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Value of the Abbreviated MRI Protocol in Preoperative Assessment of Breast Cancer

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Abstract

MRI breast has a great value in breast cancer staging with subsequent improvement in the surgical decision and management. However, the full diagnostic protocol (FDP) of breast MRI is time and cost consuming, so it is not widely applicable. The abbreviated protocol of breast MRI (MRI-AP) showed comparable accuracy to the FDP in screening high-risk women, but it has not been sufficiently tested in preoperative assessment of breast cancer. Primarily to assess the accuracy of the MRI-AP in preoperative staging of breast cancer in comparison to the FDP. Secondarily to perform time analysis of the MRI-AP. Cross sectional prospective. Sixty women (Mean age 42.71±12.17, Range 30-70) with pathologically proved breast cancer referred for preoperative MRI assessment. 1.5T/ T1-weighted, T2-weighted with fat-suppression, diffusion weighted and dynamic sequences with a spin-echo-planner images. All patients underwent mammography and breast US followed by MRI assessment using the standard FDP. Image analysis was performed blindly and independently by two MRI readers in four separate sessions. In the first two sessions, the reconstructed images from the pre and first post contrast T1WI (first MIP and subtraction) were made available to the readers as an AP. Then, the time/signal intensity curve and the remaining images of the FDP were added to the assessment in the subsequent two sessions. Both protocols were compared regarding the acquisition time, interpretation time, cancer yield, and accuracy in staging in correlation to the histopathological and operative findings. ROC curve analysis, area under the curve, Cohen Kappa, and Validity statistics. Sixty patients were included where in 31 of them (51.7%) additional pathologically proved malignant lesions were detected with AP. While FDP detected additional lesions in 33 patients (55%), resulting in upgrade of their surgical decision. The calculated sensitivity, specificity, positive predictive value and negative predictive value of AP versus FDP were 96.8% versus 100%, 100% versus 77.8%, 100% versus 96.9% and 81.8 % versus 100% respectively, while accuracy was 97.2 % for both protocols with no statistically significant difference between their AUCs (P-value=0.202), with significantly shorter acquisition and interpretation times compared to the FDP (3.3 versus 35 minutes) and (45 versus 108 seconds) respectively (P-value <0.001). AP was comparable to FDP in breast cancer staging with advantageous time saving.

Keywords: Breast cancer, Abbreviated MRI, full diagnostic protocol, preoperative assessment

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1. Introduction

Breast cancer is one of the leading causes of death among women and its prognosis is depending, largely, on the initial staging and subsequent management (1). Magnetic resonance imaging (MRI) is highly accurate in the assessment of breast cancer (BC) regarding the lesion size and extension, the detection of mammographically occult multifocal, multicentric or contralateral cancer foci, as well as the relation of the mass to the chest wall and overlaying skin; that all can modify the patient's management plan and the surgical decision if needed (2). The application of breast MRI in preoperative staging was previously limited to definite scenarios (e.g., invasive lobular carcinoma [ILC]) due to its aggressive behavior, but recently MRI is in increased use in clinical practice for the preoperative assessment of BC, with high sensitivity and acceptable specificity (3). Nevertheless, the full protocol of breast MRI is associated with high direct and indirect costs. These, together with the lack of centers that offer high-quality breast MRI, limit its clinical access (4). Hence, utilizing an abbreviated breast MRI protocol (MRI-AP) in the preoperative staging became an essential requirement to save time and cost (5).

Previous studies that advocated the use of the MRI-AP were because invasive breast cancers and high-grade DCIS tend to enhance early and often be obvious in the early post-contrast phase due to the associated increase of angiogenesis and vessel permeability. While benign lesions frequently enhance later with gradually increased background parenchymal enhancement (5–7).

The feasibility of the abbreviated breast MRI protocol for breast cancer screening was widely reported in many studies that concluded that the image acquisition and interpretation time could be significantly reduced without a negative impact on diagnostic accuracy (6,8,9). However, to our knowledge, the accuracy of the MRI-AP in detection of malignant non-mass enhancement has not been widely studied. The current study aimed primarily to assess the accuracy of the MRI-AP in comparison to the FDP, and secondarily to perform time analysis of the MRI-AP.

2. Patients and methods

2.1. Study Populations

This prospective cross-sectional study was performed as a single institutional work and was approved by the research ethics committee of the Faculty of Medicine, Assiut University. All included patients signed written informed consent to participate in this research and to publish the data contained within this study. Female patients referred from the surgery department to the diagnostic radiology department of Assiut university hospital, between March 2019 and September 2022, for MRI preoperative assessment of a pathologically proven breast cancer prior to the election of conservative or oncoplastic breast surgery were included in this study. Patients with advanced breast cancer and those with a previous history of ipsilateral breast surgery were excluded from the study. General contraindications to MRI examination and pregnancy were also from the current study exclusion criteria.

2.2. MRI imaging protocol

All MRI examinations were performed using 1.5 Tesla systems (Siemens Magnetom Sempra, Siemens Healthineers, Germany), and the four-channel phased array breast coil was used. Patients were examined in prone position, with arms by the sides of the body, and both breasts were well placed and fitted into the coil to avoid distortion of its contour. The protocol included localizer axial fast spoiled gradient echo, axial T_1WI (repetition time/ echo time “TR/TE” = 540/10ms, field of view “FOV” = 400mm, slice thickness “ST”= 3mm, matrix= 340x512), axial T_2WI (TR/TE= 4500/120ms, FOV= 380mm, ST= 3mm, matrix= 340x512). Axial T_2 with fat suppression (TR/TE= 3600/80 ms, FOV= 380mm, ST =3mm, matrix= 340x512) and axial diffusion weighted imaging (DWI) (TR/TE= 1500/80ms, FOV= 460mm, ST= 4.5mm, and matrix= 340x512) were also acquired before dynamic sequences with a spin-echo EPI (echo-planner imaging) in the axial plane, and sensitizing diffusion gradients were applied along the x, y, and z directions with b values of 50, 400, and 800 s/mm2.

Finally, the intravenous contrast agent (Gadolinium-dimeglumine) (Gd-DTPA) (Magnevist, Schering AG Berlin, Germany) was injected using an automatic power injector at a dose of (0.1 mmol/kg) and a rate of 2ml/s, followed by a 20 ml saline flush administered. Multiphasic (5 phases) dynamic post-contrast sequences were done, first phase was done after 60 seconds, each phase last for about 1 minute with 18 seconds lag time between phases.

2.3. Data processing

Image post processing techniques were applied for all MRI examinations. Subtraction images were obtained by subtraction of the non-enhanced T1 WI images from the contrast-enhanced images. Maximum intensity projection (MIP) images were also obtained from the contrast enhanced images.

2.4. Image analysis

In two separate sessions, MRI readers with different experiences performed the image analysis blindly and independently. In the first session, the reconstructed images from the pre and first post contrast T1WI (first MIP and subtraction) were assessed by the readers as an AP. In the subsequent session, time/signal intensity curves were obtained and then all images of the FDP were made available to the assessment. Both AP and FDP protocols were compared regarding the acquisition time, interpretation time, accuracy in staging in correlation to the histopathological and operative findings.

2.5. Histopathological examination and follow up

All included cases underwent histopathological examination and/or follow up according to their BIRADS. BIRADS II and III lesions were subjected to two annual MRI follow up.

2.6. Statistical analysis

Data were collected and analyzed using the statistical package for social sciences, version 20 (IBM Corp., Armonk, New York, USA). Continuous data were expressed in the form of mean, SD, or median (range), frequency (percentage), FP: false positive; and FN: false negative. The acquisition time, interpretation time, and diagnostic accuracy of the AP were investigated and compared to those of the FDP using the ROC curve and the area under the curve (AUC, 95% CI) analysis.

3. Results

Sixty patients were included in the current study yielding 71 lesions, The age range was between 30 and 70 years. The majority (55%) of women had right breast mass. Based on mammography and breast ultrasound, almost all studied women (90%) had unifocal breast mass and 6 of them had multifocal breast masses. Regarding breast MRI findings, FDP and AP MRI respectively were able to detect additional findings, as multicentricity, contralateral suspicious non mass enhancement (NME), pectoral muscle and skin invasion (Figure 2&3), that were not detected by mammography and breast ultrasound, 24 additional multicentric lesions were detected by both protocols, while contralateral suspicious NME was detected in 4 women by FDP while AP did not consider any of them suspicious, histopathological correlation resulting in 2 false negative lesions in AP. And 2 false positive lesions in FDP (Table 1).

Pectoralis muscle invasion, based on muscle enhancement, was detected in 3 cases while skin invasion was detected in 4 cases by both protocols. All these additional findings led to upgrading of the surgical decision in 33 patients (55%) in AP protocol and in 31 patients (51.7%) in FDP. The calculated sensitivity of AP versus that of FDP was 96.8% vs 100% respectively. While specificity was 100% vs 77.8% respectively.

Table 1. Additional findings in full and abbreviated protocols in preoperative group

Additional findings	Full protocol	Abbreviated protocol
multicentricity	24	24
Contralateral NME	2	0
Pectoral muscle invasion	3	3
Skin invasion	4	4

Table 2. Comparison between full and abbreviated protocols among preoperative group

	Full protocol	Abbreviated protocol
Kappa agreement	**0.859**	**0.884**
Validity measures	**Value**	**Value**
Sensitivity, %	100.0%	96.8%
Specificity, %	77.8%	100.0%
PPV, %	96.9%	100.0%
NPV, %	100.0%	81.8%
Accuracy, %	97.2%	97.2%
AUC	**0.889 (0.725-1.000)**	**0.984 (0.957-1.000) p value=0.202**

Table 3. Acquisition and interpretation times of abbreviated and full diagnostic protocols

	AP	FDP	P-value
Acquisition time	3.3 min	35 min	<0.001
Post processing and interpretation time	45 sec	108 sec	

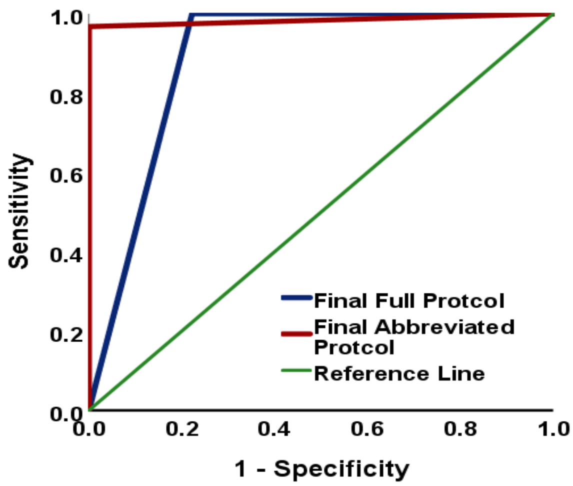


Figure 1. ROC curve for malignancy prediction via MRI full and abbreviated protocols among preoperative group

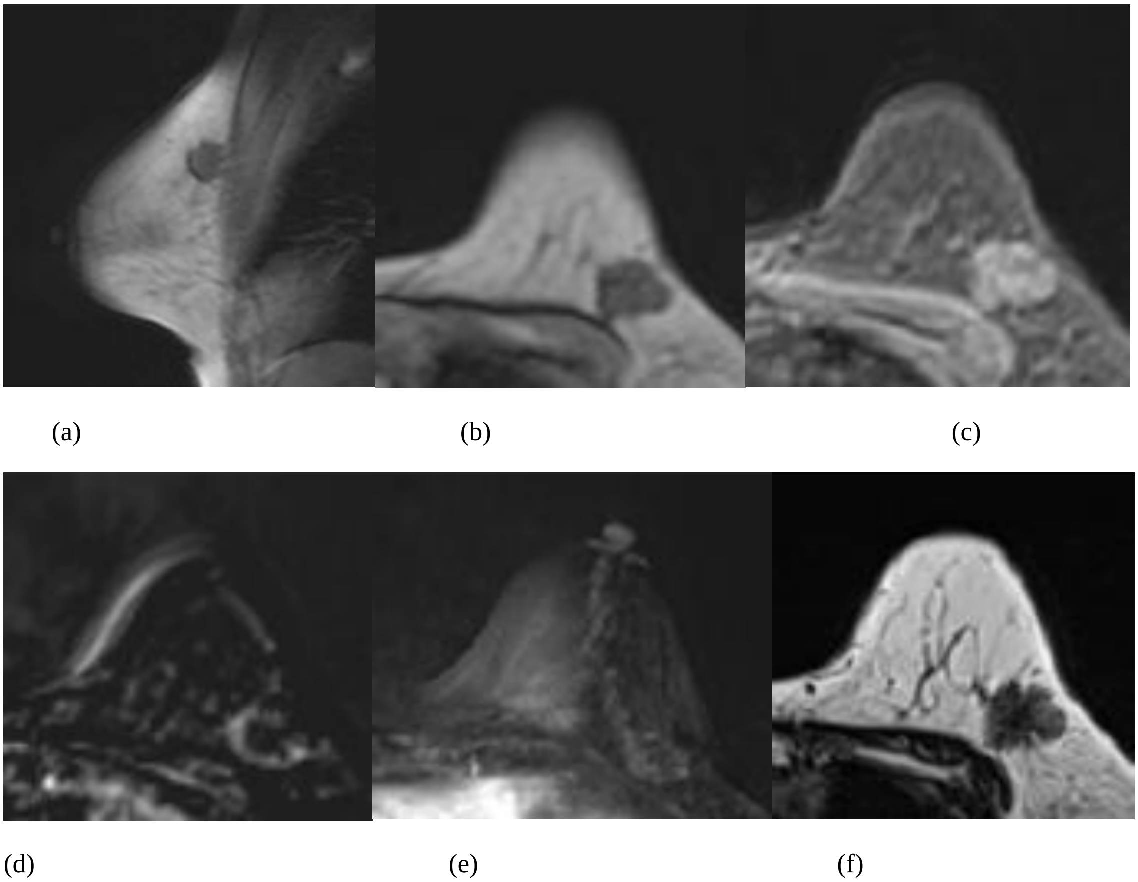
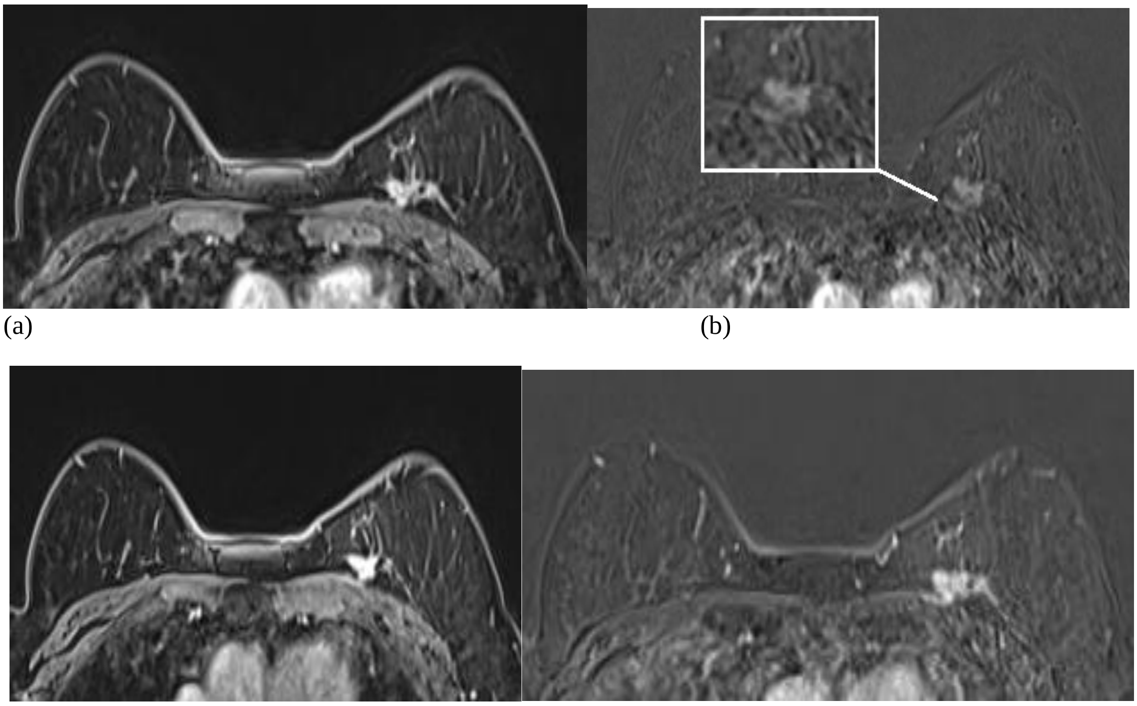


Fig. (2) A 33 yrs. old woman referred with histopathological proved posterior left breast malignant mass lesion to assess chest wall muscle invasion. Localizer T1WI sagittal and axial views (a) & (b) revealed loss of fat planes between mass and pectoralis muscle without enhancement of the muscle. Post contrast fat suppression T1WI (c), its subtraction (d) and MIP (e) no enhancement of the muscle. (f) T2WI revealed preserved fat plane between muscle and mass lesion in all cuts. Patient was scheduled for CBS, follow up after 6 months and 1 year revealed no residual or recurrence.



(a) (b)

(c) (d)

Fig. (3) A 53 yrs. old woman referred with histopathological proved left breast posteriorly located mass lesion for preoperative assessment of pectoralis muscle involvement. 1st post contrast fat supression T1WI (a) and its subtraction (b) revealed spiculated mass lesion intimetly related to the medial part of the pectoralis muscle with superficial enhancment of the pectoralis muscle denoting invasion, which confirmed precisely in late post contrast fat supression T1WI (c) and its subtraction (d). muscle invasion detected by both protocols. After these concluded findings, resection and reconstruction of pectoralis muscle was added to surgical managment.

Positive predictive value 100% vs 96.9% respectively, negative predictive value 81.8 % vs 100% and accuracy was 97.2 % for both, as showed in Table (2). It was found that AUC of AP not significantly differs from that of FDP regarding detection of contralateral malignancy, occult multicentricity, pectoralis muscle or chest wall invasion, skin, and nipple areola complex infiltration with P-value=0.202 (>0.05) as showed in Table (2) (figure 1). Furthermore, the acquisition and interpretation times were significantly reduced in abbreviated protocol (3.3 versus 35 minutes) and (45 versus 108 seconds) respectively, (P- value <0.001) (Table 3).

4. Discussion

Focusing on role of abbreviated MRI in preoperative assessment for women with newly diagnosed cancer, in whom MRI may provide more information than conventional clinical and imaging assessment and detect additional foci of disease. The preoperative diagnosis of unsuspected multifocality/ multicentricity may be advantageous as it may allow surgical treatment to be changed to maximize the chances of the surgeon obtaining clear margins without the need for re-operation. If MRI detects more extensive disease than suspected on conventional clinical and imaging assessment, a wider excision will be recommended than planned for a woman undergoing breast conservation surgery.

Numerous studies show that MRI detects the presence of multifocal and/or multicentric disease with greater accuracy than conventional imaging (10). In the present study occult multicentricity was detected equally by both protocols with smallest focus detected was 3 mm in size. On the other hand, contralateral NME, two lesions in two different patients were missed in AP, these two false negatives were DCIS. While the FDP overestimated two benign lesions as malignant, these two false positive cases were histopathologically proved as fibroadenosis. Assessment of pectolalis muscle and chest wall invasion or posterior extension of the tumor is an important issue in planning for surgery to confirm clear safety margins which is considered a significant factor affecting the prognosis. Physical examination for pectoralis muscle or chest wall involvement can be difficult especially in a large breast(11).

Orel et al. reported that when a fat plane was preserved between a tumor and pectoralis muscle, no invasion of pectoralis muscle was found (12). Kerslake et al. reported that disruption of a fat plane between tumor and pectoralis muscle indicated chest wall invasion (13). Hirose et al. reported that muscle enhancement was an important finding of pectoral muscle invasion (14). Morris et al. reported that muscle enhancement is the sole criterion of muscle invasion, and we have applied this criterion for muscle invasion in present study (15).

By evaluating posterior extension of the tumor in the present study we found that from 6 posterior masses intimately related to pectoralis muscle, 3 showed muscle enhancement and was proved by histopathology and thus their management plan was modified to neoadjuvant chemotherapy before surgical reconstruction (figure 3), the remaining 3 which considered negative for muscle invasion showed no enhancement with preserved fat plane between muscle and mass (figure 2). Skin invasion if present leads to a significant change in operative plan. Global enhanced skin thickening or nodular enhancing skin foci, may occur in a different quadrant than that in which the mass is present**.** Inflammatory breast cancer (IBC) and locally advanced breast cancer (LABC) remain two of the most aggressive forms of breast cancer, Despite being often grouped together, identifying IBC is very important, because IBC is a distinct clinical and pathological entity that requires distinct treatment from LABC (16)**.** Girardi et al. found that skin changes (thickening, edema, and enhancement) related to neoplastic involvement of the dermal lymphatics are suggestive of IBC than LABC (17)**.**

In the present study skin thickening was found as an associated finding in about 10 cases but only 4 of them showed diffuse or nodular enhancement interpreted as invasion confirmed with histopathology and shifted to neoadjuvant chemotherapy before modified radical mastectomy MRM. The current AP results on 60 patients with 71 lesions was compared to Girometti et al study on 87 patients with 89 lesions and found that we had higher AP diagnostic indices: sensitivity was 96.8% and (range 88.9–94.4%) respectively and PPV was 100% and (range 76.2–84.6%, lower values for less experienced readers) respectively (3)**.** However, in comparison to full protocol there was no statistically significant difference in this study and Girometti et al. study as well. Prior authors such as Moschetta et al. 2016 included preoperative examinations within a larger cohort of patients undergoing MRI for a variety of indications, but the analysis was not stratified for the staging subset, nor focused on additional lesions.

Upgrading of surgical plan or changing of management plan after these more added findings by AP (51.7%) and FDP (55%) in the present study was comparable to Makboul et al study who studied added value of FDP only and concluded that the initial decision as changed in (52.4%) women based on MRI findings (18)**.**

5. Conclusions

Abbreviated protocol with time saving advantage is highly sensitive in preoperative assessment of breast cancer and ca detect occult lesions by mammography and ultrasound.

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