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Original Research Article

Breast MRI: A Cornerstone in the Comprehensive Assessment of Breast Lesions

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Conflict of interest: Nil

Abstract:

Breast MRI has emerged as an indispensable asset in the thorough assessment of breast lesions, distinguished by its unmatched sensitivity in both detection and characterization. Its adeptness in identifying benign and malignant lesions proves invaluable, especially among women with dense breast tissue or elevated risk profiles for breast cancer. Beyond characterization, breast MRI plays a pivotal role in staging breast cancer, offering precise assessments of tumor size, disease extent, and neighbouring tissue involvement, thereby guiding treatment strategies and surgical interventions with unparalleled accuracy. Furthermore, its utility extends to guiding biopsy procedures, ensuring targeted sampling of suspicious lesions, and informing treatment decisions by furnishing critical insights into tumor attributes and disease burden. In summation, breast MRI emerges as an indispensable cornerstone in the holistic management of breast lesions, significantly enhancing patient outcomes and tailoring care to individual needs.

Keywords: BIRADS, Kinetics Curves, Dynamic CONTRAST MRI, ACR.

Introduction

Breast cancer is the most common malignancy among women worldwide. In 2020, it surpassed lung cancer as the leading cause of global cancer incidence, with an estimated 2.3 million new cases, representing 11.7% of total cancer cases [1].

The global burden of breast cancer is expected to reach almost 2 million by 2030. According to the data, breast cancer in India accounted for 13.5% (178,361) of all cancer cases and caused 10.6% (90,408) of all deaths, with a cumulative risk of 2.81 [2].

Radiological evaluation using mammography, ultrasound, and MR mammography is included in the triple assessment process for breast cancer. Mammography serves as the main imaging method for identifying early breast cancer.

Nevertheless, its sensitivity and specificity can vary, typically ranging between 68-88% for sensitivity and 82-98% for specificity [3].

Objectives

- To study various dynamic kinetic enhancement patterns in different breast lesions on Contrast Enhanced MRI.
- To evaluate the efficacy of Dynamic Contrast Enhanced MRI in the diagnosis of breast lesions, with histopathological correlation.

Review of Literature

Shafqat et al. (2011) found irregular margins, strong heterogeneous enhancement, and Type III kinetic curves on DCE-MRI correlate significantly with breast cancer malignancy, with MRI sensitivity of 94% and specificity of 85% [4]

Huang et al. (2016) correlated larger size, irregular shape, and heterogeneous enhancement on DCE-MRI with higher WHO histopathological grades in invasive ductal carcinoma [5]

Abe et al. (2016) demonstrated that ultrafast MRI enhances diagnostic accuracy, showing significant differences in enhancement rates and kinetic curves between benign and malignant lesions [6]

Yang et al. (2016) showed that kinetic modelling improves specificity in breast lesion classification compared to traditional methods, with sensitivity of 82% and specificity of 65% using their model [7].

Kim et al. (2018) highlighted delayed-phase MRI's accuracy in assessing residual tumor size post-chemotherapy, with ICC values of 0.76 for total tumor size agreement compared to histopathology [8].

Bakde et al. (2019) emphasized DCE-MRI's high accuracy in diagnosing breast lesions, with sensitivity of 96.29%, specificity of 89.47%, and an accuracy of 93.47% when correlated with histopathological findings [9].

Mostafa et al. (2019) evaluated DCE-MRI and DWI for distinguishing benign from malignant breast lesions, noting sensitivity of 75.8% and specificity of 73.7% for DCE-MRI, and sensitivity of 82.8% and specificity of 73.7% for DWI [10].

Kumari et al. (2020) noted DCE-MRI's high sensitivity (98.18%) but moderate specificity (55.56%) in detecting breast lesions, with PPV of 93.10% and NPV of 83.33% [11].

Veena and Baru (2020) confirmed MRI's utility in evaluating postoperative changes and distinguishing lesion types through kinetic analysis, achieving sensitivity of 88.8%, specificity of 86.3%, and an accuracy of 97.5% when combining morphological and kinetic assessments [12].

Onishi et al. (2020) linked ultrafast DCE-MRI parameters to aggressive breast cancer characteristics, demonstrating significant differences in MS and BAT values between different histological and molecular subtypes [13].

Ahluwalia et al. (2021) underscored DWI and DCE-MRI's combined efficacy in differentiating benign and malignant lesions based on morphological and kinetic features, achieving sensitivity of 98% and specificity of 86% [14].

Singh et al. (2021) validated multiparametric MRI's high sensitivity and specificity (96% and 78.5%, respectively) in characterizing breast lesions, emphasizing the complementary roles of DWI and DCE-MRI [15].

Karavas et al. (2022) noted the significance of type 2 dynamic curves in predicting malignancy when combined with morphological assessment, showing moderate sensitivity and specificity in lesion classification [16].

Dakhil et al. (2022) highlighted DCE-PWI's role in distinguishing benign from malignant breast lesions based on perfusion characteristics, contributing to accurate diagnostic differentiation [17].

Boruah et al. (2023) supported combining DCE-MRI and ADC mapping for effective characterization of palpable breast lesions, showing statistically significant differences in ADC values between benign and malignant lesions across different BI-RADS categories [18].

Materials and Methods

Source of Data: Females aged more than 18 years undergoing breast screening or presenting with clinically suspicious breast lumps at the Department of Radio diagnosis, KIMS, Bhubaneswar.

Sample Size: All consecutive cases undergoing dynamic contrast-enhanced MRI (DC-MRI) breast scans and histopathological examination during the study period.

Type of Study: Cross-sectional study.

Duration of Study: 2 years (July 2022 to July 2024).

Inclusion Criteria:

- Patients with clinically suspicious breast lesions.
- Patients with a family history of breast neoplasm presenting for screening.
- Follow-up patient's post-breast-conserving surgery and post-neoadjuvant chemotherapy.

Exclusion Criteria:

- Contraindications for MRI (e.g., incompatible metallic implants, claustrophobia).
- Contraindications to gadolinium-based contrast media (e.g., allergy, compromised renal function).

Methodology: Prospective enrollment of eligible females, MRI conducted using a 1.5T SIGNA-GE MRI Machine.

Imaging included T1/T2 axial sequences, DWI, and dynamic contrast-enhanced (DCE) MRI with VIBRANT protocol. Gadolinium-based contrast was administered intravenously.

Statistical Analysis: Data were analyzed using frequencies, percentages, mean with standard deviation (SD), Chi-square test for categorical variables, and calculation of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Significance was set at $p < 0.05$.

Result and Observation

This study enrolled 38 female patients aged 18 years and older presenting at KIMS, Bhubaneswar, with clinically suspicious breast lesions or for screening via MRI. The majority of patients were over 50 years old (44.7%), with a mean age of 47.52 years. Clinical presentations predominantly included breast lumps (78.9%), pain (26.3%), and discharge (21.1%), while 28.9% presented with nonspecific symptoms. Family history of breast disease was rare (5.3%).

MRI revealed predominantly focal lesions (73.7%) with minimal background parenchymal enhancement (47.4%). Mass-like lesions were mostly oval (39.5%) and irregular (26.3%), with internal enhancement noted in 55.3% of cases. Non-mass lesions lacked defined shapes (86.8%) and margins (89.5%). ACR BI-RADS classification showed Type B (52.6%) and Type C (31.6%) as the most common findings.

Histopathological correlation indicated malignancy in 57.9% and benignity in 42.1% of cases, with MRI demonstrating a sensitivity of 85.7% and specificity of 83.3%. Kinetic curve analysis revealed Type 3 curves as most frequent (47.4%). Associated MRI findings included lymphadenopathy (36.8%) and muscle invasion (7.9%).The findings from the current study resonate strongly with several key insights drawn from the existing literature on MRI's diagnostic capabilities in breast imaging. Shafqat et al. (2011) noted that irregular margins, heterogeneous enhancement patterns, and Type III kinetic curves on dynamic contrast-enhanced MRI (DCE-MRI) significantly correlate with breast cancer malignancy.

These characteristics align closely with the observations in the current study, where 26.3% of lesions exhibited spiculated margins, 55.3% showed heterogeneous enhancement, and kinetic curves varied across Type 1 (36.8%), Type 2 (15.8%), and Type 3 (47.4%) (4). Similarly, Huang et al. (2016) and Abe et al. (2016) emphasized the importance of irregular lesion shapes, larger sizes, and distinct enhancement features in predicting higher histopathological grades and malignancy. In this study, irregular (26.3%) and lobular (7.9%) lesion shapes were noted, with significant differences in enhancement characteristics observed among different lesion types, supporting the diagnostic relevance highlighted in these studies [5,7].

The current study's findings also align with Bakde et al. (2019), who demonstrated high sensitivity (85.7%) and specificity (83.3%) of MRI in distinguishing benign (42.1%) and malignant (57.9%) breast lesions. This aligns well with the sensitivity (85.7%) and specificity (83.3%) reported here, validating MRI's robust performance in lesion characterization [9].

Furthermore, insights from Mostafa et al. (2019) and Kumari et al. (2020) regarding MRI's role in differentiating benign from malignant lesions further corroborate the current findings. Mostafa et al. highlighted sensitivity ranging from 75.8% to 98.18% and specificity from 55.56% to 83.3% for DCE-MRI, which overlaps with the sensitivity and specificity outcomes observed in this study. Kumari et al. noted a similar trend, emphasizing high sensitivity (98.18%) but moderate specificity (55.56%) in detecting breast lesions, with positive predictive value (PPV) and negative predictive value (NPV) values also aligning with the current findings (PPV: 75.0%, NPV: 90.9%) [10,11].

Moreover, the comprehensive approach of multiparametric MRI discussed by Veena and Baru (2020), involving morphological and kinetic assessments, supports the current study's methodology and findings.

Their findings of high sensitivity (88.8%), specificity (86.3%), and overall accuracy (97.5%) in postoperative evaluation and lesion characterization resonate well with the current study's emphasis on combining morphological features and kinetic curve analysis to enhance diagnostic accuracy [12].

1. Correlation of Kinetics Curves with Type of Lesion on Histopathology

Table 1: Correlation of Kinetics curves with Type of lesion on histopathology

Type Kinetics curve on dynamic study	No. of patients	Type of lesion on histopathology				p-value[1]
		Benign		Malignant		
		No.	%	No.	%	0.001*
Type 1	14	12	85.7	2	14.3	
Type 2	6	1	16.6	5	83.3	
Type 3	18	2	11.1	16	88.9	

[1]Chi-square test, *Significant

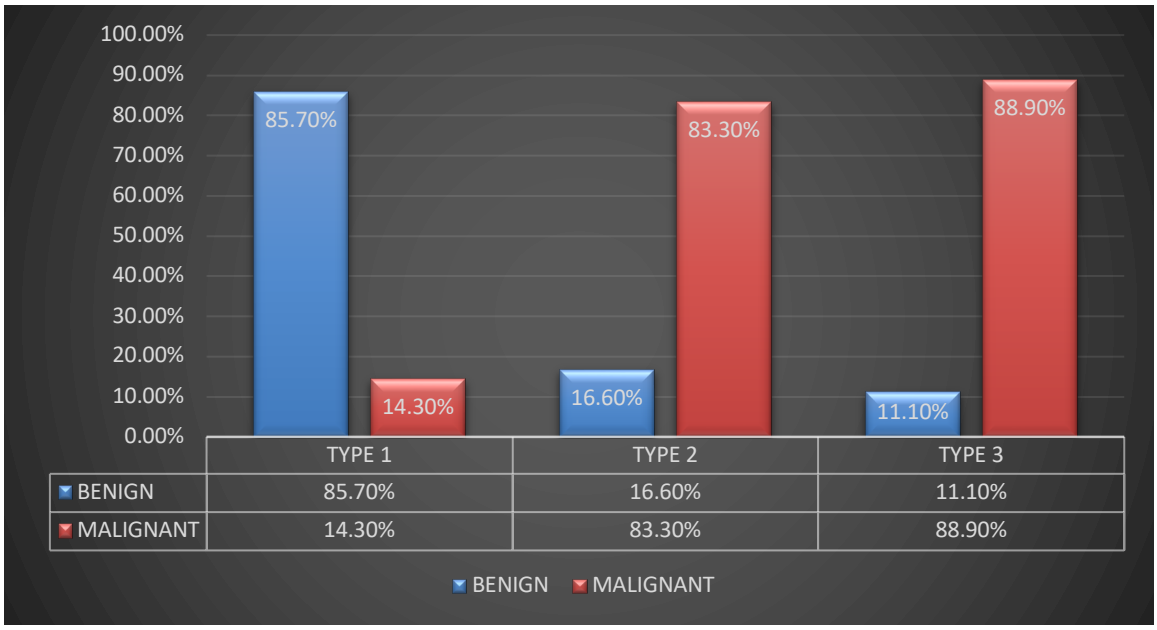

Figure 1: Correlation of Kinetics curves with Type of lesion on histopathology

2. Correlation of BIRADS (MRI) with Type of Lesion on Histopathology

Table 2: Correlation of BIRADS (MRI) with Type of lesion on histopathology

BIRADS(MRI)	No. of patients	Type of lesion on histopathology				p-value[1]
		Benign		Malignant		
		No.	%	No.	%	
BIRADS-I	1	1	100.0	0	0.0	NA
BIRADS-II	10	9	90.0	1	10.0	
BIRADS-III	10	4	40.0	6	60.0	
BIRADS-IV	1	0	0.0	1	100.0	
BIRADS-V	16	0	0.0	16	100.0	

[1]Chi-square test, NA-Not applicable as >1 0s in a column

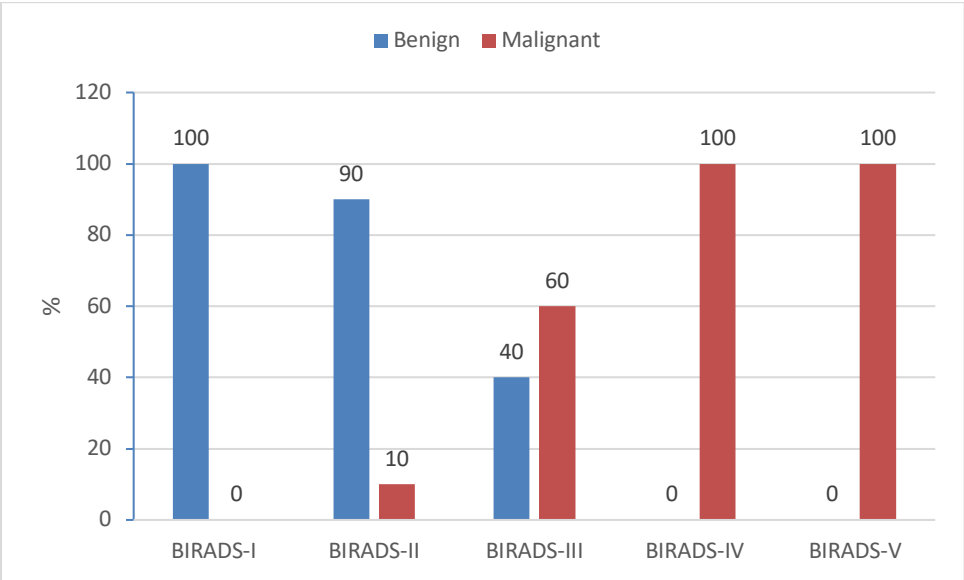

Figure 2: Correlation of BIRADS (MRI) with Type of lesion on histopathology

Table 3: Distribution of patients according to histopathology findings

Histopathology findings	No. (n=38)	%
Colloid carcinoma	1	2.6
DCIS	1	2.6
Ductal CA breast	12	31.6
Ductal papilloma	1	2.6
Fat necrosis	1	2.6
Fibroadenoma	5	13.2
Fibroadenosis	2	5.3
Fibrocystic disease	2	5.3
Fibrocystic disease of breasts	1	2.6
Invasive CA	2	5.3
Invasive ductal CA	3	7.9
Invasive CA (no ductal type)	1	2.6
Invasive CA (no otherwise specified)	1	2.6
Lobular CA of breast	1	2.6
Metastatic deposit in breast	1	2.6

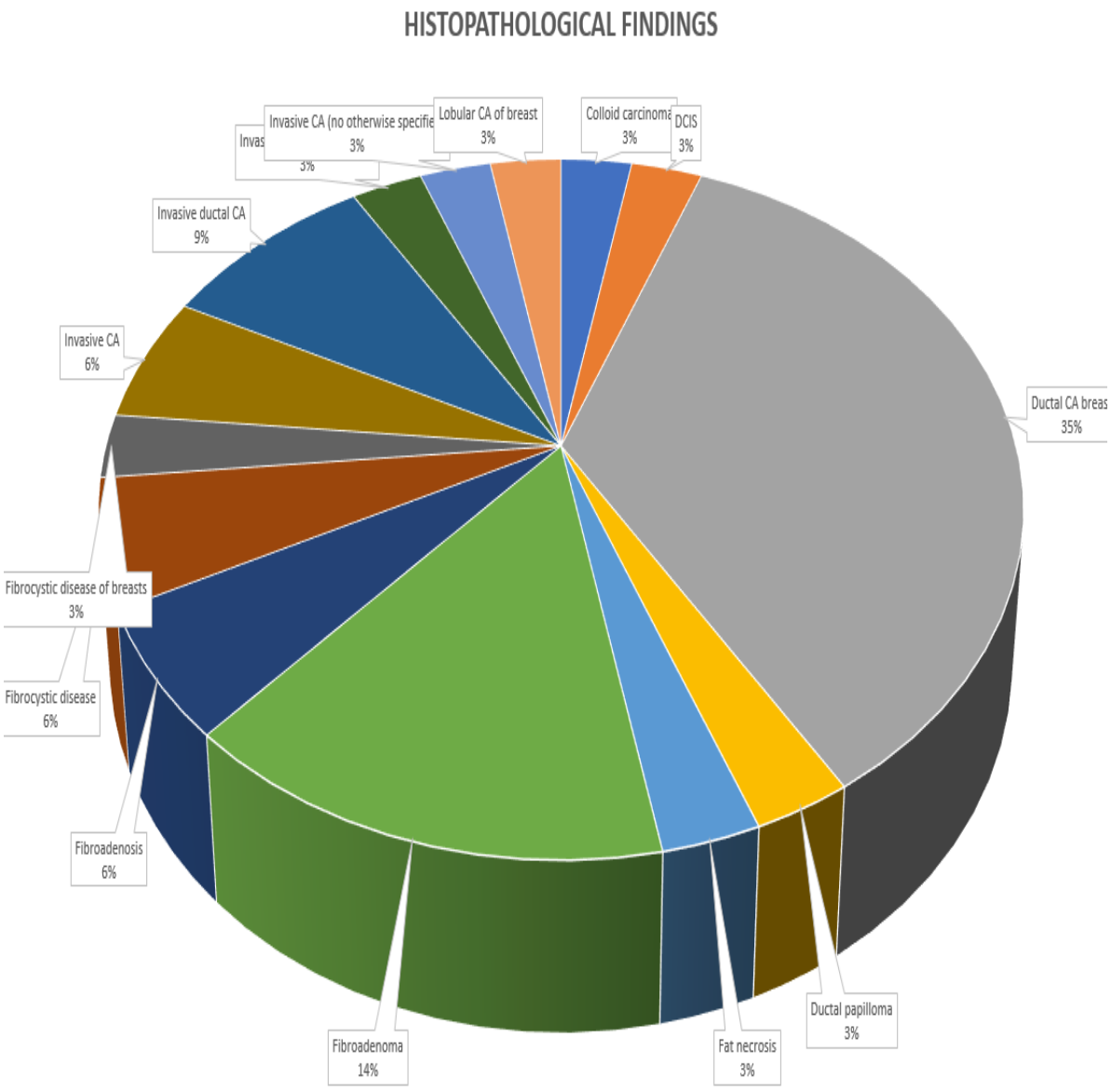

Figure 3: Distribution of patients according to histopathology finding

3. Predictive Value of MRI in Differentiating Beningn Lesion from Malignant Lesion

Table 4: Predictive value of MRI in differentiating benign lesions from malignant lesion: Histopathology as gold standard

Type of lesion on MRI	Type of lesion on histopathology				Total	
	Benign		Malignant			
	No.	%	No.	%	No.	%
Benign	12	31.6	4	10.5	16	42.1
Malignant	2	5.3	20	52.6	22	57.9
Total	14	36.8	24	63.2	38	100.0
Sensitivity	85.7					
Specificity	83.3					
PPV	75.0					
NPV	90.9					

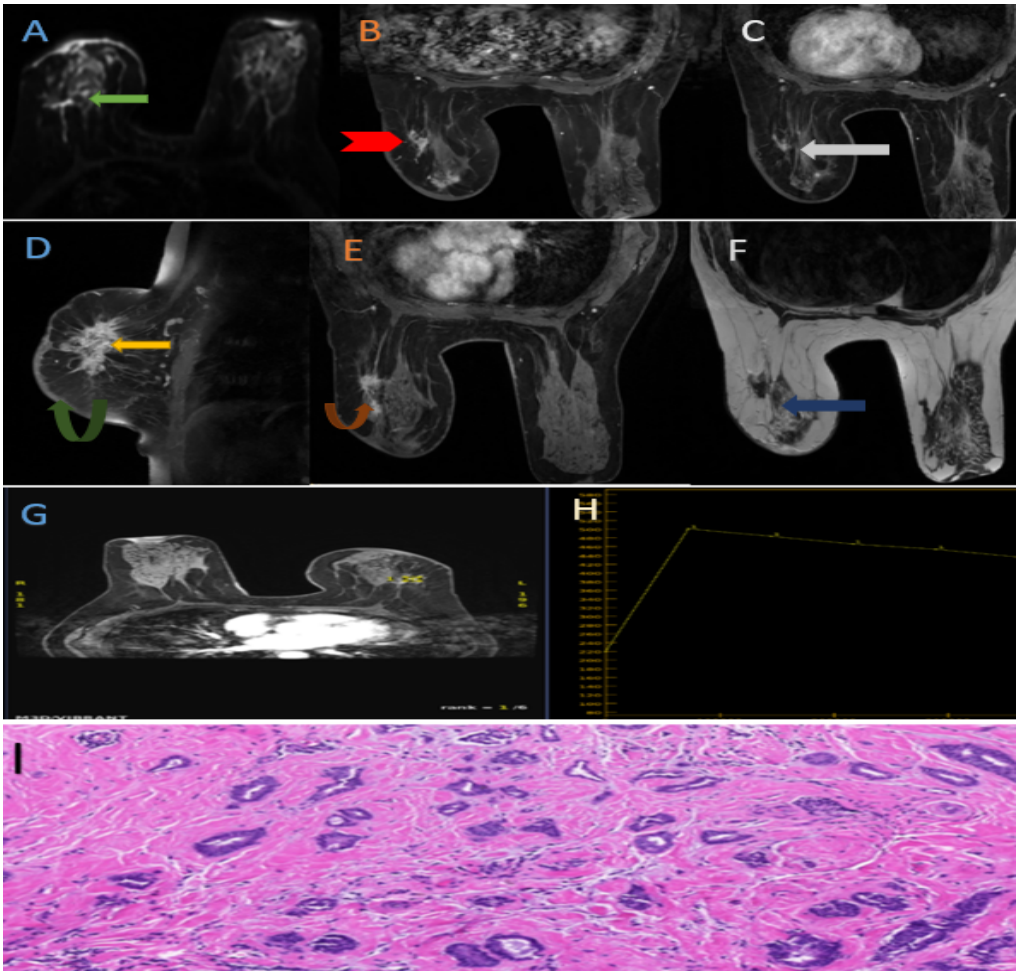

Figure 4: Invasive Ductal Carcinoma Dynamic Contrast Enhanced MRI Images. Image (A) showing Diffusion weighted images showing area of true diffusion restriction in left breast parenchyma marked in green arrow (B) showing axial post contrast images showing satellite lesion showing contrast enhancement in left breast parenchyma marked in red arrowhead (C) showing axial post contrast vibrant images showing satellite lesion showing dynamic contrast enhancement in left breast parenchyma marked in white arrow (D) Image showing sagittal post contrast image of left breast showing irregular marginated spiculated mass lesion showing contrast enhancement marked in yellow arrow and thickened left nipple areolar complex marked in curved green arrow (E)VIBRANT Image of left breast satellite lesions showing dynamic enhancement (F) T2 nonfat sat Image of left breast showing heterogenous left breast parenchyma marked in blue arrow (G&H) Image showing type III curve on dynamic study in region of interest demonstrating potential malignant nature of lesion (I) histopathological slide showing invasive ductal carcinoma with infiltrative nests of malignant cells.

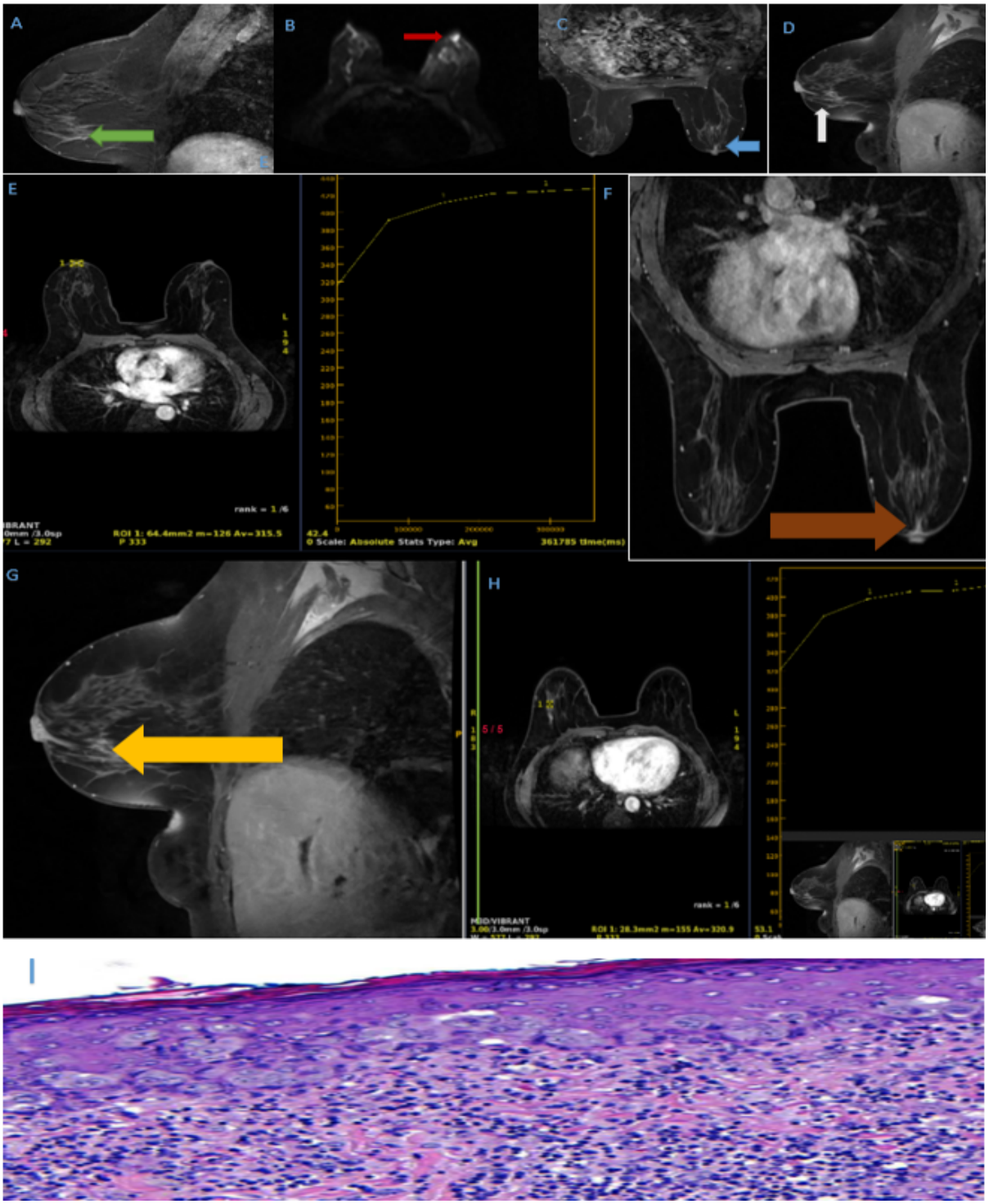

Figure 5: Pagets Disease of Breast Dynamic Contrast Enhanced MRI images. image (A) showing sagittal fat-suppressed T1-weighted image showing non-mass-like hyperintensity in the outer central right breast (green arrow) (B) Diffusion weighted image showing areas of true restriction in right nipple, periareolar lesion and in the outer central right breast. (Red arrow) (C and D) Post contrast axial and sagittal images showing non-mass-like enhancement in the outer central right breast (white arrow) and unilateral nipple enhancement on the right (sky-blue arrow) (E) Image showing type I curve on dynamic contrast study in region of interest (nipple region) (F) unilateral right sided nipple enhancement on dynamic contrast enhanced MRI. (Brown arrow) (G) Non-mass-like enhancement in the outer central right breast (Yellow arrow) (H) Image showing type I curve on dynamic contrast study in region of interest (outer central right breast) (I) Histopathological slide demonstrating Paget cells occupying the basal epidermis with chronic inflammation.

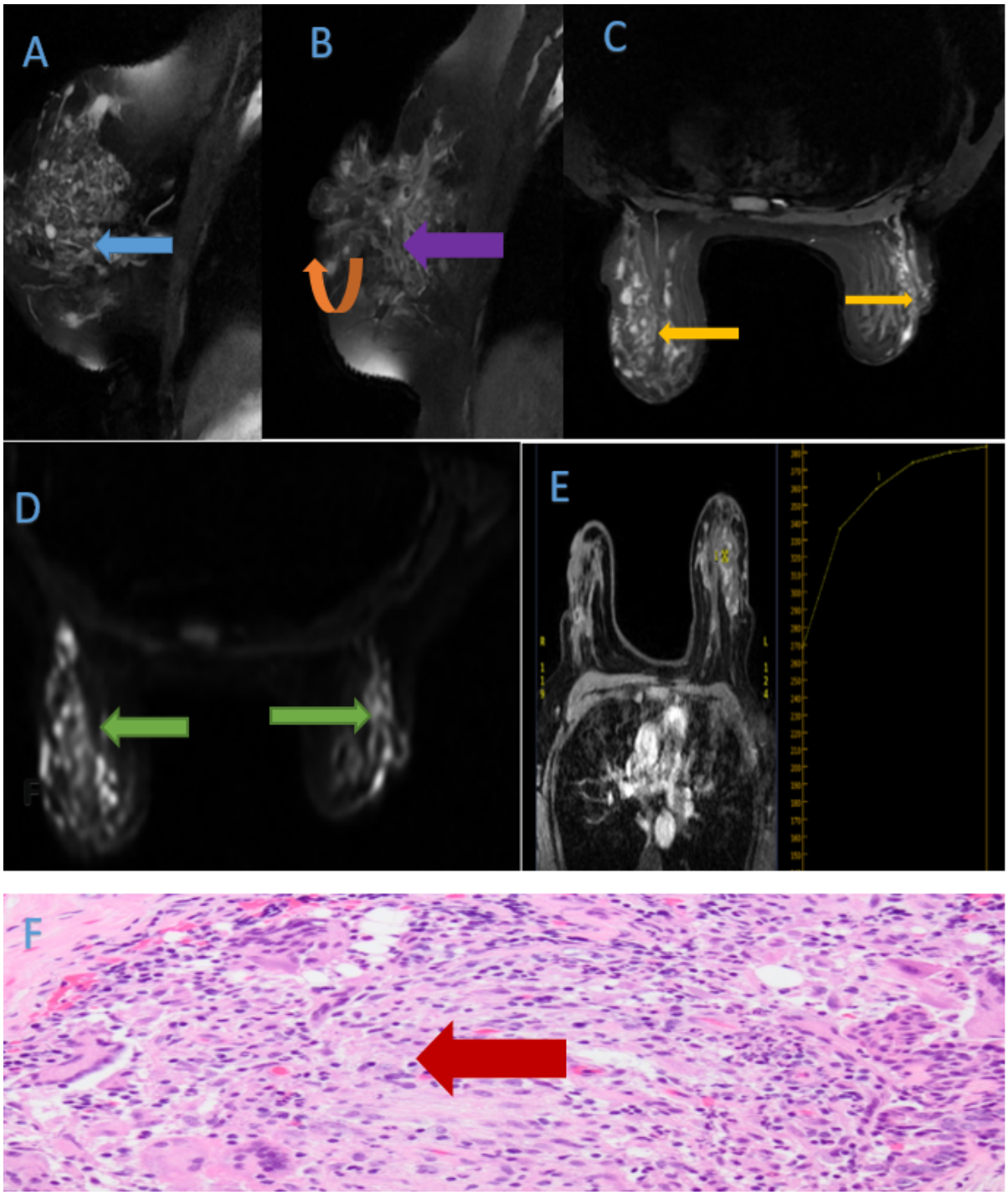

Figure 6: Tubercular Granulomatous Mastitis Dynamic Contrast Enhanced MRI images. image (A) showing left sagittal t2-weighted fat-suppressed showing heterogeneous parenchyma with areas of architectural distortion in left breast marked in sky-blue colour arrow (B) showing Right sagittal t2-weighted fat-suppressed showing heterogeneous breast parenchyma with skin thickening (curved orange arrow)and areas of architectural distortion in breast parenchyma marked in purple arrow (c) showing axial post contrast vibrant images demonstrates multiple round to oval lesions with irregular margins scattered in the bilateral breast parenchyma showing clustered ring enhancement marked in yellow arrow (d)axial image showing diffusion weighted images showing areas of true diffusion restriction in bilateral breast parenchyma marked in green arrows (E) Image showing type I curve on dynamic contrast study in region of interest demonstrating benign nature of lesions (F) Histopathological slide showing Breast lobule under haematoxylin and eosin stain showing expansion due to a granulomatous inflammation marked in red arrow

Discussion

In this study, the age distribution of patients showed that more than one-third were over 50 years old (44.7%), followed by the 40-50 age group (34.2%) and less than 40 years (21.1%). The mean age was 47.52 ± 10.16 years, ranging from 26 to 67 years. Veena and Baru (2020) reported a slightly younger mean age of 44 years, with the majority falling in the 41-60 years' age group (52.5%). Kumari et al. (2020) found a mean age of 51.42 ± 16.12 years, ranging from 17 to 80 years. Clinical presentation in this study predominantly included breast lumps (78.9%), followed by nonspecific symptoms (28.9%), pain (26.3%), and discharge (21.1%). Kumari et al. (2020) similarly found that breast lump was the most common presenting symptom in both benign and malignant lesions (89. 1%).

Family history of breast disease was present in only 5.3% of patients in this study. Kumari et al. (2020) did not specify family history prevalence but focused on the presenting symptoms and lesion characteristics. Regarding lesion characteristics on MRI, this study noted that right and left side focal lesions were present in 42.1% and 31.6% of patients, respectively. Right and left side multifocal lesions were present in 23.7% and 15.8% of patients, respectively. Kumari et al. (2020) observed multifocal/multicentric lesions in 16% of their cases and bilateral breast lesions in 6%. Background parenchymal enhancement on MRI in this study showed minimal enhancement in more than one-third of patients (47.4%), followed by mild (36.8%), moderate (13.2%), and marked (2.6%) enhancements. For mass-like lesions on MRI in this study, the shapes were predominantly oval (39.5%) and irregular (26.3%), with spiculated (26.3%) and well-defined margins (23.7%). Internal enhancement was observed in 55.3% of cases. Ahluwalia et al. (2021) highlighted that MRI features such as irregular shape, spiculated margins, and heterogeneous enhancement on DCE-MRI strongly predict malignancy. Non-mass lesions on MRI in this study were characterized by focal and linear presentations in 7.9% and 5.3% of patients, respectively, with ill-defined margins in 10.5% of cases and homogeneous internal enhancement in 10.5% of cases. Veena and Baru (2020) reported non-mass like enhancements including ductal, segmental, regional, and multiregional patterns. Lymphadenopathy was present in 36.8% of patients in this study, consistent with Veena and Baru (2020), who noted axillary lymphadenopathy in 50% of malignant lesions. Associated findings on MRI in this study included skin thickening (10.5%), muscle invasion (7.9%), and nipple retraction (2.6%). Veena and Baru (2020) similarly reported skin retraction (61.1%) and thickening (55.5%) as common findings in malignant lesions. ACR BI-RADS classification in this study showed predominance of Type B (52.6%) and Type C (31.6%) categories. Kumari et al. (2020) found BI-RADS III to be the most common category for benign lesions and BI-RADS V for malignant lesions. Kinetic curve analysis in this study revealed Type 3 curves in 47.4% of patients, Type 1 in 36.8%, and Type 2 in 15.8%. Dakhil et al. (2022) and Bakde et al. (2019) similarly found Type 3 curves to be common in malignant tumors, reflecting washout patterns. Histopathological analysis in this study indicated that malignant lesions accounted for 57.9% of cases, with ductal carcinoma being the most common (31.6%). Kumari et al. (2020) reported a higher proportion of malignant lesions (64.1%) and noted invasive ductal carcinoma as the predominant histology. MRI's diagnostic accuracy in this study, using histopathology as the gold standard, showed sensitivity of 85.7% and specificity of 83.3% in distinguishing benign from malignant lesions. This aligns with findings by Singh et al. (2021), who reported high sensitivity (96%) and specificity (78.5%) for DCE-MRI in characterizing breast lesions [15].

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