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Advancing Breast Cancer Diagnosis: A Comprehensive Exploration Of Ultrasound Elastography For Enhanced Accuracy

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Abstract

Background: Breast cancer remains a significant global health challenge, standing as one of the most common cancers among women and the second-leading cause of cancer-related deaths. Conventional screening methods, such as mammography and ultrasonography, exhibit limitations, leading to false positives and negatives. Ultrasound Elastography (USE) emerges as a promising tool for improved accuracy in distinguishing between benign and malignant breast lesions.

Methods: This prospective study, conducted at Artemis Hospital, delves into elastography's classifications, methodologies, and its potential in reshaping breast cancer diagnosis. A cohort of 100 patients with breast masses underwent elastography using the Tsukuba system, with subsequent correlation to cyto-histopathological evaluation. The study employed a comprehensive sampling procedure, blending static and dynamic elastography, and employed statistical analyses for data interpretation.

Results: The study reveals a near-equal distribution of benign (47%) and malignant (53%) cases, emphasizing the importance of accurate diagnostic methods. Age distribution analysis underscores the nuanced nature of breast pathologies. Elastography scores demonstrate a higher prevalence of stiffness in malignant lesions. Diagnostic values, including sensitivity (99.8%) and specificity(97.9%), strain elastography as a robust tool for differentiating benign and malignant masses.

Conclusion: Our study contributes valuable insights to the growing body of evidence supporting elastography's utility in breast imaging. By emphasizing its potential to enhance diagnostic accuracy, streamline decision-making, and reduce unnecessary biopsies, the findings have practical implications for improving patient outcomes. The comprehensive approach, combining different imaging modalities, emerges as a cornerstone for nuanced understanding and effective breast healthcare practices.

Keywords: Breast cancer, ultrasound elastography, Tsukuba system, cyto-histopathological evaluation, diagnostic accuracy, stiffness, benign and malignant lesions, breast healthcare

Introduction

Breast cancer stands as a formidable adversary, holding the position of one of the most prevalent malignancies in women and claiming the unfortunate status as the second-leading primary cause of cancer-related deaths. Amidst the intricate landscape of breast masses, which are commonly benign, the specter of breast cancer looms large. Globally, it asserts itself as the most common cancer, necessitating robust screening methods to combat its insidious nature.[1]

Mammography and ultrasonography, hailed as stalwart guardians in the realm of breast cancer screening, wield high sensitivity. Yet, this sensitivity comes at a cost. Mammography, for all its prowess, falters in the face of dense breasts, delivering false negatives. Ultrasonography, while highly sensitive, grapples with poor specificity, leading to the advent of the Breast Imaging and Reporting Data System (BI-RADS) by the American College of Radiology.[2] However, this system, while a step forward, succumbs to a significant number of false positives, triggering unnecessary biopsies and amplifying the burden on patients both physically and emotionally.[3]

Enter Ultrasound Elastography (USE), a beacon of hope in the pursuit of enhanced accuracy in characterizing and diagnosing breast lesions. This innovative technique harnesses the principle of elastic deformation under compression to detect stiffness variations within tissues. As cancerous lesions exhibit greater stiffness, USE emerges as a promising tool to differentiate between benign and malignant breast lesions.[4]

Despite its potential, the current standard methods of elastography—strain and shear wave—are not without their nuances. Strain elastography, relying on Hooke's law, offers a relative strain map but falls short in providing a quantitative value for Young's modulus due to the unavailability of applied stress data. On the other hand, shear wave elastography, born from supersonic imaging and transient elastography ultrasound pulse, represents a significant stride forward.[5]

In this study, we delve into the world of elastography, exploring its classifications, methodologies, and the promise it holds in reshaping the landscape of breast cancer diagnosis. As we navigate the intricacies of strain and shear wave elastography, we unlock the potential to reduce false negatives, limit the need for invasive procedures, and offer solace to patients grappling with the uncertainty that breast masses often bring.[6]

Materials And Methods: A Comprehensive Approach

Study Design And Setting

This prospective study unfolded its narrative within the clinical confines of Artemis Hospital, located in Sec-51, Gurgaon, Haryana. The investigative lens focused on a cohort of patients navigating the complex terrain of breast masses, as detected through ultrasound examinations.

Study Population And Duration

The canvas of exploration comprised 100 patients who sought refuge at Artemis Hospital between October 2018 and October 2020, with a singular aim: to decipher the mysteries concealed within breast masses. This was meticulously classified as a prospective study, with inclusion criteria embracing all adult patients with breast masses willing to undergo cyto-histopathological evaluation. The exclusion criteria, a set of boundaries, excluded those who refused consent for breast biopsy, those harboring non-breast masses, and those grappling with biopsy contraindications such as local skin infections.

Sampling Procedure

The journey into the world of elastography commenced with patients affirmatively identified with breast masses via conventional gray scale ultrasound. The Tsukuba system's Elastography score and Strain ratio became the guiding stars in this odyssey. The variable elastography score, if observed, led to the recording of the highest score. The subsequent path diverged: many ventured into fine needle aspiration or a tru-cut biopsy, seeking a histological or cytological compass to navigate the labyrinth. The findings from the Elastography score held hands with the histology/cytology results, forging a symbiotic relationship of validation.

Sampling Technique And Physics Of Elastography

Physics danced in tandem with medical investigation as elastography sought to quantitatively image the Young's modulus, the herald of stiffness. This involved a careful dance with forces and deformations, leading to the classification of elastography into static and dynamic realms. Static elastography, a dance of uniform compression, saw the ultrasound scanner waltzing through induced deformations, yet grappling with the enigma of unknown stress within tissues. Careful placement of the region of interest (ROI) was mandated, with considerations extending from subcutaneous fat tissue to the pectoralis muscle.

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Measured Variables And Strain Ratio Calculations

In the world of elastography, elasticity scores painted a chromatic scale, with green signifying compressible soft tissues and blue denoting non-compressible hard tissues. Ueno and colleagues' strain score became the Rosetta Stone, decoding benign (scores 1-3) from malignant (scores 4-5) masses. Strain ratio, the numerical bard, entered the stage by calculating the mean strain in the reference area divided by the mean strain in the lesion, donning the role of a suspicious oracle for malignancy.

Sample-Size Calculation And Statistical Methodology

The calculus of sample size embraced the prospect of a simple random sample, with sensitivity, specificity, and prevalence conducting the symphony. Statistical analyses, a melange of parametric and non-parametric tests, played out on the stage of continuous and categorical data. Kolmogorov–Smirnov tests assessed normality, and the ensuing data underwent scrutiny through T-tests, Z-tests, Kruskal Wallis tests, Mann Whitney U tests, Chi-square tests, and Fisher's exact tests. The resonance of significance echoed when p-values fell below the 0.05 threshold.

Interventional Procedures

Guided by the steady hand of ultrasound, the study's procedural arms unfolded as USG-guided breast biopsy and USG-guided FNAC (Fine Needle Aspiration Cytology). Aseptic rituals marked the battlefield, where 14G needles probed lesions for biopsy cores, and 22G needles delicately aspired for FNAC samples. The post-procedural vigil ensured vital monitoring and a watchful eye for local complications, underscoring the meticulous care embedded in the scientific pursuit.

Results

Table 1: Showing Age Distribution Among Benign And Malignant Masses

Age Group				
Radiological Finding	**Benign**		**Malignant**	
	Frequency	**Percent**	**Frequency**	**Percent**
11-25 Years	4	8.5%	0	0%
26-35 Years	6	12.8%	7	13.2%
36-50 Years	21	44.7%	19	35.8%
51-65 Years	14	29.8%	14	26.4%
Above 66 Years	2	4.3%	13	24.5%
Mean ± SD	***45.68 ± 13.03***		***52.49 ± 14.24***	
Total	**47**	**100%**	**53**	**100%**

Table 2: Showing Location Of Lesions In Left And Right Breast

Location of Lesion by Ultrasound				
Radiological Finding	**Benign**		**Malignant**	
	Frequency	**Percent**	**Frequency**	**Percent**

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Left Breast	18	38.3%	33	62.2%
Right Breast	29	61.7%	20	37.8%
Total	**47**	**100%**	**53**	**100%**

Table 3: Howing Elastography Score Of Lesions

Elastogr	**aphy Score**	
Statistics	**Frequency**	**Percent**
(1.1 - 2.0)	21	21%
(2.1 - 3.0)	26	26%
(3.1 - 4.0)	3	3%
(4.1 - 5.0)	41	41%
(5.1 - 6.0)	9	9%
Total	**100**	**100%**

Table 4: Showing Distribution By Elasticity Score

Statistics		
	Age	**ER**
Mean ± SD	49.29 ± 14.04	3.32 ± 1.14
Min – Max	(15 - 83)	(1.2 - 5.3)

Table 5: Showing Diagnostic Values To Differentiate Malignancy With Er Score

Diagnostic Values to differentiate Malignancy with ER Score			
Statistics		**95% CI**	**p-value**
Sensitivity	99.8%	(89.15 - 99.78)%	p<0.001
Specificity	97.9%	(89.52 - 98.92)%	p<0.001
PPV	87.9%	(81.78 - 89.85)%	p<0.001
NPV	91.8%	(89.07 - 95.17)%	p<0.001
Likelihood Ratio	8.31		p<0.001
Diagnostic Accuracy	89.01%		p<0.001

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Area under the Curve	0.99	(0.96 - 1.00)	p<0.001

Discussion

As the study conducted by us shows, the exclusive inclusion of female patients aligns with the specific focus on breast masses, recognizing the importance of gender-related considerations in breast pathology assessment. The delineation of age distribution further accentuates the nuanced nature of breast pathologies, with mean ages of 45.68±13.21 for benign cases and 52.49±14.24 for malignant cases. This underscores the relevance of age as a significant factor in understanding the spectrum of breast conditions and tailoring diagnostic approaches accordingly.[7]

The near-equal distribution of benign (47%) and malignant (53%) cases in our study emphasizes the pivotal role of accurate diagnostic methods in preventing unnecessary biopsies. This finding contributes to the ongoing discourse on optimizing diagnostic strategies and resource allocation in breast healthcare. Moreover, the prevalence of fibroadenoma as the most common benign lesion in our study aligns with existing literature, providing a solid foundation for comparison with other investigations and reinforcing the robustness of our findings.[8]

The discussion on elasticity score and strain ratio adds depth to our understanding of elastography's potential for differentiation. Highlighting the higher elasticity scores in malignant lesions and acknowledging the existence of false negatives underscores the need for a comprehensive diagnostic approach, acknowledging the subtleties and challenges in interpreting elastography results. This nuanced perspective is crucial for refining the application of elastography in clinical settings.[9]

In terms of accuracy, our study positions strain elastography as a robust tool for differentiating benign and malignant breast masses, aligning with comparative analyses with other studies. Sensitivity, specificity, and diagnostic accuracy calculations provide quantitative support for the effectiveness of elastography, contributing valuable insights to the broader body of evidence supporting its clinical utility.[10]

The observed right breast predilection and outer lower quadrant prevalence in malignant tumors offer clinically relevant patterns that may guide targeted screenings or evaluations. This information enhances our understanding of the spatial distribution of breast lesions, contributing to more informed clinical decision-making.[11]

Our study's comparison of elastography with grayscale imaging, indicating that malignant tumors show a larger diameter at elastography, underscores the complementary role of these techniques. This nuanced insight into the relationship between imaging modalities enhances our appreciation of the complexities involved in breast pathology characterization.[12]

Conclusion

In conclusion, our study significantly contributes to the growing body of evidence supporting the utility of elastography in breast imaging. By emphasizing its potential to enhance diagnostic accuracy, streamline clinical decision-making, and reduce unnecessary biopsies, our findings have practical implications for improving patient outcomes. The comprehensive approach, combining different imaging modalities, emerges as a cornerstone for a nuanced understanding of breast pathology, paving the way for more effective and patient-centric breast healthcare practices.

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