RESEARCH

Performance evaluation of digital mammography, digital breast tomosynthesis and ultrasound in the detection of breast cancer using pathology as gold standard: an institutional experience

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Abstract

Background: Mammography is the primary imaging modality for diagnosing breast cancer in women more than 40 years of age. Digital breast tomosynthesis (DBT), when supplemented with digital mammography (DM), is useful for increasing the sensitivity and improving BIRADS characterization by removing the overlapping effect. Ultrasonography (US), when combined with the above combination, further increases the sensitivity and diagnostic confidence. Since most of the research regarding tomosynthesis has been in screening settings, we wanted to quantify its role in diagnostic mammography. The purpose of this study was to assess the performance of DM alone vs. DM combined with DBT vs. DM plus DBT and ultrasound in diagnosing malignant breast neoplasms with the gold standard being histopathology or cytology.

Results: A prospective study of 1228 breasts undergoing diagnostic or screening mammograms was undertaken at our institute. Patients underwent 2 views DM, single view DBT and US. BIRADS category was updated after each step. Final categorization was made with all three modalities combined and pathological correlation was done for those cases in which suspicious findings were detected, i.e. 256 cases. Diagnosis based on pathology was done for 256 cases out of which 193 (75.4%) were malignant and the rest 63 (24.6%) were benign. The diagnostic accuracy of DM alone was 81.1%. Sensitivity, Specificity, PPV and NPV were 87.8%, 60%, 81.3% and 61.1%, respectively. With DM + DBT the diagnostic accuracy was 84.8%. Sensitivity, Specificity, PPV and NPV were 92%, 56.5%, 89% and 65%, respectively. The diagnostic accuracy of DM + DBT + US was found to be 85.1% and Sensitivity, Specificity, PPV and NPV were 96.3%, 50.7%, 85.7% and 82%, respectively.

Conclusion: The combination of DBT to DM led to higher diagnostic accuracy, sensitivity and PPV. The addition of US to DM and DBT further increased the sensitivity and diagnostic accuracy and significantly increased the NPV even in diagnostic mammograms and should be introduced in routine practice for characterizing breast neoplasms.

Keywords: Breast cancer, Mammography, Tomosynthesis, US

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Background

Breast cancer is the most often encountered and the most dreaded of the various pathologies that affect the breast [1]. It is the most common cancer in Indian women [2]. There is a higher probability of having cancer in those

Joshi *et al. Egypt J Radiol Nucl Med* (2022) 53:1

Page 2 of 11

women who present with palpable breast lumps as compared to all the women undergoing breast imaging [3]. Current guidelines for imaging patients with a palpable breast lump differ according to patient age. Mammography is the primary imaging modality (followed by ultrasound) for those 40 years and older, and ultrasound is the primary modality for those younger than 30 years [4]. The most recent version of the American College of Radiology (ACR) Appropriateness Criteria for palpable breast masses states that evaluation of women 30–39 years old can begin with either mammography or ultrasound, but the previous standard recommended approach was mammography [4]. There are two limitations of digital mammography (DM), the first being a masking effect in dense breasts, which occurs because of overlying parenchyma, causing its low sensitivity. Since overlap of normal parenchyma can mimic a lesion, the second drawback is that it also has low specificity [5].

In recent years, a major effort has been expended to develop new approaches to breast imaging, one of which is the use of digital breast tomosynthesis (DBT) that enables the reconstruction of cross-sectional images that aims to assist radiologists with the interpretation process [6]. DBT creates cross-sectional images of the breast, as the x-ray tube moves in a limited arc over a compressed breast, by imaging in a series of different projections. The individual images are then reconstructed into a series of thin, high-resolution slices [7]. Units that are now developed for clinical use have dual functionality; that is, both two-dimensional (2D) digital mammography and breast tomosynthesis may be performed with the same unit. Hence breast tomosynthesis has the advantages of digital mammography, such as reproducibility and can eliminate the problem of overlapping structures in the breast as well thereby enhancing margin visibility [8].

Several previous studies have highlighted the advantages of the addition of DBT in screening studies, resulting in reduced recall rates and improved sensitivity [5, 9]. It is probable that similar improvements in mammographic sensitivity and specificity will also be demonstrated in the diagnostic setting, but this needs further exploration [10].

Supplemental ultrasound (US) has the potential to depict early breast cancers not seen on mammography and its performance is improved in dense parenchyma [11]. US plays a key role in differentiating cystic and solid masses. It is useful in the evaluation of palpable masses not visible in radiographically dense breasts, for the evaluation of abscesses and masses that cannot be completely evaluated with mammography and in young patients who want to avoid radiation exposure [12].

In the diagnostic setting, DM+DBT may improve lesion characterization and reduce further imaging follow-ups. When used in combination with US, the lesion nature may be more confidently ascertained leading to better BIRADS assessment. To the best of our knowledge, very few studies have compared all 3 modalities together. Hence, this study was performed to assess the performance of digital mammography alone vs DM in combination with DBT vs DM in combination with DBT and ultrasound in diagnosing malignant breast neoplasms with the gold standard being histopathology or cytology for lesions that had undergone breast biopsy or FNAC.

Materials and methods
Patient selection
This prospective study was undertaken at the department of Radiodiagnosis between May 2019 and March 2020. Most of the study population were undergoing diagnostic mammography. All women with any breast symptoms attending OPD clinics and being referred to the radiology department for mammography were included in the study. Women undergoing screening for breast cancer and women on follow up of breast cancer (post-chemotherapy, radiotherapy, modified radical mastectomy or lumpectomy) were also included in the study. Pregnant women, male patients and pubertal females were excluded from the study. A total of 702 patients with 1228 breasts were the study population. All patients provided informed consent. The hospital ethics committee provided ethical clearance, IEC number 40/18.

Study methodology
These patients underwent DM in two views: the craniocaudal (CC) and medio-lateral oblique (MLO) views and tomosynthesis in one view (MLO) of both breasts using Digital Mammography Unit (GE Healthcare Senographe Essential 54020/CESM1/SenoClaireA.6). Additional views like spot compression, cleavage views, axillary tail views, etc. were taken when necessary for digital mammography.

They also underwent 3D digital tomosynthesis on the same machine. During a tomosynthesis scan, multiple projections of low-dose exposure of the breast were acquired at angles of ± 15.6 degrees while the X-ray tube moved in an arc fashion across the breast. Then the thin slices were reconstructed to a three-dimensional image. Images were displayed in slice or cine loop mode on dedicated high-resolution workstations.

Each breast was categorized according to the American College of Radiology (ACR) 5th edition Breast Imaging Data and Reporting System (BI-RADS) [13] categories first by analyzing the DM images only. Then DBT images were evaluated and BIRADS score was updated or kept the same as per the case, in each breast. Indeterminate

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 3 of 11

cases (BIRADS 3 and 4) and BIRADS 5 cases were then taken for ultrasound examinations on Supersonic AIX-PLORER Multiwave Version 12.2.0808 USG scanner which were done using 2–10 MHz and 5–18 MHz high-frequency probes. Final BIRADS category was assigned after US examination using a combination of 2D images plus tomosynthesis images plus US findings.

BIRADS 4 and 5 cases diagnosed after combined usage of DM+DBT+US were made to undergo either US guided or non-guided biopsy/FNAC and the gold standard for such cases ($n=256$) was pathological correlation and these cases formed the final sample set.

Statistical analysis

Statistical analysis was done using SPSS (Statistical Package for Social Sciences) Version 21.0 statistical Analysis Software. The values were represented in Number (%) and Mean±SD. Sensitivity, specificity, PPV, NPV, Diagnostic accuracy was calculated. Chi-square test was done for comparison and p-value >0.05 was considered not significant while $p<0.05$ was significant, $p<0.01$ highly significant and $p<0.001$ was very highly significant.

Results

A total of 702 females were enrolled in the study and mammography of a total of 1228 breasts was done. The mean age was 48.82 ± 10.94 years with ages ranging between 20 and 83 years. ACR breast density B and C showed prominence being 38.8% and 39.4% respectively (Table 1).

On DM alone, a total of 313 masses were detected, the majority of which were irregularly shaped (54.3%) and had high density (78.0%). The most common margins observed for the masses were obscured (29.7%), circumscribed (24.6%) and spiculated (22.7%). Architectural distortion was observed in 3.1% of breasts, skin lesions in 9 (0.7%). Focal asymmetries (58.1%) were most common followed by global asymmetry (31.2%). Calcification distribution revealed prominence of diffuse calcifications (65.3%) and grouped calcifications (21.4%). Regional, segmental and linear calcifications were observed in 8.9%, 4.1% and 2.0% breasts (Table 2). Using 2D Mammography 8.4% of cases were BIRADS 3 and 248 (20.2%) breasts were in BI-RADS Grade 4 and Grade 5.

2D+3D mammography detected 361 masses with the majority of them showing irregular shape (54.8%) and high density (83.7%). The most common margins of the breast masses were circumscribed (34.1%) followed by obscured (27.4%) and spiculated (24.7%), the rest of the masses had microlobulated and indistinct margins (5.3% & 8.3%, respectively). Architectural distortion was observed in 48 (3.9%) breasts. Focal asymmetry was the most common (60.8%), followed by global asymmetry

Table 1 Patient data

Variable	Value
Age	20–83 years; Mean age±SD: 48.82±10.94
ACR breast density	
A	81
B	477
C	484
D	186
Pathological findings	
Benign	
Abscess	8
Inflammation	11
Fibroadenosis and fibroadenoma	26
Cysts	5
Filariasis	1
Mastitis	5
Duct papilloma	1
Phyllodes tumor	6
Malignant	
Infiltrating ductal carcinoma	181
Invasive lobular carcinoma	1
Malignant phyllodes tumor	2
Mucinous carcinoma	1
Primary breast lymphoma	1
DCIS	2
Paget's disease	2
Neuroendocrine tumor	1
Invasive papillary carcinoma	1
Carcinosarcoma	1

(35.1%) (Table 2). With DM+DBT, 8.5% cases were BIRADS 3 and 273 (22.2%) cases fell in Grade 4(a–c) & 5.

A total of 413 breast masses were detected after the addition of USG with 2D+3D mammography. The majority of breast masses were of irregular shape (51.3%) had circumscribed margins (52.0%), had parallel orientation and were hypoechoic (55.6%). No posterior features were observed in 50.8% of the breasts, shadowing was found in 25.2%, 13.7% had posterior enhancement and 10.7% had combined posterior features. The majority of the axillary lymph nodes were benign (87.0%) and 13% were suspicious. Post-surgical fluid collection was seen in 11 (0.9%) breasts (Table 3). With the addition of US, BIRADS 2(50.2%) was the most common grade assigned followed by BIRADS 3(17.7%). No case was given category 0. Final BIRADS was 3 in 17.7% cases and 26.3% fell in category 4(a–c) & 5.

Final diagnosis of breasts was done on radiological features for 895 (72.8%) breasts. For 333 breasts

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 4 of 11

Table 2 Characteristics on mammography

SN		DM No. of breasts	Percentage	DM + DBT No. of breasts	Percentage
1.	**Mass**				
	Shape	n = 313		n = 361	
	Oval	90	28.8	120	33.2
	Round	53	16.9	43	11.9
	Irregular	170	54.3	198	54.8
	Margins				
	Circumscribed	77	24.6	123	34.1
	Obscured	93	29.7	99	27.4
	Microlobulated	16	5.1	19	5.3
	Indistinct	56	17.9	31	8.6
	Spiculated	71	22.7	89	24.7
	Density				
	High density	244	78.0	302	83.7
	Equal density	66	21.1	57	15.8
	Low density	1	0.3	0	0.0
	Fat containing	2	0.6	2	0.6
2.	**Calcifications**				
	Morphology				
	Amorphous	25	2.0	28	2.3
	Coarse heterogeneous	33	2.7	40	3.3
	Fine pleomorphic	47	3.8	45	3.7
	Fine linear and branching	11	0.9	12	1.0
	Distribution				
	Diffuse	64	65.3	62	62.0
	Regional	7	8.9	8	8.0
	Grouped	21	21.4	16	16.0
	Linear	2	2	3	3.0
	Segmental	4	4.1	10	10.0
3	**Architectural distortion**	38	3.1	48	3.9

pathology was needed to make a diagnosis however 77 cases were lost to follow up and pathological findings were available for 256 patients. Out of 256 specimens, 193 (75.4%) were found to be malignant and the rest 63 (24.6%) were found to be benign. The most common malignancy detected was infiltrating ductal carcinoma (93%) followed by DCIS (1%), malignant phyllodes (1%) and Paget's disease (1%). Fibroadenosis and fibroadenomas formed the majority of benign cases (41.2%) followed by inflammation (17%), both acute and/or chronic and abscess (12.6%) (Table 1).

BIRADS 4 and 5 cases were considered suspicious for malignancy. On correlating the results of DM with pathological findings (gold-standard), DM correctly diagnosed malignancy in 152/174 cases with a diagnostic accuracy of 81.1%. Sensitivity, Specificity, PPV and NPV were 87.8%, 60%, 81.3% and 61.1%, respectively.

DM+DBT correctly identified malignancy in 165/185 suspicious cases with a diagnostic accuracy of 84.8%. Sensitivity, Specificity, PPV and NPV were 92%, 56.5%, 89% and 65%, respectively.

DM+DBT+US correctly detected malignancy in 186/217 suspicious cases with a diagnostic accuracy of 85.1%. Sensitivity, Specificity, PPV and NPV were 96.3%, 50.7%, 85.7% and 82%, respectively.

Of the 256 cases confirmed on pathological grounds, we retrospectively analyzed the number of BIRADS upgradations, from 3 to 4 or within 4 or from 4 to 5, that occurred with the combined use of DBT and US. The addition of DBT led to 62 upgrades of which 52 were correctly identified as malignancies (83.8%). The combination of US showed 92 upgrades of which 72 were correctly identified as malignant (78.2%). US also downgraded the BIRADS correctly in 18 cases that were confirmed to be benign.

Joshi *et al. Egypt J Radiol Nucl Med* (2022) 53:1

Page 5 of 11

Table 3 Characteristics on USG

SN		No. of breasts	Percentage
1.	**Mass**		
	Shape (n=413)		
	Oval	172	41.6
	Round	29	7.0
	Irregular	212	51.3
	Margins		
	Circumscribed	215	52
	Indistinct	47	11.3
	Angular	63	15.2
	Microlobulated	39	9.4
	Spiculated	49	11.8
	Orientation		
	Parallel	250	60.5
	Non-parallel	163	39.5
	Echo Pattern		
	Hyperechoic	21	4.6
	Complex solid cystic	41	9.9
	Hypoechoic	230	55.6
	Isoechoic	3	0.7
	Heterogeneous	118	28.5
	Posterior features		
	None	210	50.8
	Enhancement	56	13.5
	Shadow	102	24.6
	Combined	44	10.6
2.	**Calcifications**		
	In mass	49	92.4
	Intraductal	3	5.6
	Outside mass	5	9.4
3.	**Associated features**		
	Architecture distortion	56	13.5
	Duct change	119	28.8
	Skin thickening	43	10.4
	Skin retraction	11	2.6
	Edema	29	7
	Vascularity (n=413)		
	Absent	244	59
	Internal	136	32.9
	Rim	33	7.9

Discussion

The study was performed to assess the role of DBT as an addition to routine DM as it is a promising and emerging tool for breast cancer screening and diagnosis. Supplemental US was used to analyze the increased accuracy of this modality for lesion characterization.

A total of 313 masses were picked up on 2D mammography alone while 2D and 3D mammography combined picked up 361 lesions thus showing that 3D mammography improves lesion visualization (Fig. 1). A total of 77 circumscribed lesions were picked up on 2D mammography while 123 circumscribed lesions were picked up on 3D mammography. This finding coincides with that of Nakashima et al. [14] who showed superior overall visibility of circumscribed masses on DBT images as compared to 2D mammograms in 59 cases. Lesion conspicuity was improved with DBT with fewer lesions having obscured (27.4%) and indistinct margins (8.6%) as compared to DM which showed 29.7% obscured and 17.9% indistinct margins. The detection of spiculated margins also increased to 24.7% with DBT as compared to 22.7% with DM alone (Figs. 2, 3). This is consistent with the findings of Chan et al. [15] who showed significantly higher conspicuity of lesions on DBT than in DM.

The reason for improved visibility of lesions on DBT was that the overlapping tissue in DM was largely removed by DBT. Lesion characteristics such as the shape and margin, therefore, became more visible. The improved conspicuity and margin characterization contributed to the improved assessment of the degrees of suspicion.

DBT has shown higher sensitivity in detecting architectural distortion as compared to DM. Studies by Dibble et al. [16] had higher confidence and higher agreement with DBT as compared to DM in detecting architectural distortion in screening mammograms. Rafferty et al. [17] also showed that digital mammography plus tomosynthesis demonstrated superior diagnostic accuracy in identifying architectural distortion. In our study, we did not observe a significant difference with the addition of DBT possibly because our study had very limited screening cases like Dibbles and Rafferty (Fig. 4). We also had a smaller sample size as compared to the above studies.

The role of DBT in detecting microcalcifications has been studied and lesions that have microcalcifications as their main feature may not be seen at DBT occasionally [18]. In our study, DBT did not show superior performance for the detection of microcalcifications and rather showed no significant difference in identifying them as compared to DM alone. A reason for this could be that we were analyzing DBT images after viewing DM images hence a potential bias could have formed and only the microcalcifications viewed on DM were confirmed on DBT. Studies by Li et al. [19] and Kopans et al. [20] have also demonstrated that DBT enabled the detection and characterization of microcalcifications with no significant differences from DM, similar to ours.

The combination of DBT with DM led to better BIRADS characterization with fewer lesions being characterized as BIRADS 0 (3 as compared to 6 on DM alone), and BIRADS 4 lesions being upgraded to

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 6 of 11
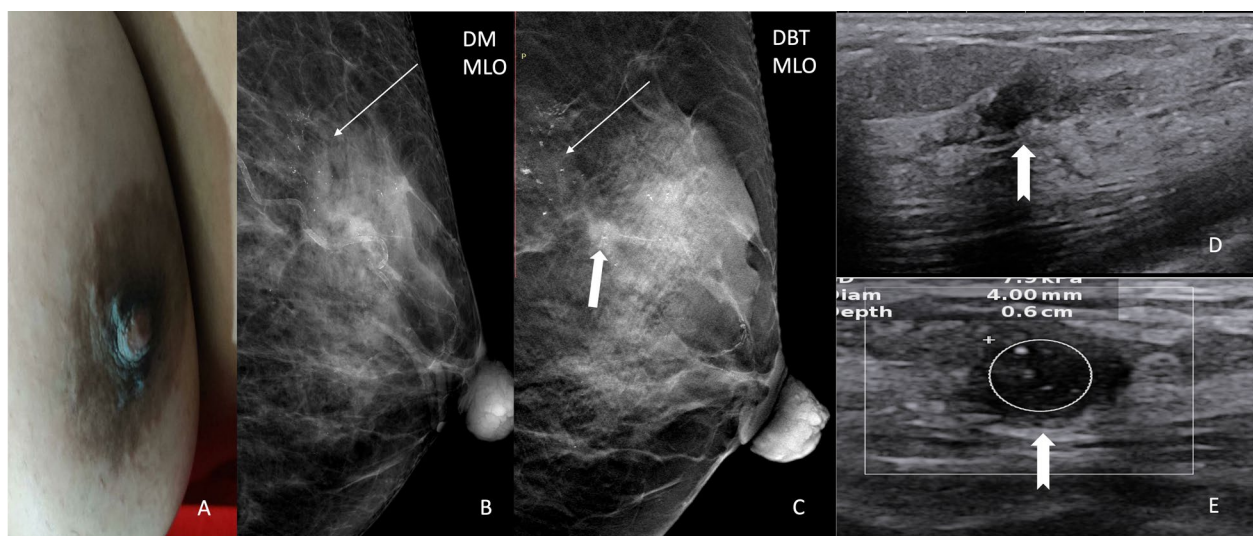
Fig. 1 A 60-year-old patient complained of itching in her left breast (**A**). DM MLO image (**B**) showed fine pleomorphic calcifications (thin arrows in **B** and **C**). DBT image confirmed the presence of fine pleomorphic calcifications and revealed an oval mass with obscured margins (solid arrow in **C**). USG images **D** and **E** demonstrated one irregular heterogeneously hypoechoic mass with internal calcifications (notched arrow). Vacuum assisted biopsy was performed and histopathological diagnosis (HPE) was Paget's disease

a higher category with 5.6% BIRADS 5 lesions being detected on DM + DBT as compared to 4.3% being detected on DM alone.

For DM alone, the sensitivity was 87.8%, specificity was 60%, PPV was 81.3%, NPV was 61.1% with a diagnostic accuracy of 81.1%. For DM with DBT the sensitivity was 92%, specificity was 56.5%, PPV was 89%, NPV was 65% with a diagnostic accuracy of 84.8%. Our study showed higher sensitivity, NPV and diagnostic accuracy of combined DBT with DM as compared to DM alone. This is similar to the findings of Lei et al. [21] who in their meta-analysis of 7 studies found higher pooled sensitivity with DM in combination with DBT as compared to DM alone, similar to our study. Gilbert et al. [9] in the TOMMY trial also reported an increase in sensitivity with 2D + DBT where the dominant radiological feature was a mass, with 89% sensitivity for DM and 92% for DM + DBT, in concordance with our findings. Similar findings were also reported by Rafferty et al. [17] and Asbeutah et al. [22] who had higher sensitivity, NPV, PPV and diagnostic accuracy with DM + DBT. Our study shows higher diagnostic accuracy with combined DBT and DM, correlating with the findings of Mariscotti et al. [23] who also demonstrated higher accuracy with the addition of DBT to DM.

However, this is in slight contrast with the OSLO trial conducted by Skaane et al. [5] in 2019, and study by Ohashi et al. [24] who reported significantly higher sensitivities with the addition of DBT (54.1% for DM vs 70.4 for DM + DBT% and 61% for DM vs 83% for DM + DBT, respectively). Our modest improvement in sensitivity could be explained by the fact that ours is a tertiary care cancer hospital where most of the referred women were already at an advanced stage in their cancer development, i.e. presenting with BIRAD 4 and 5 category masses in contrast with the OSLO trial which was a screening trial. Since most malignant masses may be demonstrable on DM alone, we may have underestimated the contribution of DBT, serving as a potential limitation in our study. The above studies also operated with very large sample sizes as compared to our modest sample size of 1228 breasts. This could be a potential factor affecting the results.

Ultrasonography is complementary to mammography in patients with palpable abnormalities; its superiority over mammography is in being able to show lesions obscured by dense breast tissue and in characterizing palpable lesions that are mammographically visible or occult. Ultrasound is instrumental in determining solid vs. cystic nature of a lesion, vascularity of a lesion (Fig. 5) and duct changes which have been documented in studies by Jackson [25] and Chao et al. [26].

In our study, 413 masses were detected on USG which were higher than the 313 picked up on DM alone and 361 detected on DM with DBT. A total of 119 cases in our study showed duct changes on US which could not be assessed on mammography alone and 158 cases showed increased vascularity (either internal or rim or a combination of both) on US which could, again, not be demonstrated on mammography alone. Posterior
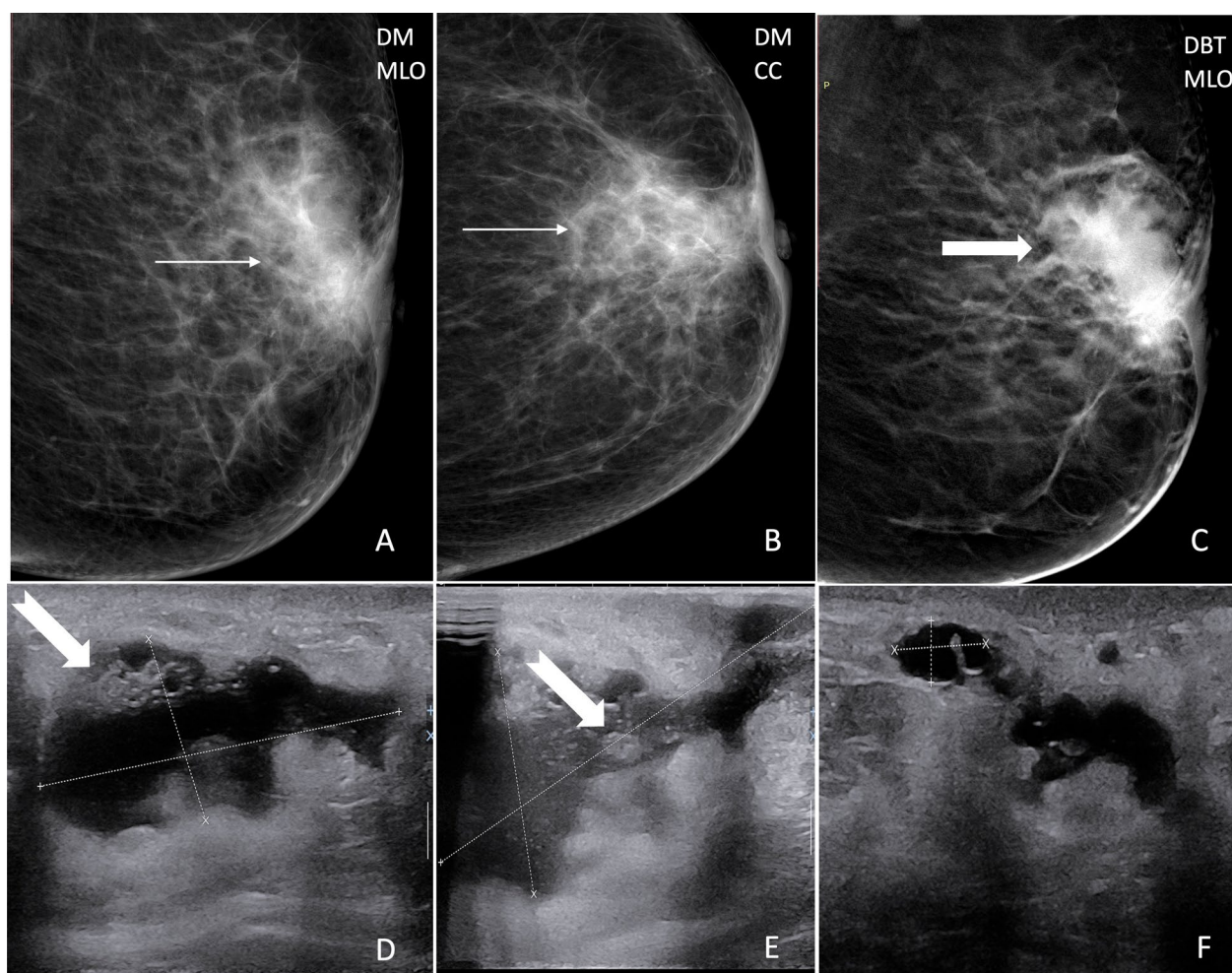
Fig. 2 A 57-year-old patient presented with a lump and nipple retraction in her left breast. DM images showed an indistinct mass in the retroareolar region on MLO (**A**) and CC (**B**) views (thin arrows in A and B) with nipple retraction. DBT was useful in clearly demonstrating a mass with spiculated margins (block arrow in **C**). USG images **D**, **E**, **F** were instrumental in characterizing the solid-cystic nature of the lesion (notched arrows in D and E point toward eccentric solid component). US-guided biopsy was performed and HPE was invasive papillary carcinoma

features as an adjunctive finding in the diagnosis of breast lesions could only be determined with US. In total, 40 intramammary lymph nodes were diagnosed with US while only 20 and 14 were diagnosed with DBT + DM and DM alone, respectively. A total of 11 cases on ultrasound showed post-surgical fluid collection and simple or clustered microcysts could only be detected on US.

Few benign appearing lesions on mammography (round with circumscribed margins) demonstrated solid nature on US with internal vascularity thus highlighting the role of US in characterization of the internal contents of benign appearing masses.

With the use of US, no breast was given a BIRADS 0 assessment as compared to 6 on DM and 3 on DBT,

reducing the number of non-diagnostic cases. There was a reshuffling of BIRADS with a higher number of lesions being assigned BIRADS 3, 4a, 4c and 5 categories as compared to DM alone or DM + DBT. The number of BIRADS 1 and 4b category was lesser with the use of US than with mammography alone, being re-assigned to a higher category.

The combination of all the modalities together yielded a higher sensitivity of 96.3% as compared to DM alone or DM + DBT. We also observed a significantly higher NPV of 82% with all the modalities combined. Higher diagnostic accuracy of 85.1% was observed with all three modalities combined but specificity and PPV were slightly lower than with DM and DM + DBT. This is in concordance with the findings of Mariscotti et al.

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 8 of 11
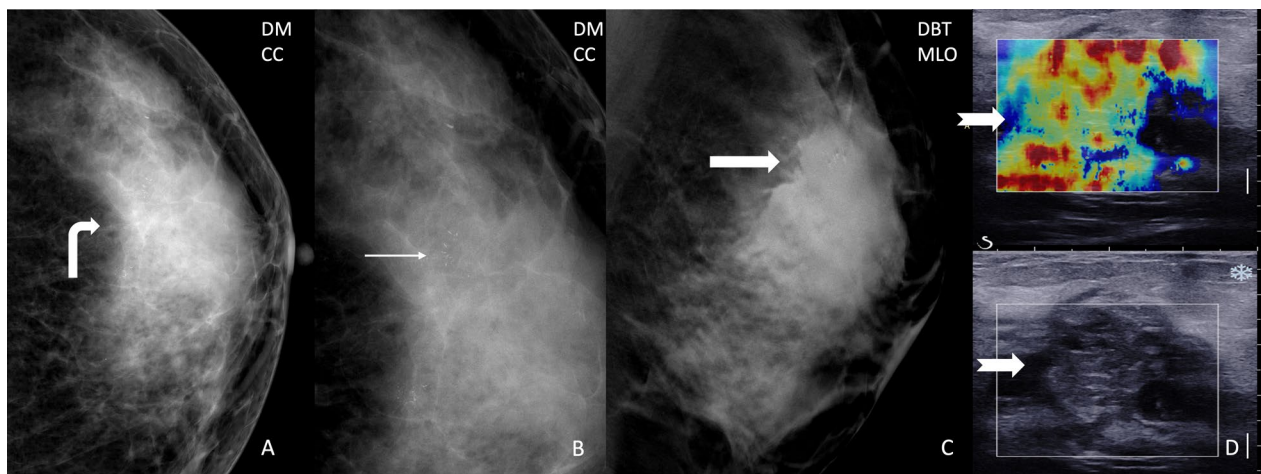
Fig. 3 A 46-year-old patient with a palpable lump in left breast underwent mammography which showed an irregular high density lesion with indistinct margins seen on DM (curved arrow) on CC views (**A** and **B**) with amorphous calcifications (thin arrow in **B**). DBT showed superior lesion conspicuity and demonstrated spiculated margins in the lesion making it a BIRADS 5 category mass (Thick arrow in **C**). USG image **D** confirmed the presence of the heterogenous mass lesion with increased stiffness as shown on elastography map (notched tail arrow in **D**). Percutaneous unguided biopsy was performed and HPE was a mucinous carcinoma
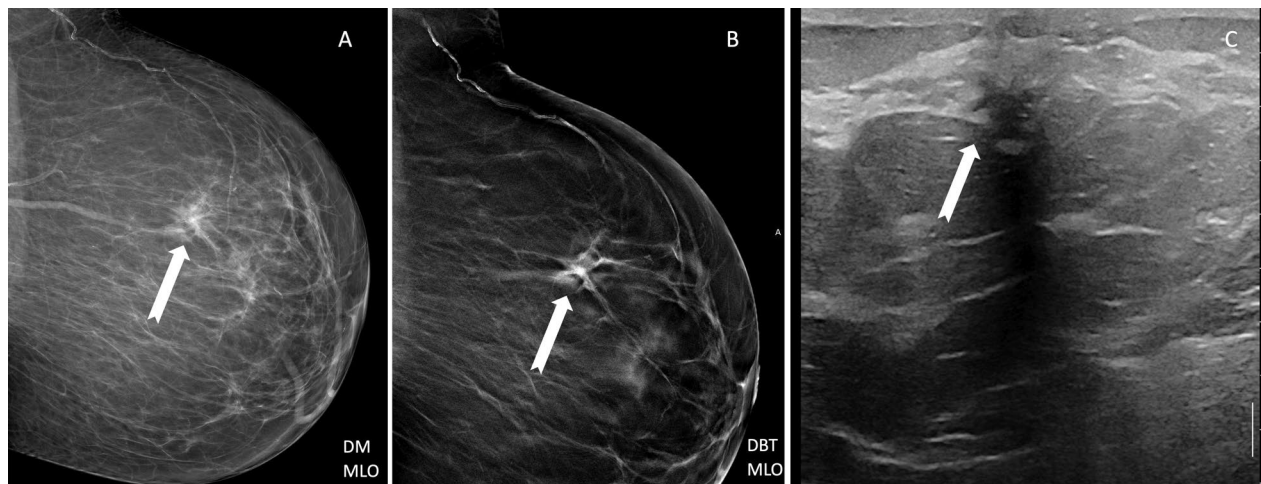
Fig. 4 A 48-year-old patient had undergone right modified radical mastectomy for breast cancer and came to us for screening of the left breast after 1 year. One post-operative scan after 6 months of operation had been done in a private diagnostic center which was reported as normal. In the current scan, 6 months after the first postoperatives scan, a focal area of architectural distortion (notched tail arrow) was visible on DM (**A**) and DBT (**B**) images. USG (**C**) also revealed a focal heterogenous area with posterior shadowing and BIRADS 4 assessment was made. US guided biopsy was done and HPE was invasive carcinoma

[23] who found overall accuracy rates of 86.9% using DM alone, 90% with DM + DBT and 93.7% with the combined usage of all three modalities in conjunction with each other. They also reported higher sensitivity for DM + DBT + US of 95–98.9% as compared to DM alone (80.5–89.2%), similar to ours.

Higher diagnostic accuracy and higher sensitivity of the combination of mammography and ultrasound in contrast with mammography alone was also demonstrated by Berg et al. [27]. The combination had a higher sensitivity of 77.5% as compared to mammography alone which had a sensitivity of 50%. They found a significantly higher diagnostic accuracy of 91% for mammography plus ultrasound combined in comparison to mammography alone which was 78%.

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 9 of 11
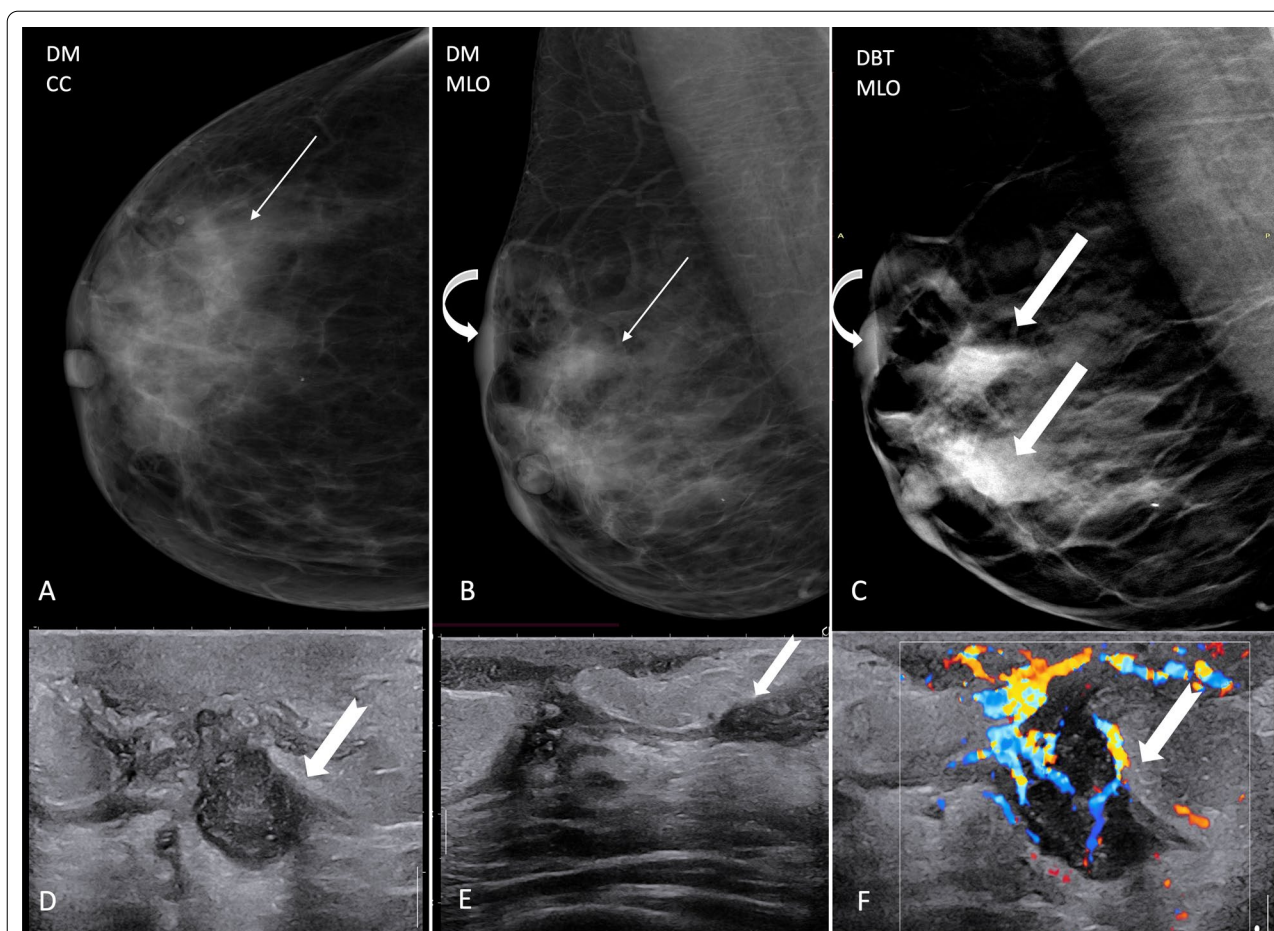
Fig. 5 A 44-year-old patient presented with breast pain and swelling. DM images **A** and **B** revealed an indistinct high density lesion (thin arrow) with associated skin thickening (curved arrow). DBT image **C** showed two high density masses with obscured margins (block arrows) and BIRADS 4B was assigned to this case. However, USG images helped to characterize the nature of the lesions and showed the presence of homogenous internal echoes extending into ducts with increased vascularity (notched tail arrows) raising the suspicion of an inflammatory/infective etiology (**D**–**F**). US-guided aspiration of this lesion confirmed it to be an acute inflammatory pathology

Ying et al. [28] also reported higher sensitivity of 99.19% and higher NPV of 99.37% with combined US and Mammography. Buchberger et al. [29] also had higher sensitivity of 90.6% with combined MM + USG as compared to 78.5% with mammography alone.

Our study had a few limitations: As compared to western screening studies, our study had a relatively small sample size. Awareness about screening for breast cancer is, unfortunately, still lacking in our nation and thus we had very few cases that came for screening. Since ours is a tertiary care cancer hospital, our data set comprised of patients who had advanced stages of malignancies that could be detected on DM alone, thus we might have underestimated the importance of DBT to a certain extent. Pathological specimens of 77 cases were not available as some of these women were lost to follow up while others did not get treated further in our institute.

Conclusions

Our study showed that DM + DBT combined showed higher sensitivity, PPV, NPV and diagnostic accuracy in diagnosing breast neoplasms. It provided better lesion conspicuity and more confident diagnosis. The addition of US to DM and DBT was instrumental in characterizing lesions and further increased the sensitivity and diagnostic accuracy and significantly increased the NPV, thus proving useful in better BIRADS characterization. Most of the current data on the usefulness of DBT has been demonstrated in screening mammograms. Since the bulk of mammograms in our study were diagnostic, DBT also showed usefulness in such cases, signifying its role in diagnostic mammography.

Joshi *et al. Egypt J Radiol Nucl Med*   (2022) 53:1

Page 10 of 11

predictive value; NPV: Negative predictive value; ACR: American college of radiology; CC: Cranio-caudal; MLO: Mediolateral oblique.

Authors' contributions
Pranjali Joshi and Neha Singh conceptualized the project and collected the data, wrote the manuscript. Gaurav Raj, Ragini Singh helped in writing the manuscript. Kiranpreet Malhotra and Namrata Awasthi proof read the manuscript. All authors read and approved the final manuscript.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The hospital ethics committee gave approval for the study. IEC number- 40/18.

Consent for publication
N/A.

Competing interests
The authors declare that they have no competing interests.

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Joshi *et al. Egypt J Radiol Nucl Med*   *(2022) 53:1*

Page 11 of 11

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