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Quantitative Relationship Between Breast Parenchymal Stiffness on Shear-Wave Elastography and Computed Tomography Attenuation: A Single-Center Observational Study

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ABSTRACT

Objective: Breast density reflects fibroglandular tissue composition and affects imaging interpretation and cancer risk. Ultrasound (US) shear-wave elastography (SWE) offers a quantitative method for assessing tissue stiffness. This study aimed to investigate the correlation between breast parenchymal stiffness values measured by SWE and attenuation values obtained from computed tomography (CT).

Materials and Methods: Fifty-four female patients who underwent both breast SWE and chest CT were evaluated. SWE stiffness (kilopascal, kPa) and CT attenuation (Hounsfield Units [HU]) were measured from corresponding parenchymal regions. Correlations were analyzed using Pearson's and Spearman's coefficients, and linear regression analysis was performed.

Results: The mean CT attenuation was −24.8±30.1 HU, and the mean SWE stiffness was 11.7±3.1 kPa. SWE stiffness progressively increased with higher breast parenchymal types according to the Breast Imaging Reporting and Data System classification. CT attenuation and SWE stiffness values demonstrated a strong positive correlation (r=0.91, p<0.001).

Conclusion: SWE stiffness values strongly correlate with CT attenuation and may serve as a radiation-free surrogate marker for quantitative assessment of breast parenchymal density.

Keywords: Breast density, Breast imaging reporting and data system, Computed tomography, Parenchymal pattern, Shear wave elastography, Stiffness

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INTRODUCTION

Breast tissue composition is highly variable among individuals and is largely determined by the relative proportions of fibroglandular and fatty components. This heterogeneity influences not only breast imaging appearance but also disease risk and diagnostic performance across modalities.[1,2] Breast density, as defined by the Breast Imaging Reporting and Data System (BI-RADS), is an established imaging biomarker associated with both masking effects on mammography and an increased risk of breast cancer.[3,4] Dense parenchyma, which

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contains higher fibroglandular tissue content, exhibits increased attenuation on computed tomography (CT) and greater stiffness on ultrasound (US)-based elastography.[5,6]

Quantitative assessment of tissue stiffness has become feasible with the advent of US shear-wave elastography (SWE), which provides real-time, reproducible measurements of mechanical properties in kilopascals (kPa). SWE has been increasingly applied in breast imaging for lesion characterization, differential diagnosis, and evaluation of parenchymal background.[7-9] Previous studies have demonstrated that SWE values correlate with histologic composition and mammographic density, supporting its role as a surrogate marker of breast microstructure.[10,11]

Although both CT and SWE offer quantitative insights into tissue composition, few studies have directly compared the relationship between CT attenuation (in Hounsfield Units, HU) and SWE stiffness values in normal breast parenchyma. Understanding this relationship may help validate SWE as a radiation-free alternative for quantitative evaluation of breast density and microstructural properties.[12,13]

Therefore, the aim of this study was to investigate the correlation between CT attenuation values and SWE stiffness measurements of the breast parenchyma in female patients, and to assess whether elastography-derived stiffness reflects tissue density as measured by CT.

MATERIALS AND METHODS

Ethics, Study Design, and Population

Ethical approval had been obtained from the institutional review board before data collection, and all procedures were performed in accordance with the Declaration of Helsinki. The study was carried out with the approval and permission of the Academic Board and Ethics Committee of İstanbul Nişantaşı University (date: 14.06.2023, decision No: 2023/24).

The study was conducted at the Radiology Department of BHT Clinic İstanbul Tema Hospital, between July 2023 and October 2025. Among patients referred for breast ultrasonography, those who had undergone chest CT within the previous month for any other clinical indication were selected. During the breast US examination, SWE was additionally performed without imposing any extra physical or financial burden on the patients or the institution. The regions where stiffness measurements were obtained were noted and schematically marked. Subsequently, the patients' chest CT images and US elastography (image and worksheet) findings were evaluated through the imaging archive.

Inclusion criteria were as follows: Patients aged between 20 and 80 years, and cases in which the location of the elastography measurement could be confidently matched with the corresponding region on the chest CT images.

Exclusion criteria were a history of breast surgery, radiation therapy, or any known breast malignancy.

US Features and Examination Protocol

US examinations were performed using a General Electric (GE) LOGIQ S8 (2019) system equipped with a 9 MHz linear transducer and integrated elastography software.

Breast parenchymal patterns were categorized according to sonographic appearance, corresponding to BI-RADS-like density types (A–D), based on the relative proportion of fibroglandular to fatty tissue observed during US evaluation.

SWE measurements were obtained in the upper outer quadrant of the breast, avoiding ducts and focal lesions. For each patient, three valid stiffness measurements (in kPa) were obtained from the same parenchymal area, and the mean value was used for analysis. The acquisition depth ranged between 10 and 30 mm (Fig. 1), and all examinations were performed by a radiologist with 10 years of breast imaging experience.

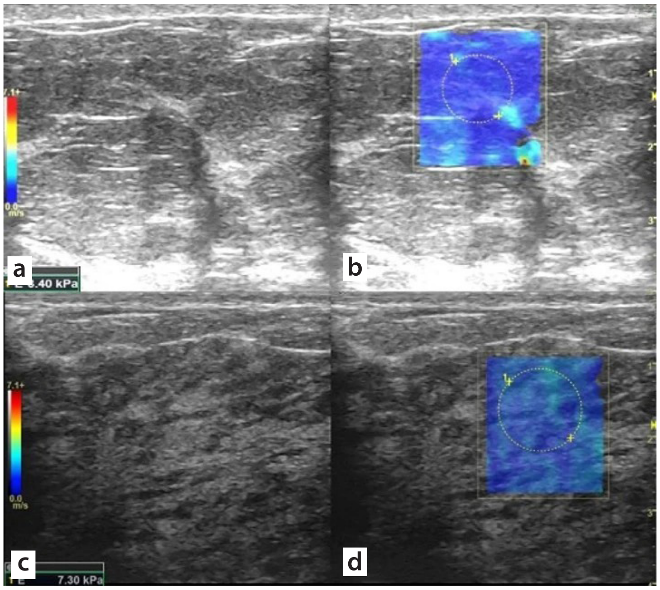

Figure 1. Representative images from two of our cases. The upper images **(a and b)** belong to a 55-year-old female patient and demonstrate the measurement obtained from the fatty parenchymal area. Grayscale ultrasonography image **(a)** and shear-wave elastography (SWE) image **(b)** are shown. In the SWE image **(b)**, the region of interest (ROI) used for stiffness measurement is marked, and the measurement was performed from the upper outer quadrant of the breast. The lower images **(c and d)** belong to a 33-year-old female patient and similarly show the grayscale US image **(c)** and the SWE image **(d)**. In the SWE image **(d)**, the ROI used for stiffness measurement is marked, and the measurement was also performed from the upper outer quadrant of the breast. The quantitative stiffness value in kilopascals (kPa) is displayed in the lower left corner of the images.

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CT Acquisition and Attenuation Measurement

All CT examinations were performed on a GE Revolution GSI 256-detector Multislice CT scanner (GE Healthcare, Waukesha, WI, USA). Non-contrast axial images covering the breast parenchyma were analyzed. CT attenuation (HU) measurements for all cases were obtained from the hospital's Digital Imaging and Communications in Medicine Picture Archiving and Communication Systems archive. Using a circular region of interest (ROI) of approximately 1 cm^2 (Fig. 2), attenuation values were recorded in HUs at the corresponding SWE measurement sites, avoiding visible ducts, vessels, or artifacts. Each measurement was repeated three times and averaged for consistency.

Data Analysis and Statistical Methods

US SWE stiffness and CT HU value measurements were obtained from parenchymal regions that corresponded as closely as possible, ensuring maximal anatomical consistency between the two modalities. For each patient, both SWE kPa and CT attenuation values were derived from nearly identical parenchymal sites to achieve optimal comparability across imaging techniques. Both US SWE (kPa) and CT attenuation (HU) measurements were obtained from circular ROIs of approximately 1 cm^2 (100 mm^2).

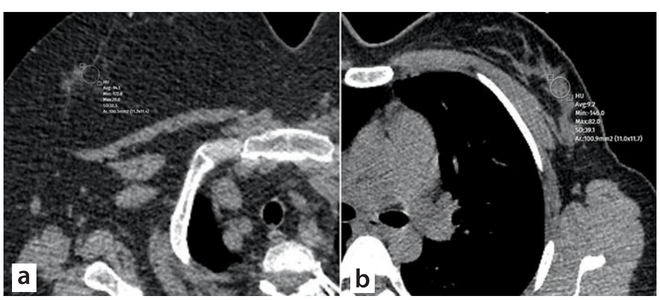

Figure 2. Representative axial chest computed tomography (CT) images demonstrating CT attenuation (hounsfield unit) measurements. These images show the location and technique of attenuation measurement corresponding to the regions where ultrasonographic imaging and stiffness assessment were performed in the same patients. The measurements were obtained from the parenchymal areas within the regions of interest, indicated by thin white circles. The image on the left **(a)** belongs to a 57-year-old female patient, with the measurement obtained from the upper outer quadrant of the right breast, while the image on the right **(b)** belongs to a 42-year-old female patient, with the measurement obtained from the upper outer quadrant of the left breast.

Statistical analyses were performed using the Statistical Package for the Social Sciences version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean±standard deviation, and categorical variables as numbers and percentages. Normality was evaluated using the Shapiro–Wilk test. The correlation between CT attenuation (HU) and SWE stiffness (kPa) was assessed using both Pearson's and Spearman's correlation coefficients. A simple linear regression model was used to determine the relationship between HU and SWE values. Statistical significance was set at $p<0.05$.

RESULTS

A total of 54 female patients with a mean age of 42.4±11.0 years (range, 20–78 years) were included in the analysis. Of these, 36 (66.7%) were premenopausal and 18 (33.3%) were postmenopausal. According to the BI-RADS breast density classification, 10 patients (18.5%) were type A, 19 (35.2%) type B, 16 (29.6%) type C, and 9 (16.7%) type D (Table 1).

The mean CT attenuation value of breast parenchyma was −24.8±30.1 HU, whereas the mean SWE stiffness was 11.7±3.1 kPa. SWE stiffness values gradually increased with higher BI-RADS density categories. The mean stiffness values were 7.5±1.6 kPa in type A, 10.4±1.8 kPa in type B, 13.2±2.0 kPa in type C, and 15.6±2.1 kPa in type D parenchyma, demonstrating a stepwise pattern of increasing tissue stiffness with increasing CT attenuation ($p<0.001$) (Table 1).

A strong, positive correlation was observed between CT attenuation and SWE stiffness (Pearson $r=0.91$, Spearman $\rho=0.92$, both $p<0.001$) (Table 2 and Fig. 3). The linear regression model showed that CT density significantly predicted SWE stiffness ($\beta=0.10\pm0.01$, 95% CI=0.08–0.12, $p<0.001$). The regression equation was defined as:

$$\text{SWE (kPa)}=4.0+0.10\times(\text{CT HU}+100)$$

Indicating that for every 10 HU increase in CT density, the SWE stiffness increased by approximately 1 kPa.

DISCUSSION

In this study, a significant positive correlation was observed between breast parenchymal stiffness values measured by SWE and attenuation values obtained from CT. These findings suggest that SWE-derived stiffness is closely related to tissue composition and density, as represented by HU values on CT. Similar relationships between SWE stiffness and parenchymal density have been reported in previous studies evaluating quantitative elastography in breast tissue.[14,15]

Previous investigations demonstrated that dense breast tissue, containing a higher proportion of fibroglandular elements, exhibits both higher stiffness values on elastography and higher attenuation on CT compared with fatty tissue.[6,16]

Table 1. Demographic and imaging characteristics of the study population (n=54)

Variable	Category / Range	n (%) or Mean±SD
Age (years)	20–78	42.4±11.0
Menopausal status		
Premenopausal	36 (66.7%)	
Postmenopausal	18 (33.3%)	
BI-RADS category		
A (Homogeneously hypoechoic parenchyma with predominantly fatty tissue)	10 (18.5%)	
B (Hypoechoic background with scattered linear or patchy hyperechoic fibroglandular areas)	19 (35.2%)	
C (Irregular or heterogeneous echotexture with multiple hyperechoic fibroglandular areas)	16 (29.6%)	
D (Diffusely hyperechoic parenchyma with minimal fatty areas)	9 (16.7%)	
CT attenuation (HU)	−100 to +45	−24.8±30.1
SWE stiffness (kPa)	3.8–17.9	11.7±3.1
Side of measurement	Right / Left	25 (46.3%) / 29 (53.7%)
Depth of measurement (mm)	10–30	19.8±4.7

BI-RADS: Breast Imaging Reporting and Data System; CT: Computed Tomography; HU: Hounsfield Unit; kPa: kilopascal; mm: millimeter; SD: Standard deviation; SWE: Shear-Wave Elastography.

Table 2. Correlation and linear regression analysis between CT HU and SWE kPa

Variable	Pearson r	Spearman ρ	p	Linear regression (β±SE)	95% CI for β	p
CT attenuation (HU)	0.91	0.92	<0.001	0.10±0.01	0.08 – 0.12	<0.001

β: Standardized regression coefficient; CI: Confidence interval; HU: Hounsfield Unit; kPa: kilopascal; p: Probability value; r: Pearson correlation coefficient; ρ: Spearman rank correlation coefficient; SE: Standard error; SWE: Shear-Wave Elastography.

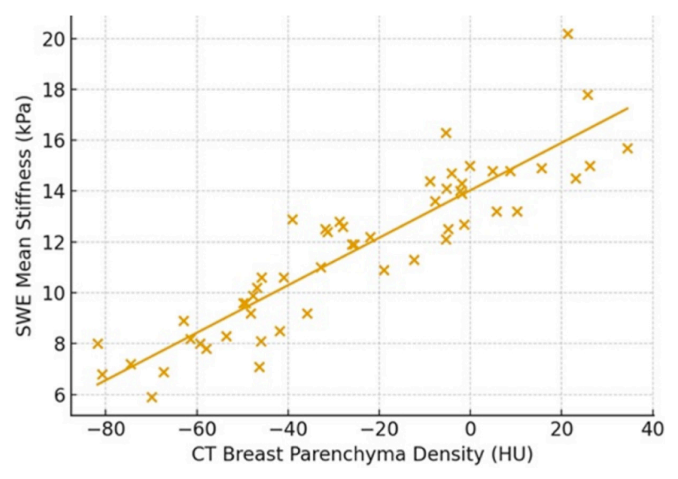

Figure 3. Correlation between computed tomography hounsfield unit and shear-wave elastography stiffness (kPa) in breast parenchyma. Scatter plot illustrating the positive relationship between the two parameters.

Our results are consistent with those reports, demonstrating a stepwise increase in stiffness across BI-RADS density categories, from type A (predominantly fatty) to type D (extremely dense) parenchyma. This relationship supports the physiologic link between tissue microstructure and its mechanical and radiological properties.[5]

Several authors have highlighted the diagnostic value and reproducibility of SWE in breast imaging.[8,9] The strong correlation (r=0.91) observed in our study suggests that SWE stiffness can serve as a reliable quantitative biomarker reflecting breast density and fibroglandular composition. Because both HU and SWE respond to tissue composition, SWE may provide a non-ionizing, reproducible alternative for estimating parenchymal density in women who require frequent imaging follow-up.[10]

The potential integration of SWE into breast density assessment is also noteworthy. Mammographic density has been recognized as an independent risk factor for breast cancer, and SWE could complement mammographic evaluation by providing addition-al biomechanical information.[4,17] Combining SWE findings with CT or magnetic resonance imaging-based metrics could enhance personalized risk stratification and screening protocols.[18]

The limitations of this study include its modest sample size and single-center setting. Another limitation is that, since the measurements were obtained using different imaging modalities, an exact millimeter-to-millimeter overlap of the measurement locations could not be achieved. Furthermore, although the time interval between CT and US examinations did not exceed one month, variations in breast parenchymal composition – particularly in women of reproductive age – may have influenced the results. In addition, stiffness and attenuation values may vary depending on differences in imaging systems or acquisition parameters. Nevertheless, the strong correlation observed between the measurements supports the reliability of the findings. Future multicenter studies incorporating histopathological correlation are warranted to validate these results and to further clarify their clinical implications.[19,20]

CONCLUSION

This study demonstrated a strong, positive correlation between breast parenchymal stiffness measured by SWE and attenuation values obtained from CT. The results indicate that elastography-derived stiffness reliably reflects tissue density and composition, supporting its potential role as a radiation-free surrogate for quantitative assessment of breast parenchymal characteristics. Integration of SWE into breast imaging protocols may improve evaluation of parenchymal density and contribute to more personalized diagnostic and screening strategies. Further prospective, large-scale studies are warranted to validate these findings and explore their clinical implications.

DECLARATIONS

Ethics Committee Approval: The study was approved by İstanbul Nişantaşı University Ethics Committee (No: 2023/24 Date: 14/06/2023).

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Conflict of Interest: The authors declare that there is no conflict of interest.

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