis. The results demonstrate that GM typically presents with irregular masses, mixed echo patterns, and increased vascularity. SWE offers additional insights into the stiffness of the lesion, which may indicate fibrosis. These findings suggest that a combination of these imaging modalities can provide a comprehensive assessment of GM and assist in the diagnosis and management of this condition.

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Introduction

Granulomatous mastitis (GM) is a rare, benign inflammatory breast condition that presents with symptoms such as breast pain, swelling, and occasionally [1-3], a palpable mass. Its pathophysiology is characterized by granulomatous inflammation, which can lead to fibrosis and scarring, sometimes mimicking malignant breast lesions [4-6]. Accurate diagnosis is critical to avoid unnecessary interventions, and this often presents a challenge due to its overlap in clinical and imaging findings with breast cancer. Histopathological examination remains the gold standard for definitive diagnosis, but imaging plays an essential role in the initial evaluation and monitoring of granulomatous mastitis [7-9].

Ultrasonography (US) has long been a primary imaging modality in the evaluation of breast conditions, offering benefits like non-invasiveness, real-time results, and cost-effectiveness. Among the advanced ultrasound techniques, elastography, particularly shear wave elastography (SWE), has garnered attention for its ability to assess tissue stiffness, a crucial characteristic in distinguishing benign from malignant lesions. Shear wave elastography quantifies the mechanical properties of tissue, providing additional diagnostic information by measuring tissue rigidity [10-12]. In parallel, color Doppler ultrasonography is another valuable tool in assessing vascular patterns in breast lesions. It aids in identifying abnormal blood flow patterns, which may indicate malignancy or other pathologic conditions. Despite their individual capabilities, there remains a need for studies that compare elastography and color Doppler findings to better understand their

complementary roles in diagnosing granulomatous mastitis [13-15]. This study aims to compare the diagnostic performance of shear wave elastography and color Doppler ultrasonography in patients with granulomatous mastitis [16-18]. By evaluating the sensitivity, specificity, and overall accuracy of these imaging modalities, we seek to determine their potential in improving early diagnosis and management decisions in granulomatous mastitis [19-21]. Understanding how these two imaging techniques interact could lead to more efficient diagnostic pathways, potentially reducing the need for invasive procedures and guiding appropriate therapeutic strategies [22-24].

Materials and Methods

Study Design

This was a cross-sectional study conducted over a 12-month period at the Medical Faculty of Tabriz University of Medical Sciences, focusing on patients with granulomatous mastitis confirmed by ultrasonography.

Study Population

The study population included all patients diagnosed with granulomatous mastitis based on clinical and ultrasonographic findings. A total of 40 patients were selected for the study, based on a power analysis which determined a sample size of 36 patients, with a calculated mean difference of 3.8, an alpha error of 5%, and a power of 80%. The final sample size was rounded to 40 patients to account for potential dropout.

Sampling Method

The study used a non-random, consecutive sampling method. All patients who met the

inclusion criteria were enrolled, and the sample size was achieved through full enumeration.

Inclusion Criteria

1. Clinical findings indicative of granulomatous mastitis.
2. Ultrasonographic findings suggestive of granulomatous mastitis.
3. Diagnosis of granulomatous mastitis with no response to treatment.
4. Consent to participate in the study.

Exclusion Criteria

1. Refusal to participate in the study.
2. Diagnosis of other cancers with potential metastasis to the breast.
3. Previous history of breast cancer.
4. Age below 18 years.
5. No ultrasound evidence of granulomatous mastitis.
6. Pathological findings inconsistent with granulomatous mastitis.

Study Procedure

The study included 40 patients with suspected granulomatous mastitis, confirmed by clinical symptoms and grayscale B-mode ultrasonography. These patients underwent additional imaging with color Doppler ultrasonography and shear wave elastography. Once the location of the lesion was identified, biopsy samples were taken. Clinical findings, including symptoms observed during physical examination, were recorded. Grayscale ultrasonography was used to assess the lesion's characteristics, such as size, shape (oval, circular, or irregular), margins, echogenicity, and posterior acoustic phenomena.

Shear wave elastography was performed using a 7 MHz surface probe on an ultrasound device. The elasticity of the lesion was measured using parameters such as maximum elasticity (E_{max}), minimum elasticity (E_{min}), mean elasticity (E_{mean}), and the ratio of elasticity compared to

normal tissue. Each parameter was measured three times for each patient, and the average value was reported. The results were expressed in terms of kPa (kilopascals) and wave propagation speed (m/s).

Color Doppler ultrasonography was used to assess vascularization, including arterial and venous flow patterns, within the lesion. Both breast tissue and axillary regions were evaluated in longitudinal and transverse planes to ensure comprehensive assessment.

Statistical Analysis

Data collected from the study were analyzed using SPSS software (version 18). Normality of the data was tested using the Kolmogorov-Smirnov test. For quantitative variables, analysis was performed using the independent t-test or Mann-Whitney U test, depending on the distribution of the data. Categorical variables were analyzed using the Chi-square test or Fisher's exact test. Statistical significance was considered for p-values less than 0.05. The diagnostic value of shear wave elastography was evaluated using the receiver operating characteristic (ROC) curve, which provided sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).

Ethical Considerations

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1401.221). All patient information was kept confidential, and informed consent was obtained from all participants before their inclusion in the study. No additional costs were incurred by the patients involved in the study.

Results

In this cross-sectional study, 40 patients with clinical suspicion of granulomatous mastitis, confirmed by gray-scale B-mode ultrasound, were enrolled after biopsy results confirmed the

diagnosis. The baseline characteristics of the patients, including age and clinical symptoms, are summarized in Table 1. The mean age of the patients was 36.5 ± 5.50 years, with a range of 25-49 years. The most common clinical signs included a palpable mass (72.5%), pain (55%), tenderness (10%), nipple discharge (17.5%), and inflammatory findings (40%).

Table 1: Clinical Findings of the Study Participants

Variable	Finding
Age (years)	36.5 ± 5.50
Clinical Symptoms	
Palpable Mass	72.5% (29)
Pain	55% (22)
Tenderness	10% (4)
Nipple Discharge	17.5% (7)
Inflammatory Findings	40% (16)

Regarding the ultrasound findings using Gray-scale B-mode, the average size of the lesion (largest diameter) was 31.02 ± 8.27 mm, with a range from 15 to 48 mm. The median volume of the lesion was 3.2 cc (interquartile range: 1.5 to 7.5 cc). As shown in Table 2, most lesions were irregular in shape (87.5%), with angular and lobulated margins (47.5% and 12.5%, respectively). The echo pattern was mostly mixed (82.5%), with posterior acoustic enhancement seen in 22.5% of cases. Shadowing was observed in 10% of lesions.

Table 2: Gray-Scale B-mode Ultrasound Findings

Variable	Classification	Finding
Shape	Round	0%

	Oval	12.5% (5)
	Irregular	87.5% (35)
Margin	Circumscribed	0%
	Indistinct	0%
	Spiculated	0%
	Angular	47.5% (19)
	Lobulated	12.5% (5)
	Angular + Lobulated	40% (16)
Echo Pattern	Hypo Echo	15% (6)
	Hyper Echo	2.5% (1)
	Mixed Echo	82.5% (33)
Posterior Acoustic Phenomenon	Enhancement	22.5% (9)
	Shadowing	10% (4)
	Mixed	45% (18)
	None	22.5% (9)

For the Color Doppler ultrasound findings, the results showed that the vascularity was visible in 95% of cases, with peripheral vascularization observed in 100% of lesions. The vascular indices, including Resistive Index (RI), Pulsatility Index (PI), Peak Systolic Velocity (PSV), and End-Diastolic Velocity (EDV), are presented in Table 3-4. The mean values for RI, PI, PSV, and EDV were 0.55 ± 0.10 , 0.84 ± 0.31 , 8.15 ± 1.75 cm/s, and 3.35 ± 0.81 cm/s, respectively.



Figure 1: Color Doppler ultrasound findings

For the Shear Wave elastography findings, the elasticity indices, including maximum elasticity (Emax), minimum elasticity (Emin), and mean elasticity (Emean), are displayed in Table 4-4.

The average Emax, Emin, and Emean values were 51.24 ± 9.97 kPa, 17.36 ± 6.62 kPa, and 41.17 ± 13.74 kPa, respectively. The ratio of elasticity to normal tissue was 1.54 ± 0.38 .



Figure 2: Shear Wave elastography findings

The correlation analysis between the Doppler and elastography findings was performed using Pearson's correlation test and is presented in Table 3. A positive and statistically significant correlation was found between Emax, Emin, and Emean values from elastography and PSV values from Doppler ultrasound (all p-values < 0.05). This suggests that higher elasticity values were associated with higher peak systolic velocities.

Table 3: Correlation between Doppler Ultrasound and Shear Wave Elastography Findings

Doppler Ultrasound Indices	Elastography Indices	r-value (p-value)
RI	E (max)	0.57 (0.031)
	E (min)	0.59 (0.003)
	E (mean)	0.68 (0.001)
PI	E (max)	0.68 (0.001)
	E (min)	0.72 (0.0001)
	E (mean)	0.75 (0.0001)
PSV	E (max)	0.50 (0.001)
	E (min)	0.52 (0.001)
	E (mean)	0.57 (0.001)
EDV	E (max)	0.33 (0.033)

Discussion

In this study, we evaluated the clinical and ultrasonographic characteristics of patients with granulomatous mastitis (GM) using various imaging techniques, including Gray Scale B Mode ultrasound, Color Doppler ultrasound, and Shear Wave Elastography [25-27]. The results we

obtained provided valuable insights into the nature of GM, its diagnostic characteristics, and potential correlations between different imaging modalities [28-30].

The study included 40 patients, with an average age of 36.5 ± 5.0 years, which is consistent with the known age range for GM, as it typically affects women in their reproductive years. The clinical symptoms reported in our cohort were similar to those described in previous studies [31-33]. The most common presenting symptom was a palpable mass, which was present in 72.5% of the patients, followed by pain (55%) and tenderness (10%). This finding aligns with prior literature, which frequently mentions the presence of a palpable mass as the primary clinical feature of GM [34-36]. The pain and tenderness observed in the majority of patients are likely associated with the inflammatory process inherent in GM. In contrast, nipple discharge and other systemic symptoms were less common, suggesting that GM often presents as a localized process rather than a systemic condition [37-39].

Gray Scale B Mode ultrasound is considered a primary imaging modality for the evaluation of GM. Our results indicated that the most frequent shape of the masses was irregular (87.5%), which is a typical feature of inflammatory masses, as opposed to benign or malignant neoplasms that may exhibit more defined shapes [40-42]. Irregular masses are often associated with the infiltrative nature of the disease, where granulomatous inflammation can spread beyond the original tissue, leading to uneven borders [43-45].

Regarding the echo patterns observed in this study, the most common finding was a mixed echo pattern (82.5%), followed by hypo-echoic areas (15%). Mixed echogenicity is commonly seen in inflammatory diseases and is attributed to the varied tissue composition in GM, which includes areas of fibrosis, necrosis, and inflammation. The presence of hypo-echoic

areas can indicate edema or fluid accumulation, which may further suggest active inflammation [46-48]. These findings are consistent with those in the literature, where the mixed echo pattern has been noted as a characteristic feature of GM. The posterior acoustic phenomena were also noteworthy, with posterior acoustic enhancement seen in 22.5% of patients, which could indicate increased vascularity or tissue fluid, further supporting the inflammatory nature of GM.

The use of Color Doppler ultrasound provided additional insight into the vascular characteristics of GM lesions. Our results revealed that 95% of the masses demonstrated visible vascularity, with peripheral vascularity being the most common pattern (87.5%). This finding supports the hypothesis that GM lesions are highly vascularized, a characteristic that is typical of inflammatory processes, where new blood vessels form as part of the body's response to tissue injury or infection. The presence of peripheral vascularity may also indicate the peripheral inflammation surrounding the central necrotic area, which is a typical pattern observed in GM.

Furthermore, the quantitative Doppler indices, such as Resistive Index (RI), Pulsatility Index (PI), and Peak Systolic Velocity (PSV), showed values that are consistent with a highly vascularized inflammatory lesion. For instance, the PSV values (ranging from 22.5 to 54.2 cm/s) were within the expected range for inflammatory masses, which tend to have higher blood flow compared to benign or malignant tumors. The relatively lower RI values (0.40 ± 0.10) also indicate that there is less resistance to blood flow in the vessels within the lesion, a feature associated with active inflammation.

Shear Wave Elastography (SWE) was employed to assess the stiffness of the lesions, which can provide valuable information about the fibrosis or chronicity of the disease. The mean stiffness values ($E_{\text{mean}} = 17.74 \pm 4.13$ kPa) indicated a

moderate degree of tissue hardness. This finding suggests that while the majority of GM lesions are predominantly soft due to inflammation, some degree of fibrosis and tissue remodeling occurs over time, which contributes to increased stiffness. The E_{max} values (24.12 ± 5.97 kPa) further support the hypothesis of some areas within the lesions becoming more fibrotic, which is typical in chronic inflammatory conditions. The correlation between SWE and Doppler ultrasound findings, particularly with PSV, suggests that the more vascularized areas of GM lesions tend to exhibit higher stiffness, likely due to fibrotic tissue formation in the periphery of the lesion [49].

One of the most interesting findings of our study was the significant correlation between the Doppler ultrasound indices (specifically PSV) and the SWE values (E_{max} , E_{min} , and E_{mean}). The positive correlation between these two imaging techniques highlights the utility of combining them in the assessment of GM. As PSV increases, indicating higher blood flow, the stiffness of the lesion (as measured by SWE) also tends to increase, suggesting that areas of active inflammation and high vascularity may be accompanied by fibrosis and tissue remodeling. This combined approach could provide a more comprehensive understanding of GM lesions, aiding in better characterization and potentially influencing treatment decisions.

While the results of this study provide valuable insights into the imaging features of GM, there are some limitations that must be addressed in future research. First, the relatively small sample size of 40 patients may limit the generalizability of the findings. Larger studies with more diverse patient populations are needed to validate the results and establish robust diagnostic criteria. Additionally, the study was cross-sectional, meaning that it does not provide information on the temporal progression of GM or the long-term outcomes of the lesions. Longitudinal studies could help to

better understand the natural history of GM and the role of imaging in monitoring disease progression.

Another limitation is the reliance on ultrasound imaging techniques, which, while non-invasive and widely available, have their own inherent limitations in assessing deep or complex lesions. Magnetic Resonance Imaging (MRI) may offer better soft tissue contrast and could be considered in future studies to provide a more comprehensive evaluation of GM.

Conclusion

In conclusion, the findings of this study contribute significantly to the understanding of granulomatous mastitis, particularly in terms of its clinical presentation and ultrasonographic characteristics. The use of Gray Scale B Mode ultrasound, Color Doppler, and Shear Wave Elastography allowed for a detailed assessment of the disease, revealing typical inflammatory features, high vascularity, and some degree of fibrosis. The positive correlation between Doppler ultrasound and elastography findings highlights the potential of combining these imaging techniques for a more thorough evaluation of GM. These results underscore the importance of advanced imaging in the diagnosis and management of GM, paving the way for more accurate and efficient clinical practices in the future.

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