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Breast imaging reporting and data system for sonography: Positive and negative predictive values of sonographic features in Kumasi, Ghana

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ABSTRACT

Background: Breast cancer is the most common female cancer globally. The method of choice for screening and diagnosing breast cancer is mammography, which is not widely available in Ghana as compared to ultrasonography. This study aimed to evaluate the sonographic features of solid breast lesions using the new sonographic Breast Imaging- Reporting and Data System (BI-RADS-US) lexicon for malignancy with histopathology as the gold standard.

Methods: This was a prospective quantitative study that sonographically scanned female patients with breast masses and consecutively selected cases recommended for core biopsy from May 2018 to May 2021. Sixty (60) solid breast masses were described using the sonographic BI-RADS lexicon features. Lesion description and biopsy results from histopathology were compared and analyzed using Pearson's Chi-square test. Odds ratios, sensitivity, specificity, and predictive values were also calculated. Statistical significance level was set at $p \leq 0.05$.

Results: Irregular shape ($p < 0.0001$), spiculated mass margins ($p < 0.0001$), and not parallel mass orientation ($p = 0.0007$) were more commonly associated with malignant masses. The sensitivity of breast ultrasound for malignancy was 93.9 % and the specificity was 55.6 % with an overall accuracy rate of 76.6 %. The negative predictive value was 88.7 % and the positive predictive value was 72.1 %. Descriptors like irregular shape, non-parallel orientation, angular and spiculated margins, echogenic halo, and markedly hypoechoic internal content, demonstrated higher odds ratios for malignancy.

Conclusions: This study adds valuable insights to the diagnosis of breast cancer using the sonographic BI-RADS lexicon features. The results demonstrate that specific sonographic descriptors can effectively differentiate between benign and malignant breast masses.

Introduction

Breast cancer is by far the most frequent cancer of women (19.1 % of all cancers) and ranks third overall when both sexes are considered together [1]. One in 8 women in the United States will develop breast cancer in her lifetime but rates increase slightly among African American women [2]. In Accra, Ghana, it accounts for about 16.0 % of all female cancers, being now the commonest cancer in females with about 200 new cases diagnosed yearly in Korle Bu Teaching Hospital [3].

In Benin City, Nigeria the 5-year survival rate for breast cancer is estimated to be 8.7 % [4]. Late presentation of patients at advanced stages has been the hallmark of breast cancer in Ghanaian women [5,6]. A greater proportion of breast cancers in Sub-Saharan Africa occur among premenopausal women as compared to elsewhere [7]. In Kumasi, Ghana where this study is being carried out 75.2 % of people with breast cancer present with a breast lump [8]. With the rising life expectancy and the increasing standard of living, cancer of the breast is likely to become a major problem in Africa [9]. Hence early detection with appropriate treatment is the key to increasing the survival rate and prolonging the life expectancy of breast cancer patients [10].

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The cause of breast cancer remains unknown [11]. Epidemiologically, however, there are certain associated factors that influence the risk of a woman developing the disease, one of these factors is age [12]. The incidence rises steadily from 30 to 75 years before it becomes flat [13].

Despite being the preferred method for breast cancer screening and diagnosis, mammography is comparatively expensive and less accessible in terms of infrastructure and human resources in Ghana when compared to breast ultrasonography[6]. In Price et al.'s study [14]. evaluating the Availability and Geographic Access to Breast Cancer Diagnostic Services in Ghana, mammography availability was recorded at 35 %, while ultrasound availability stood at 56 % across the country. Meanwhile, Moustafa et al.'s survey in the Eastern region of Ghana found a lack of mammography services and 75 % availability of ultrasound services within healthcare facilities in the region [15]. Recommendations from Boadu et al. in Ghana and Omidiji et al. in Nigeria advocate for ultrasound as the primary breast imaging modality. Boadu et al. emphasize this recommendation to circumvent unnecessary breast radiation, while Omidiji et al. attribute it to the scarcity of globally preferred mammography services [16,17].

In 1993, Breast Imaging- Reporting and Data System (BI-RADS) was developed by the American College of Radiology (ACR) to standardize the language for reporting mammography and to facilitate communication between clinicians by clarifying mammographic interpretation [18].

Though there are other breast imaging modalities like magnetic resonance imaging and ultrasonography, until recently, BI-RADS had been applied to mammography alone. Sonography use is now widespread in many African countries including Ghana and to standardize the characterization of sonographic lesions, the ACR recently developed a BI-RADS lexicon for sonography [18–21].

This lexicon gives various descriptors for masses such as shape, margin, internal echo pattern, posterior acoustic features, and other sonographic features according to the fifth edition of the ACR BI-RADS® Atlas, Breast Imaging Reporting and Data System 2013 [22] these descriptors are described as follows:

1. SHAPE
a. Oval shape refers to a mass that is elliptical or egg-shaped (may include two or three undulations, i.e., gently lobulated or macrolobulated.
b. A round shape mass is one that is spherical, ball-shaped, circular, or globular. It has an anteroposterior diameter equal to its transverse diameter; to qualify as a round mass, it must be circular in perpendicular projections.
c. Irregular shape mass is a mass that is neither round nor oval.
2. ORIENTATION
Orientation is defined with reference to the skin line.
a. Parallel (historically, "wider-than-tall" or "horizontal")
The long axis of the mass parallels the skin line. Masses that are only slightly obliquely oriented might be considered parallel.
b. Not Parallel
The long axis of the mass is not parallel to the skin line. The anterior-posterior or vertical dimension is greater than the transverse or horizontal dimension. These masses can also be obliquely oriented to the skin line. Round masses are not parallel in their orientation.
3. MARGIN
The margin is the edge or border of the lesion.
a. Circumscribed (historically, "well-defined" or "sharply defined")
A circumscribed margin is one that is well defined, with an abrupt transition between the lesion and the surrounding tissue in its entire margin.
b. Not Circumscribed
If any portion of the margin is not circumscribed, the mass should be characterized as not circumscribed. A mass that is not circumscribed may further be described as having indistinct, angular, microlobulated, or spiculated margins, or any combination of these. "Irregular" is not used to group these marginal attributes because irregular describes the shape of a mass.
i. Indistinct margin refers to having no clear demarcation of the entire margin or any portion of the margin from the surrounding tissue. The descriptor "indistinct" includes echogenic rim (historically, "echogenic halo") because one may not be able to distinguish between an indistinct margin and one that displays an echogenic rim.
ii. Angular margin refers to having some or all of the margin with sharp corners, often forming acute angles.
iii. Microlobulated margin is characterized by short-cycle undulations, about 1 mm to 2 mm.
iv. Spiculated margin is characterized by sharp lines radiating from the mass.
4. ECHO PATTERN
The echogenicity of mass compared with mammary fat.
a. Anechoic mass is without internal echoes.
b. Hyperechoic is defined as having increased echogenicity relative to fat or equal to fibroglandular tissue.
c. Complex (Cystic and Solid) mass contains both anechoic (cystic or fluid) and echogenic (solid) components.
d. Hypoechoic masses are less echogenic than fat and are characterized by low-level echoes throughout.
e. Isoechoic is defined as having the same echogenicity as subcutaneous fat. Isoechoic masses may be relatively inconspicuous, particularly when they are situated within an area of fat lobules.
f. Heterogeneous mass is a mass with a mixture of echogenic patterns within a solid mass.
5. POSTERIOR FEATURES
Posterior features represent the attenuation characteristics of a mass with respect to its acoustic transmission.
a. No Posterior Features is used when the echogenicity of the area immediately behind the mass is not different from that of the adjacent tissue at the same depth.
b. Enhancement appears as a column that is more echogenic (whiter) deep to the mass.
c. Shadowing appears as a central column that is darker deep to the mass.
d. Combined Pattern refers to having both posterior acoustic enhancement and shadowing.
6. CALCIFICATIONS IN A MASS: Calcifications embedded in a mass will appear as small hyperechoic foci.
7. ASSOCIATED FEATURES
1. Architectural distortion may be manifested by compression of the tissue around the mass, obliteration of the tissue planes by an infiltrating lesion, straightening or thickening of Cooper ligaments, aberrations of ductal patterns, and an echogenic rim.
2. Skin thickening may be focal or diffuse, and is defined as being > 2 mm. However, in the periareolar area and inframammary folds, normal skin thickness may be up to 4 mm.
3. Skin Retraction is when the skin surface is concave or ill-defined and appears pulled in.
4. Edema is indicated by increased echogenicity of the surrounding tissue and reticulation (angular network of hypoechoic lines representing either dilated lymphatics or interstitial fluid).
5. VASCULARITY
To describe a mass or other lesion as hypovascular or hypervascular, one must reference a contralateral normal area or unaffected site in the same breast as the basis for comparison.
a. Absent vascularity refers to masses showing no vascularity.
b. Internal Vascularity is when Blood vessels are present within the mass. Vessels may penetrate the margin of the mass or display an orderly or disorderly pattern within the mass.
c. Vessels in Rim is when The blood vessels are marginal, forming part or all of a rim around a mass.

In the original mammography BI-RADS lexicon, the positive predictive value (PPV) of mammographic features described has been investigated and was found useful in differentiating benign and malignant breast lesions [23]. The utility of sonographic features in distinguishing benign from malignant lesions has been assessed by several studies [24–26]. A study to assess the positive predictive value (PPV) and negative predictive value (NPV) of sonographic features as described in the new sonographic BI-RADS lexicon has also been assessed [26]. Sensitivity, specificity, negative and positive predictive values, and accuracy of mammography and ultrasonography have been reported by some authors in other jurisdictions [27]. In Ghana, Badu-Peprah et al. conducted a study similar to this one, but they did not evaluate the specific performances of each sonographic feature in diagnosing malignant breast masses [28]. Similarly, a study in Uganda by Mubuuke et al. [29]. on the Comparative Accuracy of Sonography, Mammography, and BI-RADS Characterization of Breast Masses among adult women at Mulago Hospital did not provide detailed descriptions of the individual diagnostic features observed on imaging.

The purpose of this study is to evaluate the sonographic features of solid breast masses and determine the sensitivity, specificity, negative and positive predictive values, and accuracy of the descriptors from the new sonographic BI-RADS lexicon for malignant versus benign diagnosis with histopathology as the gold standard.

Materials and methods

Study design and site

This was a prospective quantitative study that sonographically scanned female patients with breast masses and consecutively selected cases recommended for core biopsy at the breast clinic at the Komfo Anokye Teaching Hospital (KATH) from May 2018 to May 2021. KATH is the second-largest hospital in Ghana, and the only tertiary health institution in the Ashanti Region. The geographical location of the 1200-bed Komfo Anokye Teaching Hospital, the road network of the country and commercial nature of Kumasi makes the hospital accessible to all the areas that share boundaries with Ashanti Region and others that are further away. As such, referrals are received from most of the regions of Ghana.

Over a three-year period, our facility conducted sonographic evaluations on 120 clinically palpated breast masses. Each mass underwent sonographic examination by one of three dedicated radiologists, all affiliated with the same academic institution and possessing 2 to 11 years of experience. To streamline patient care and minimize anxiety, each case was assessed by a single radiologist, a protocol similar to that described by Hong et al. [21]. Masses were included in the study if they appeared as solid breast masses on sonography.

Seventeen lesions were excluded from the study as sonography revealed no solid mass, indicating pathologies such as duct ectasia or entirely cystic masses. Additionally, forty-three masses were excluded due to unavailable biopsy results, mainly because patients could not afford the out-of-pocket biopsy costs, which were not covered by insurance. The study thus focused on the remaining sixty (60) solid breast masses with available histology results, resulting in a power of 0.8162.

Information about the patient's age, physical examination findings, family history of breast cancer, and personal history of breast malignancy was available to each radiologist to best reproduce a realistic clinical situation.

In Park et al.'s research [20], aimed at assessing Observer Agreement Using the ACR Breast Imaging Reporting and Data System (BI-RADS)-Ultrasound, static breast images of 314 masses underwent independent evaluation by four radiologists. The findings highlighted significant intraobserver agreement but only moderate interobserver agreement regarding mass description and final assessment of breast abnormalities. To mitigate interobserver variability, the study recommended pre-study training. Consequently, all three radiologists underwent pre-study training in the BI-RADS for sonography lexicon descriptors, aiming to standardize the ultrasound reporting process. This initiative aimed to reduce interobserver variability and enhance result validity by ensuring consistent description of mass features.

To mitigate intraobserver variability, each test was repeated by the radiologists to confirm the accuracy of the collected data, thereby ensuring that the variables measured in the study accurately represented the intended metrics.

This prospective study was conducted after obtaining ethical approval from the Ethical Committee Board of KATH, under reference numbers CHRPE/AP/260/18, CHRPE/AP/337/19, and CHRPE/AP/183/20 and written informed consent from the patients.

Sonographic imaging technique

Sonography was performed using a variable-frequency linear transducer set at 12 MHz using a Toshiba Aplio 300 ultrasound machine. Each case was performed and interpreted by one of three radiologists. For masses in the lateral aspect of the breast, the patient was imaged in the supine-oblique position, and for medial masses, the patients were supine. Images were acquired in both radial and antiradial projections with and without calliper measurements. Additional gray-scale images were obtained when necessary to better show the mass. color Doppler, and power Doppler were applied to the masses to assess for vascularity. Findings were recorded using the sonographic BIRADS lexicon [18].

Data analysis

Data in Microsoft version 16 was cleaned, coded and transferred to STATA 14.1 for the appropriate statistical analysis. Results were presented using descriptive statistical tools in the form of frequency, percentages, mean and standard deviation. Sonographic characteristics of patients were compared with histological findings through frequency distribution produced through cross-tabulation analysis.

A structured data collection sheet was used to collect the data. Each case was initially categorized using text and then coded numerically as either benign or malignant through both ultrasonography and histopathology. This process was undertaken to ease comparison and enable subsequent analysis.

For ultrasonography, classification of cases into benign or malignant categories utilized the sonographic BIRADS lexicon. Masses categorized as BIRADS II and III were deemed benign, whereas those classified as BIRADS IV, and V were designated as malignant.

A Pearson's Chi-square test was further carried out to examine the relationship between sonographic characteristics and histology diagnosis at a confidence interval of 95 %. The distribution of the biopsy results by socio-demographic variables of participants presented through cross-tabulation was also tested through Chi-square analysis. Cohen's kappa was utilized to assess the agreement between sonographic characteristics and biopsy results, calculating sensitivity, specificity, negative predictive values, and positive predictive values for the classifications. Sensitivity was calculated as true positive divided by the sum of true positive and false negative. Specificity was calculated as true negative divided by the sum of true negative and false positive. Negative predictive value was calculated as true negative divided by the sum of true negative and false negative while positive predictive value was calculated as true positive divided by the sum of true positive and false positive. Accuracy was calculated as the sum of true positive and true negative divided by the sum of true positive, true negative, false positive, and false negative.

Odds ratios were also calculated to evaluate the chances of malignancy by the presence of a particular sonographic descriptor. Odds ratios were computed by dividing the post-test probability by the pre-test probability. The pre-test probability, defined as the prevalence of malignancy (55 %, 33 out of 60 cases), served as the basis. In cases of malignancy, the post-test probability corresponds to the positive predictive value. Findings associated with an elevated risk of malignancy yield odds ratios greater than one. Conversely, for benign lesions, odds ratios were calculated as one minus the negative predictive value divided by the prevalence. Therefore, the odds ratio required for classifying a finding as benign hinges on both the prevalence of malignancy and the tolerance for false-negative results. Statistical significance level (*p*) was set as less or equal to 5 % ($p \leq 0.05$).

Results

The morphology descriptors defined by Stavros et al., (1995) are shown in Table 1. It shows that the shape of the malignant masses was largely characterized by irregular shape, whilst benign masses were characterized by oval shape. There was a single round solid mass that ended up being malignant. A significant number of irregular shaped solid masses were benign, these were mostly inflammatory lesions. Most of the malignant masses had spiculated margins, whilst most of the orientations were parallel. The benign masses were descriptively characterized by oval shape, parallel, enhanced posterior acoustic features, and circumscribed margin. Statistically, the chosen descriptors for mass margin, mass shape, and mass orientation features were significantly different for benign and malignant masses ($p < 0.0001$, $p = 0.0007$).

Table 1
Frequency of Benign and Malignant Masses for Sonographic BI-RADS Lexicon Descriptors.

Descriptor	Total	Benign (%)	Malignant (%)	P-Value
Mass Shape				<0.0001*
Oval	15 (25.0)	10(66.7)	5(33.3)	
Round	1(1.7)	0(0.0)	1(100.0)	
Irregular	44 (73.3)	5(11.4)	39(88.6)	
Mass Margin				<0.0001*
Angular	10 (16.7)	1(10.0)	9(90.0)	
Circumscribed	20 (33,3)	11(55.0)	9(45.0)	
Indistinct	7(11.7)	3(42.9)	4(57.1)	
Microlobulated	4(6.7)	0(0.0)	4(100.0)	
Spiculated	19 (31.7)	0(0.0)	19(100.0)	
Mass Orientation				0.0007*
Not Parallel	22 (35.6)	3(13.6)	19(86.4)	
Parallel	38 (64.4)	14(36.8)	24(63.2)	
Posterior Acoustic Features				0.0580
No Posterior Acoustic Feature	20 (33.3)	2(10.0)	18(90.0)	
Combined Pattern	5(8.3)	2(40.0)	3(60.0)	
Shadowing	10 (16.7)	3(30.0)	7(70.0)	
Enhancement	25 (41.7)	16(64.0)	9(36.0)	
Lesion Boundary				0.1030
Abrupt Interface	24 (64.9)	10(41.7)	14(58.3)	
Echogenic Halo	13 (35.1)	2(15.4)	11(84.6)	
Echo pattern				0.3300
Hyperechoic	2(3.3)	1(50.0)	1(50.0)	
Isoechoic	1(1.7)	0(0.0)	1(100.0)	
Hypoechoic	46 (76.7)	11(23.9)	35(76.1)	
Markedly Hypo Echogenic	5(8.3)	0(0.0)	5(100.0)	
Complex	5(8.3)	1(20.0)	4(80.0)	
Anechoic	1(1.7)	1(100.0)	0(0.0)	

* Statistically Significant; BI-RADS=Breast Imaging Reporting and Data System.

Table 2 shows the comparism of US classification with histologic findings. Out of the histologically proven malignant masses, 2 (6.1 %, 2 out of 33) were incorrectly classified as benign on sonography, while 12 benign lesions (44.4 %, 12 out of 27) were mistakenly classified as malignant. The sensitivity of breast ultrasound in detecting malignancy stood at 93.9 %, with a specificity of 55.6 %, resulting in an overall accuracy rate of 76.6 %. The negative predictive value was 88.7 %, and the positive predictive value was 72.1 %.

Table 3 shows that malignant characteristics in the form of irregular, non-parallel, angular, spiculated, echogenic halo and markedly hypo echogenic provided evidence of a higher likelihood of 'true positive' relative to being 'false positive' since their odds ratios were greater than 1 (LR+ >1). These characteristics therefore provide evidence of a higher likelihood of the presence of cancer than being absent. Contrarily, micro lobulated margin, indistinct margin, and posterior acoustic shadowing had a greater likelihood of being 'false positive' than being 'true positive', which suggests that these characteristics provide evidence of the absence of cancer than the presence.

Table 4 shows that the sonographic characteristics in the form of architectural distortion, calcification within mass, skin thickening, skin edema, adjacent tissue infiltration, and vascularity exhibited a higher likelihood of 'true positive' than 'false positive'. Thus, these associated sonographic characteristics provided significant support for the presence of the malignancy relative to absence.

Table 5 shows that benign characteristics in the form of a round shape provided evidence of a higher likelihood of 'true negative' relative to being 'false negative' since its odds ratio is greater than 1 (OR >1).

Discussion

Breast cancer remains a significant global health concern, particularly impacting women's well-being. Ultrasound once limited to distinguishing cysts from solid masses, has evolved into a crucial tool in breast radiology, capable of discerning between benign and malignant lesions with high accuracy. In this study, the recently developed Breast Imaging-Reporting and Data System (BI-RADS) lexicon for sonography was used to evaluate the diagnostic accuracy of sonographic features in differentiating between benign and malignant solid breast masses in Kumasi, Ghana, where mammography is not widely accessible [15,16].

Stavros et al. [25]. demonstrated the efficacy of high-resolution breast ultrasound in this regard, achieving a sensitivity of 98.4 % and a negative predictive value (NPV) of 99.5 % for malignancy. Our study supports this finding though it yielded slightly lower values (sensitivity: 93.9 %, NPV: 88.7 %). The slightly lower values observed could be ascribed to the reduced sensitivity of certain characteristics like marked hypoechogenicity, indistinct margins, and micro-lobulated margins. Discrepancies in tumor biology [31] and breast composition might contribute to the diminished performance of these characteristics, given that studies suggest denser breasts lead to more precise ultrasound diagnostics [29]. This variance could have influenced our results, notably since only 18.3 % (11 out of 60) of participants had dense breast (homogeneously fibroglandular) composition. The study's findings offer

Table 2
Comparism of US classification with Histologic findings.

Ultrasound Diagnosis	Histology Diagnosis		Total
	Benign	Malignant	
Benign	TN, 15	FN, 2	17
Malignant	FP, 12	TP, 31	43
Total	27	33	60

FN = false negative, FP = false positive, TN = true negative, TP = true positive. Sensitivity = TP/(TP + FN) = 31/33(93.9 %). Specificity = TN/(TN + FP) = 15/27(55.6 %). Positive predictive value = TP/(TP + FP) = 31/43 (72.1 %). Negative predictive value = TN/(TN + FN) = 15/17 (88.7 %). Accuracy = (TP + TN)/(TP + TN + FP +FN) = 46/60 (76.6 %).

Table 3
Malignant sonographic characteristics versus malignant histologic findings.

Characteristics	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Odd Ratio
Irregular	93.9	56.0	73.8	87.5	77.6	1.30
Not parallel	56.3	88.0	85.7	61.1	70.2	1.53
Microlobulated	6.1	92.0	50.0	42.6	43.1	0.88
Indistinct	6.1	80.0	28.6	39.2	37.9	0.50
Angular	21.2	88.0	70.0	45.8	50.0	1.23
Spiculated	54.6	100.0	100.0	62.5	74.1	1.76
Shadowing	57.6	24.0	50.0	30.0	43.1	0.88
Echogenic Halo	47.1	73.7	61.5	60.9	61.1	1.30
Hypoechoic	78.8	20.8	57.8	41.7	54.4	1.00
Markedly Hypo Echogenic	12.1	95.8	80.0	44.2	47.4	1.38

PPV= Positive Predictive Value; NPV= Negative Predictive Value.

Table 4
Performance of associated sonographic features.

Characteristics	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Odd Ratio
Architectural Distortion	51.7	68.4	71.4	48.2	58.3	1.18
Calcification Within Mass	62.1	52.6	66.7	47.6	58.3	1.10
Skin Thickening	55.2	57.9	66.7	45.8	56.3	1.10
Adj. Tissue Retraction	10.3	84.2	50.0	38.1	39.6	0.83
Skin Edema	44.8	79.0	76.5	48.4	58.3	1.27
Adj. Tissue Infiltration	27.6	89.5	80.0	44.7	52.1	1.32
Vascularity	79.3	42.1	67.7	57.1	64.6	1.12

PPV= Positive Predictive Value; NPV= Negative Predictive Value; Adj= Adjacent.

Table 5
Benign sonographic characteristics versus benign histologic findings.

Characteristics	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Odd Ratio
Oval	3.0	44.0	6.7	25.6	21.4	0.12
Round	3.0	100.0	100.0	43.9	44.8	1.76
Circumscribed	12.1	40.0	21.1	25.6	24.1	0.37
Parallel	43.8	12.0	38.9	14.3	29.8	0.69
Abrupt Interface	52.9	26.3	39.1	38.5	38.9	0.83
Hyperechoic	3.0	92.0	33.3	41.8	41.4	0.59
Isoechoic	0.0	95.8	0.0	41.1	40.4	0.00

PPV= Positive Predictive Value; NPV= Negative Predictive Value.

valuable insights into the diagnostic potential of sonographic features, in line with research by Stavros et al. and Kolb et al. [25,27].

In a study conducted in Uganda, Mubuuke et al. [29]., found a sensitivity of 68.5 % and a negative predictive value (NPV) of 61.0 % among a sample size of 212. However, their results showed lower sensitivity and NPV compared to the present study. This difference could possibly be attributed to variations in the subregions studied, each with its own distinct tumor biology as noted in a study by Jiagge et al. [30]. Similarly, a study carried out in Abuja, Nigeria, by Okeji et al. [31]., revealed a sensitivity of 83.33 %, a positive predictive value (PPV) of 71.42 %, and an NPV of 85.10 % among a sample size of 150. Despite the larger sample size in their study compared to ours, their findings closely resembled those of the current study. This similarity might be explained by the shared subregion and its similar tumor biology [30].

Characteristics such as irregular shape, not parallel orientation, angular margin, spiculated margin, echogenic halo, architectural distortion, and vascularity exhibited higher sensitivity, specificity, and predictive values, indicating their potential as robust indicators of malignancy. In the study of Hong et al. [26], they also found irregular shape, spiculated margins, and not parallel had high predictive value for malignancy. In Nigeria, Okeji et al. [31] identified irregular shape, not parallel orientation, echogenic halo, hypoechogenic echogenicity, non-circumscribed margins, shadowing, and architectural distortion as common descriptors for malignancy. Therefore, solid breast masses exhibiting any of these features should raise suspicion of malignancy. These findings provide valuable guidance for clinicians in interpreting sonographic results and making informed decisions regarding patient care. Among sonographic findings, spiculated mass margin emerged as a significant indicator of malignancy, demonstrating the highest positive predictive value (PPV) in our study. Spiculations, although reported infrequently, are recognized as manifestations of infiltrating tentacles of tumours extending into surrounding tissues, thereby aiding in the detection of malignant masses [32]. This finding is consistent with the observations of Stavros et al. [25]and Hong et al. [26].

Not parallel masses, often associated with malignancy, typically exhibit a larger anteroposterior dimension relative to their width. Conversely, benign masses tend to remain within tissue planes and appear wider than they are tall. In our study, not parallel orientation demonstrated notable sensitivity, specificity, PPV, negative predictive value (NPV), accuracy, and odds ratio (56.3 %, 88.0 %, 85.7 %, 61.1 %, 70.2 %, and 1.53, respectively), further underscoring its significance in malignancy detection. These findings are consistent with the observations of Stavros et al. [25].

Shadowing, previously associated with a variable percentage of malignant masses [33], exhibited sensitivity, specificity, positive predictive value (PPV), NPV, accuracy, and odds ratio of 57.6 %, 24.0 %, 50.0 %, 30.0 %, 43.1 %, and 0.88, respectively, in our study. While the presence of shadowing is concerning for malignancy, its absence does not exclude the possibility, as evidenced by studies suggesting that normal or enhanced through-transmission should be considered indeterminate findings [34]. While marked hypoechogenicity is typically regarded as a concerning feature for malignancy, our study uncovered a notably low sensitivity of 12.1 % associated with this characteristic. Conversely, hypoechogenicity, though considered less worrisome than marked hypoechogenicity, demonstrated a higher sensitivity of 78.8 %. Thus, it is imperative not to perceive hypoechogenicity as reassuring; rather, these findings should be viewed as indeterminate, necessitating further evaluation. This interpretation is consistent with the findings of Stavros et al. [25].

While ultrasound lacks the capability to depict microcalcifications for breast cancer screening, calcifications within masses are suggestive of malignancy [35], as corroborated by our study's odds ratio of 1.1. Identification of surrounding tissue effects such as edema, architectural distortion, or vascularity holds promise in malignancy assessment, echoing the findings of Hong et al. [26].. Similarly, the analysis of benign sonographic characteristics (Table 5) offers insights into distinguishing benign from malignant masses. In the study of Hong et al., and Okeji et al., their study revealed circumscribed margin, parallel orientation, and oval shape as high predictors for benignity [26,31]. Sensitivity, specificity, and predictive values associated with different descriptors provide practical information for diagnosing benign masses based on their sonographic attributes. However, the relatively low specificity can be thought of as being too eager to find a positive result, even when it is not present, it may give a high number of false positives. Malignant sonographic characteristics hypoechoic, shadowing, and irregular had lower specificity ratios of 20.8 %, 24.0 %, and 56.0 % respectively. Practitioners in our setting are therefore advised to be alert on this to reduce cases of false positives.

The presence of a single malignant feature in solid breast masses should therefore exclude them from benign classification and must be biopsied for definite diagnosis and appropriate treatment. It still underscores the utility of ultrasound in this domain for the accurate diagnosis of malignancy, preventing unnecessary biopsies, reducing cost, and helping with appropriate patient management since patients pay out of pocket for most of these diagnostic imaging and histology.

By leveraging benign characteristics after excluding malignancy, a biopsy can potentially be avoided in over 80 % of benign masses, with a negative predictive value of 88.9 % as indicated in our study. This aligns with findings from Hong et al. [26]., highlighting the reliability of this approach. Despite appearing benign on ultrasound, a notable proportion of masses described as oval, hypoechogenic, parallel, and circumscribed were malignant at histology, as observed in our study (6.1 % of 33 masses) and by Hong et al. [3] (9 % of 172 masses). This highlights the importance of short-term re-evaluation of apparently benign solid masses, and possible biopsy especially when concomitant mammographic features raise concerns.

The high negative predictive value (88.7 %) suggests that the BI-RADS lexicon in breast ultrasound is reliable in ruling out malignancy. The implications of this high negative predictive value are improvements in patient outcomes and the reduction of potentially unnecessary biopsies thereby saving cost. The positive predictive value of 72.1 % also indicates a moderate rate of false positives. Potential reasons for false positives were sonographic characteristics like hypoechoic, shadowing, and irregular, which were classified as malignant but contributed less to malignancy. Even though the overall accuracy rate of 76.6 % is acceptable, it can have a negative impact on patient management and treatment decisions.

It's important to emphasize that when utilizing sonography for diagnosing solid breast masses, it's not intended as the primary screening tool and its accuracy can vary depending on the operator. It's also noteworthy that its performance is impacted by tumor biology and breast composition when precisely categorizing solid breast masses. Nonetheless, it proves valuable in low-resource settings where mammography and biopsy tests are unavailable, when utilizing the descriptors in the BI-RADS for sonography. However, in cases of disagreement, follow-up imaging and biopsy are recommended. With advancements in ultrasound technology, such as automated imaging and AI-assisted reporting, we anticipate enhanced outcomes in the future.

Conclusion

In conclusion, this study adds valuable insights to the realm of breast cancer diagnosis using sonographic features from the BI-RADS for sonography lexicon (BI-RADS-US lexicon). The results affirm the potential of specific sonographic descriptors in distinguishing between benign and malignant solid breast masses with a sensitivity of 93.9 % and a negative predictive value of 88.7 %. While affirming the pivotal role of sonography in early detection, particularly in resource-limited settings, our research also emphasizes the importance of thorough evaluation and follow-up, given the observed 6.1 % false negative rate for initially classified benign masses.

Moreover, our study enhances the application of sonographic features from the BI-RADS-US lexicon in diagnosing solid breast masses, particularly in regions with limited access to advanced imaging modalities like mammography. By shedding light on the effectiveness of sonography, especially in early detection, this research contributes to the broader goal of improving breast cancer diagnosis. These insights underscore the significance of sonography in enhancing patient care and ultimately benefiting women's health globally. Moreover, the potential to reduce unnecessary biopsies highlighted in this study promises to optimize patient management, mitigating associated costs.

In conclusion, our study provides significant contributions to breast cancer diagnosis through the utilization of sonographic features from the BI-RADS for sonography lexicon. The findings underscore the efficacy of specific sonographic descriptors in accurately distinguishing between benign and malignant breast masses. This has the potential to mitigate unnecessary biopsies, minimize costs, facilitate precise diagnosis, and enable appropriate patient management. Nonetheless, the presence of a 6.1 % false positive rate indicates the importance of short-term follow-up for solid masses initially classified as benign.

Recommendations and limitations

1. Due to the unavailability of biopsy results for certain solid masses, the sample size was limited to 60, yielding a power of 0.8162. Future research initiatives could benefit from broader and more diverse population samples to improve the accuracy of results.
2. The study's reliance on histopathology as the gold standard introduces the possibility of bias.
3. Interobserver variability was not evaluated in this study, though each mass was assessed by only one radiologist. While sufficient pretraining was conducted to standardize reporting and ensure consistent mass description, future studies to assess interobserver agreement in the use of the BI-RADS lexicon for sonography is recommended.

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Declaration of generative Ai in scientific writing

We did not use AI or AI-assisted technology in the writing process of this manuscript.

Data availability

The data generated in this study for the prospective study are available upon request from the corresponding author. The data generated in this study, apart from the data used for the analyses, are available within the article.

CRediT authorship contribution statement

Augustina Badu-Peprah: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Obed Kojo Otoo:** Writing – review & editing, Writing – original draft, Resources, Project administration, Investigation. **Mansa Amamoo:** Writing – review & editing, Writing – original draft, Resources, Project administration, Investigation. **Frank Quarshie:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation. **Benjamin Adomako:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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