Original Article

Role of Diffusion MRI, Volumetry and Tumor Necrosis in the Assessment of the Response of Breast Cancer after Neoadjuvant Systemic Therapy (NAST)

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ABSTRACT

Background: To study the role of diffusion MRI, volumetry, tumor necrosis in the assessment of the response of breast cancer after neoadjuvant systemic therapy (NAST)

Results: Only 88 patients completed the study, with a mean age of 56 years old. Among these patients, 72 were categorized as respondents and 16 as non-respondents. The signal criteria changes of DCE, DWI, and ADC values, as well as the tumor volume, were significant among the respondents with a significant *p value*<0.001. No significant association between tumor necrosis volume and complete pathological response (*p value*=0.96).

Conclusion: The combination of DCE, volumetry, and diffusion as well as the ADC changes increase the ability and power of the MRI examination as a tool for assessment of the breast malignant neoplasms after NAST. No significant associations between the necrosis of breast cancer lesion by pre-therapy MRI and the collective image characteristics regarding the tumor necrosis.

Key Words: ADC, breast cancer, diffusion-weighted images (DWI), dynamic contrast enhancement (DCE), Neoadjuvant systemic therapy (NAST).

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INTRODUCTION

The last two decades have shown a change in the treatment strategy of breast cancer with the use of systemic chemotherapy before surgery (neoadjuvant) rather than following surgery (adjuvant) for those patients eligible for systemic chemotherapy [1]. Patients who receive neoadjuvant systemic therapy (NAST) are more likely to achieve breast conservation surgery than those receiving systemic chemotherapy after surgery [2]. The definite assessment of both the response to neoadjuvant chemotherapy and the extent of residual disease is crucial to establish further therapeutic plans in patients with locally advanced breast cancer [3,4]. Relative to the conventional method of breast imaging by sono-mammography, magnetic resonance imaging (MRI) is playing an important role in breast cancer detection, particularly for the screening of high-risk patients, staging and evaluating the extent of the disease process in patients with a recent diagnosis of breast cancer[5]. Also, breast MRI plays an increasing role in the detection of multicentric and multifocal breast cancer, differentiation a scar tissue from local recurrence in those with breast-conserving surgery, evaluation of response to NAST, and the integrity of breast implants [6]. Among the different breast imaging modalities used to detect whether residual malignancy is present or not after NAST, MRI has been increasingly used and recommended in recent decades[7]. Moreover, MRI can quantify the tumor size, estimating the tumor volume, and detect tumor necrosis after NAST. The tumor size following NAST has been considered as one of the prognostic and therapeutic factors by which the response to therapy can be predicted [8].

DWI which reflects the tissue microstructure can provide complementary information for the characterization of breast lesions. DWI is a short scan having the potential role in the differentiation between benign and malignant lesions and evaluation of patients post-NAST [9].

MRI can provide an adequate assessment of breast cancer and the associated necrotic component, which could reflect the tumor response or the aggressiveness of the lesion. MRI with high spatial resolution, using the multiple

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imaging parameters as DWI, T2WI, and post-contrast subtracted 3D images can determine the response to NAST in cases with breast cancer [10,11].

The objective of our study was to assess the association between the findings of the collective imaging parameters of breast cancer as well as the necrotic component after neoadjuvant systemic therapy (NAST) and their relation to the response in breast cancer.

METHODS

Patients:

This study was conducted on 94 female patients with stage II–III breast cancer confirmed by histo-pathological assessment, before the start and after the end of NAST. Only 88 patients completed the study, while the remaining 6 patients were excluded due to lack of post-chemotherapy follow up. The patients were referred from the surgical oncology and clinical oncology departments and were imaged by magnetic resonance imaging (MRI), at a university hospital between January 2017 and May 2020. Follow up study was done within 40-60 days after the NAST.

The study was approved by the hospital ethics board. All patients signed a well-informed consent.

Inclusion criteria:

- Pathologically proven staged II-III breast cancer.
- The patient will undergo conservative surgical approach or make surgery possible in cases ineligible for surgery before NAT.
- Pretreatment dynamic MRI with volumetry.
- Normal renal function for post-contrast study.

Exclusion criteria:

- Lack of available pathological report or definitive surgical intervention,
- Stage I and IV breast cancer
- No pre-treatment MRI.
- History of treated breast cancer.
- Abnormal renal function.

MRI acquisition and analysis:

Exams were done using Philips Achieva XR (1.5T). All the patients were in a prone position and the examinations were performed by specific eight-channel breast coils.

All patients underwent the following: axial non-contrast TIWI, axial non-fat-suppressed T2WI, axial STIR images, axial DWI, pre and post-contrast fat-saturated T1-weighted, and delayed post-contrast sagittal fat-saturated T1-weighted imaging.

The parameter of DW1 axial sequence as follows: {TR = 5100, TE =70ms, frequency-phase 96 x 96, matrix 256 x 128, thickness = 4mm, 0 interval, FOV = 320-340 mm, NEX= 8} with b-values of 0, 500 and 1000 s/mm2. DWI was performed before the post contrast sequences.

Dynamic MR was performed before and at 0, 90, 180, and 270 s after injection of contrast. Finally, axial three-dimensional (3D) T1-Weighed gradient-echo images were obtained for contrast fat-suppressed (CE-FS) T1 W1. The parameters were as follows: TR, 13.0-13.2 ms; TE, 6.6 ms; NEX, 1; flip angle, 20o; FOV: 360 x 360 mm; matrix, 384x384; slice thickness, 4.0 mm; and slice interval, 2.0 mm (slice overlap, 2.0mm).

MRI analysis of the images:

We merged the images obtained from the ADC maps with post-contrast MRI, for better delineation of the breast lesion, followed by calculation of the ADC values. In all cases, we had measured the ADC values at the hypointense zones seen on the ADC map.

A 3D subtracted maximum intensity projection (3D MIP) image was obtained by subtraction of the pre-enhanced 3D MR image from the early-phase contrast-enhanced 3D image. The resultant 3D MIP image was observed from various angles by rotating the image manually, and the extent of the tumor was determined, the tumor volume as well as the necrotic volume, if was present was also measured by using the same software.

MRI interpretation of the images:

First, all tumors were divided into two groups; the first group was non-necrotic tumors with no evidence of any necrotic component, while the second one was necrotic tumors with the presence of tumor necrosis. The central necrosis was identified by the detection of the following imaging characteristics: hyper-intense zones on axial fat-suppressed T2WI, a bright signal of this central area on ADC maps, and no appreciable post-contrast enhancement (Figure 3).

The viable breast tumors were identified by the presence of high signal intensity on DWI, low ADC value, and detection of post-contrast enhancement.

Two groups were identified responders and non-responders according to the combination of volumetric changes using modified RECIST criteria, ADC value, and diffusion signal criteria of the malignant lesions before

and after NAST, presence of post-contrast enhancement on DCE as well as the necrotic volume.

Response assessment:

Patients were divided into two groups according to the results obtained from histopathology after performing surgical intervention; the first group was pathological complete response (pCR), while the second one was non-pCR. Pathological CR was defined as no residual malignant cells.

Statistical analysis:

Statistical analysis for the results was done and statistical figures were plotted with calculated *P-value* for determination of the significance of the ratios between the values of the diffusion, ADC, and volume of the lesions pre and post neoadjuvant treatment, presence of enhancement on DCE and necrotic volume within the tumor showing central necrosis.

To assess the importance of tumor necrosis as a predictor of response to NAST, the odds ratio (OR) analysis was performed. *P-value* was considered statistically significant if less than 0.05.

RESULTS

This study included patients between 20 and 70 years old presenting with malignant breast lesions and received neoadjuvant treatment. The mean age was 56 years old. Among these patients, 72 were categorized as respondents and 16 as non-respondents.

Between the 72 responders, there were 39 patients had central necrotic component seen at the pre-chemotherapy MRI, while the remaining 33 patients didn't show definitive central necrosis on DWI, ADC, or DCE.

All the 16 non-responding patients had a solid tumor with no evidence of central necrotic zones based on the visual assessment of three radiological features of necrosis (Figure 4). For those patients, assessment of the tumor response was based upon the tumor volume, diffusion restriction, ADC value as well as DCE images.

Among the 72 responders, there were 8 cases with rather stable tumor volume, however with the change of their diffusion signal criteria from restriction to facilitation as well as showing a significant rise in their ADC values exceeding 30%, thus being categorized as responders and so consequently combination of all parameters together make it better for assessment of the tumor's response to the neoadjuvant treatment. (Table 1, Figures 3,5)

Table 1: Showing ratios between various patients regarding their volumetric changes following treatment into stationary, increased and reduced volume size of the tumor.

Post treatment volume change		
	N	%
Stationary	16	18.18
Reduced	64	72.73
Increased	8	9.09
Total	88	100.00

After NAST treatment, our data showed an increase in the ADC values of tumors compared with the pre-therapy values, among both respondents and non-respondents; being less significant among the non-respondents and more significant among the respondents with a significant *p-value* < 0.001. (Table 2)

Table 2: Showing comparison between the diffusion signal criteria changes of the malignant breast lesions before and after the NAST treatment presenting significant numerical change from restriction to facilitation after the NAST treatment.

Diffusion	Pre		Post		Chi-Square	
	N	%	N	%	X^2	*P-value*
Facilitated	12	13.64	68	77.27		
Restricted	76	86.36	20	22.73	15.492	<0.001*
Total	88	100.00	88	100.00		

The signal criteria changes were significant among the respondents as regards the change in the water molecular diffusion criteria and change from a restricted state to a facilitated state. Also, there was a significant difference between responders and non-responders regarding the mean percentage decrease in the volume of breast lesions. This suggests the potential of the diffusion criteria change from restriction to facilitation, ADC values, as well as the tumor volumetric changes, gathered together in differentiating non-responder from responder group after the NAST with significant *p-value* < 0.001 for the responder group. (Table 3, Figure 2)

Table 3: Showing comparison between the diffusion signal criteria changes of the malignant breast lesions before and after the NAST treatment among responders and non-responders showing significant numerical change from restriction to facilitation after the NAC treatment among the respondent group.

Diffusion		Response						Chi-Square	
		Non-Respondent		Respondent		Total			
		N	%	N	%	N	%	X^2	*P-value*
Pre	Facilitated	4	25.00	8	11.11	12	13.64	0.536	0.464
	Restricted	12	75.00	64	88.89	76	86.36		
Post	Facilitated	8	50.00	60	83.33	68	77.27	2.071	0.150
	Restricted	8	50.00	12	16.67	20	22.73		
P-value		1.000		<0.001*					

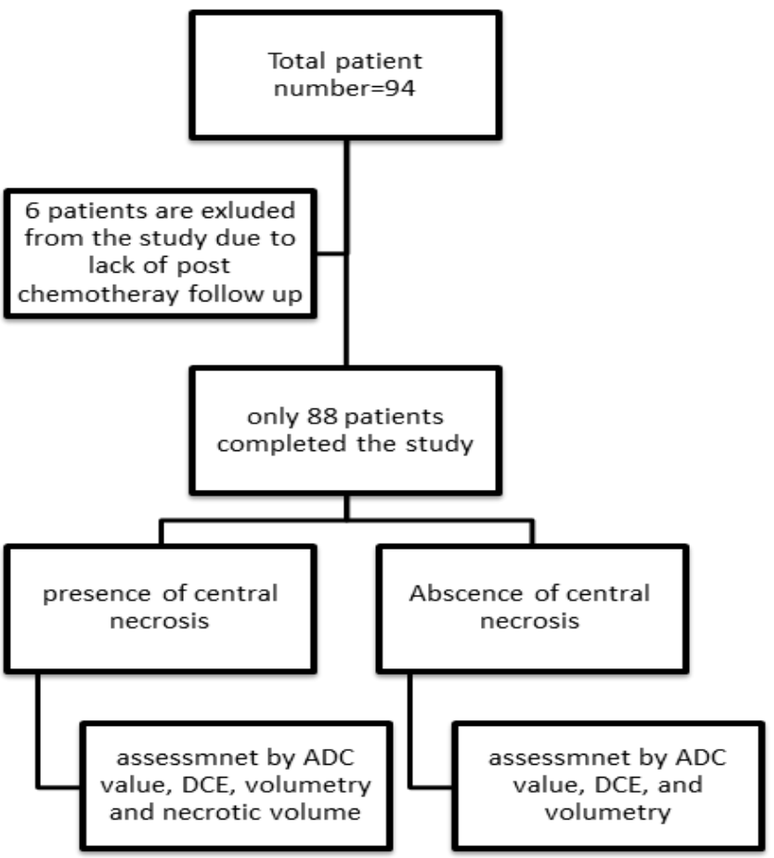

Fig. 1: Assignment of analysis for each group.

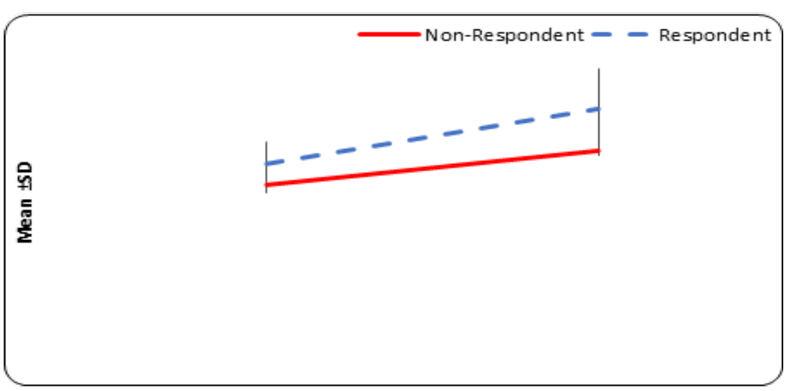

Fig. 2: Linear curve chart showing comparison between the changes in the ADC values of the malignant breast lesions before and after NAST treatment among responders and non-responders presenting significant changes among both study groups; being more significant among the responders and less significant among the non-responders.

Case 1: 55 years old female presented to the oncology department by right breast hardness, by clinical examination there was an infiltrative lesion with ill-defined borders. Then true cut core biopsy was requested and the lesion was pathologically proved to be infiltrating ductal carcinoma.

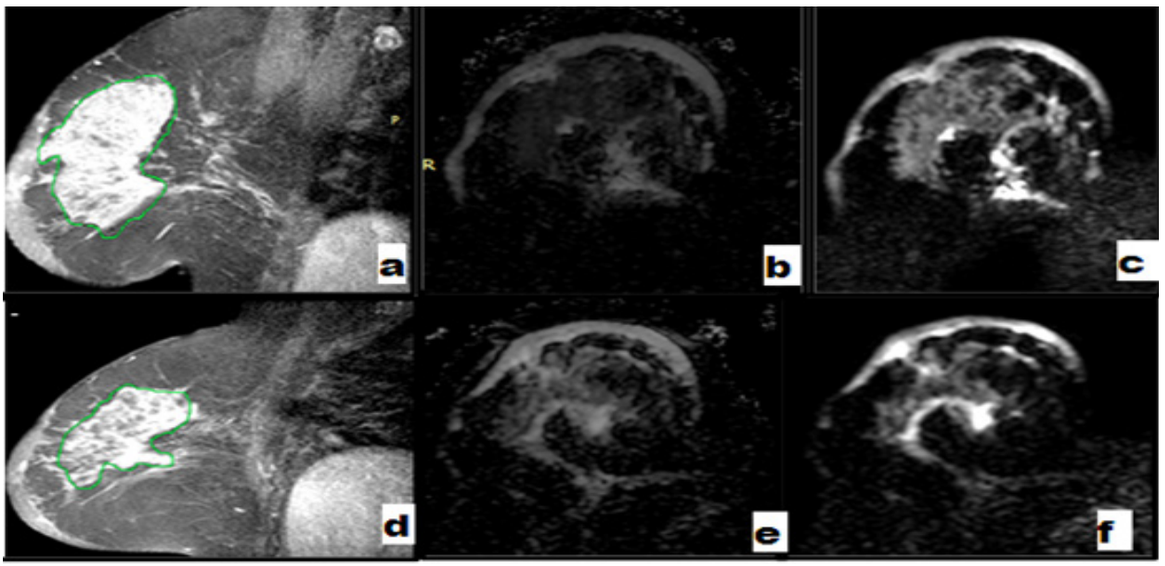

Fig. 3: Pre-neoadjuvant MRI findings: a: Post contrast fat suppression 3DVolumetric MIP showing retroareolar intense in-homogenously enhancing irregular outer surface mass lesion. b: ADC images shows a fairly defined large right breast retroareolar and upper outer quadrant speculated outer surface mass lesion with low "dark" signal denoting restricted diffusion with ADC value (10^{-3} mm^2 /s =0.82). C: axial DWIs: Presents the retroareolar mass lesion showing diffuse variable degrees of bright "high" signal in the DWIs. Average pretreatment volume was about 260-280 cm^3. The central necrotic volume within the tumor was 30-40 cm^3.
Post-neoadjuvant MRI findings: Remarkable regressive course as regards the tumor volume recently that was measuring about 95-110 cm^3. d: Post contrast fat suppression 3d Volumetric MIP remarkable regressive of the retroareolar mass . e and f : ADC and DWIs respectively revealed bright" high" signal within the ADC black and white map (e image) with ADC value (10^{-3} mm^2 /s =1.4). with decrease bright "high" signal in the DWIs (f image) denoting facilitated diffusion. The central necrotic volume within the tumor was relatively increased 55-60 cm^3. Features were favoring a good respondent to treatment.

Case 2: 60 years old female presented to the oncology department by right breast swelling, by clinical examination there was an infiltrative lesion with ill-defined borders. Then true cut core biopsy was requested and the lesion was pathologically proved to be invasive duct carcinoma.

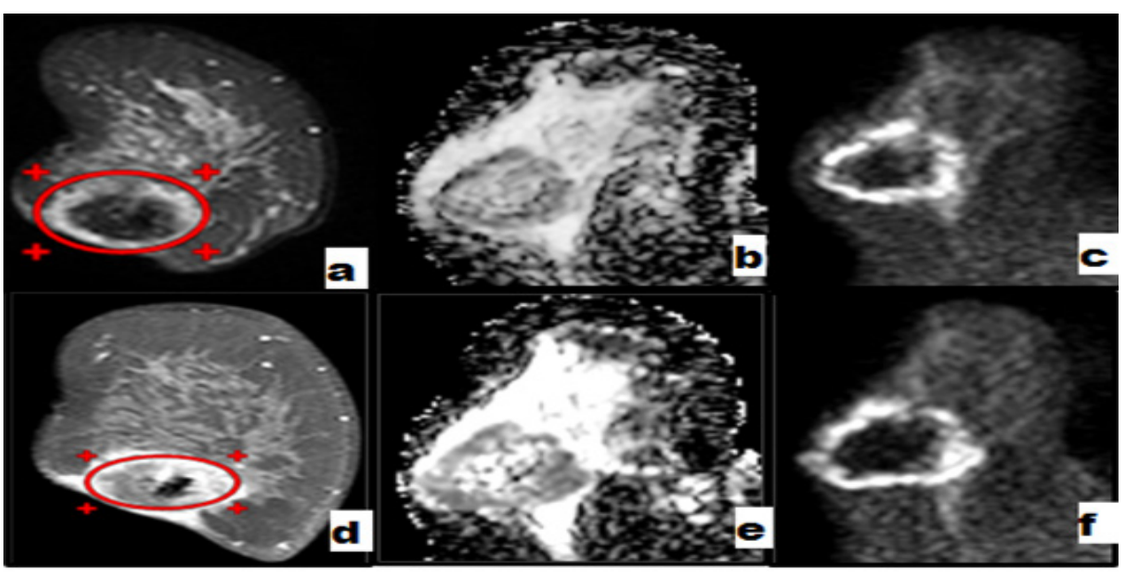

Fig. 4: Pre-neoadjuvant MRI findings (a,b and c images) were as follows: a: Post contrast fat suppression 3D Volumetric MIP showing intense marginally intensely enhancing irregular outer surface mass lesion with non-significantly enhancing central degeneration. b: ADC revealed dark "low" signal thick peripheral margin of the mass lesion, denoting restricted diffusion with ADC value (10^{-3} mm^2 /s =0.99). .c: DWIs images shows a well-defined lesion with hyperintense "bright" peripheral margin. The average estimated volume was about 65-70 cm^3. Post NAST therapy MRI study (d,e and f images) were as follows:d: post contrast 3D Volumetric MIP revealed still noted marginally enhancing mass lesion showing subtle volume reduction with an average estimated volume measured about 60-65 cm^3 denoting a non-respondent to the treatment. e: ADC and f: DWIs images: revealed bright peripheral margin in DWIs "f image" and low signal in ADC map "e image" denoting also still noted diffusion restriction with ADC value (10^{-3} mm^2 /s =1.1). No appreciable necrotic component either at pre or post NAST therapy.

Case 3: 57 old female presented to the oncology department by right breast swelling, by clinical examination there was a swelling with lobulated borders. Then true cut core biopsy was requested and the lesion was pathologically proved to be infiltrating lobular carcinoma. The patient was then directed to neoadjuvant chemotherapy (NEC) treatment and MRI assessment was requested before starting and then after the end of the cycles of NAST to assess the response to treatment.

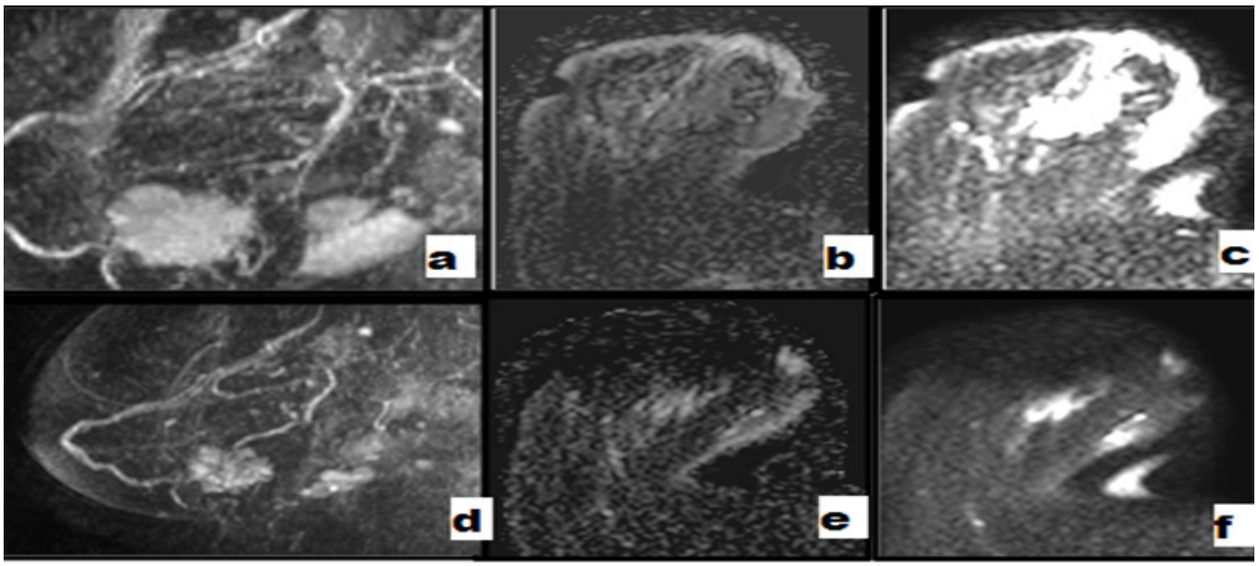

Fig. 5: Preneoadjuvant MRI findings were as follows: a: Post contrast fat suppression 3D Volumetric MIP: An ill-defined large right breast speculated outer surface heterogenous mass lesion with average estimated volume was about 85-90 cm^3. b: ADC black and white map: Revealed low signal of the mass lesion, denoting restricted diffusion with ADC value (10^{-3} mm^2 /s =1.2). c: DWIs images revealed: very high "intense bright" signal of the mass lesion. Necrotc volume was 10-15cm^3
Post NAST therapy MRI study (d,e and f images) was as follows: d: Post contrast 3D Volumetric MIP revealed significant volume reduction as well as the intensity of the contrast enhancement of the speculated enhancing mass lesion with average estimated volume of about 35-40 cm^3 which represents more than 55 % size reduction according to RECIST criteria. e: ADC and f: DWIs images: revealed bright signal of the residual tumor in DWIs "f image" and low "dark" signal in ADC map "e image", with ADC value (10^{-3} mm^2 /s =1.3). denoting still noted restricted diffusion,and denoting overall favorable treatment response (Can be categorized as partial responder). Necrotic volume was almost the same.

For those 39 patients with central necrotic tumor, 13 patients show almost stable size regarding the central necrotic volume, while 12 and 14 patients show relative reduction and progression of the necrotic volume (Figure 3) respectively. (Table 4)

Table 4: Showing comparison between the volume of the central necrotic component before and after the NAST treatment among responders group.

Post treatment change in the central necrotic component		
	N	%
Stationary	13	33.3
Reduced	12	30.7
Increased	14	36
Total	39	100.00
P value	0.96	

In our study, we had considered ≥ 30% decrease in the volume of the tumoral tissue and necrotic volume post-NAST, compared with baseline to be regressive course, and considered ≥ 20% increase was to be progressive according to the Revised RECIST Guideline. There was no significant correlation between the volume of the central necrotic component before and after the NAST among the responders' group with a *p-value* of 0.96.

DISCUSSION

The role of NAST in the treatment of breast cancer is increasing as it has been used successfully to downstage tumors and conserves the breast in large operable lesions[11]. The use of MRI in the follow-up post-NAST has improved the diagnostic accuracy by measuring the tumor size and volume[12].

Several studies have suggested using DWI as a predictor for the detection of pathological response depending upon the intrinsic characteristics of tumor tissue, which precede the changes in the tumor volume. The cytotoxic drugs damage the cancer cells, resulting in a change in the cell membrane integrity, thereby increasing water diffusion in the damaged cancer cells [13].

An accurate assessment of residual disease at MR imaging is required for pre-surgical planning. Positive margins following surgery are associated with an increased long-term risk of recurrence while over excision of breast tissue can compromise the patients' quality of life. Conventional MRI often overestimates the residual tumor and does not correlate well with the histopathological response. Thus, DW MR imaging has been investigated as a means of overcoming the limitations of conventional MR imaging assessment [14,15].

The current study was designed to evaluate the accuracy of MRI DW, measurement of the tumor volume, and the necrotic component in predicting tumor response after the NAST. Also, our study focused on the benefit of estimation of the necrotic volume to provide additive information regarding the presence of residual tumor tissue following NAST.

There have been numerous studies that have reported the utility of tumor volume, and the importance of this parameter in prediction of neoadjuvant therapy outcome. Tumor volume has been reported to be more indicative of ultimate outcome to treatment than other simpler measures such as tumor diameter, and diffusion-weighted parameters[16,17].

Qadir et al (2025) highlighted that unidimensional MRI measurements of tumor size may not consistently align with histopathological measurements, while MRI-derived tumor volume measurements provide greater insights[18]. These findings aligned with other studies in neoadjuvant chemotherapy, which had demonstrated that reduction in tumor volume yields higher MRI sensitivity and specificity than unidimensional measurements[19]. This is likely due to the superior ability of volumetric measurements to capture angiogenic changes, providing a more comprehensive representation of tumor burden.

Both the structural (tumor volume) and functional parameters (ADC) in the 88 patients included within the study group with breast cancer were obtained at two time periods (before and after NAST) was done. A retrospective analysis of the percentage change in the tumor volume and the ADC values was carried out to determine the ability of these imaging characteristics in predicting the tumor response.

After NAST, our data showed an increase in the ADC values of tumors compared with the pre-therapy values among both respondents and non-respondents being less significant increase among the non-respondents and more significant among the respondents. The signal criteria showed significant change regarding the respondents and non-respondents as regards the change in the water molecular diffusion criteria and change from restricted to facilitated state, more evident for the respondent. This suggests the potential of the diffusion criteria change from restriction to facilitation, ADC as well as the tumor volumetric changes in differentiating non-responders from responders after NAST treatment, these parameters showed significant differences in the percentage change between responders and non-responders.

Hu et al. (2017) studied a total of 164 patients undergoing NAST. The mean ADCpost values significantly increased both in responders and non-responders compared with mean ADCpre values, but mean ADCpost values of responders increased more significantly than that of non-responders. Moreover, the mean ADCpost values were positively correlated to changes in tumor diameter after two cycles of NAST, as well as changes in mean ADC values [16].

Such findings were also matching with ***Li et al.*** (2012) who studied the tumors after chemotherapy and the changes in tumor volume which were positively correlated with response to NAST in patients with locally advanced breast cancer [17,18].

The presence of tumor necrosis is considered one of the poor prognostic factor in several tumors as it is thought to be secondary to prolonged hypoxia or poor vascularity[19,20]. Our study did not find a significant association between the volume of the tumor necrosis by pre-therapy MRI and the response to NAST in patients with known breast cancer. This was matching with ***Abdelhafez et al.***[20] where 85 patients were included in a study to assess the tumor necrosis by pre-therapy breast MRI in triple-negative breast cancer, 39 patients with necrotic tumor were assessed using segmentation of the necrotic volume and they found no significant associations between tumor necrosis by pretreatment MRI and the collective imaging features of tumor necrosis. In contrast, ***Bae et al.***[21] studied 132 patients with a history of triple-negative breast cancer and found that there was an association between pre-therapy breast MRI and pCR by detection of tumor necrosis. However, such an association had no statistical significance.

CONCLUSION

The combination of DCE, volumetry, and diffusion as well as the ADC changes increase the ability and power of the MRI examination as a tool for assessment of the breast malignant neoplasms after NAST. No significant associations between tumor necrosis by pretreatment MRI and the quantitative image characteristics of tumor necrosis.

LIST OF ABBREVIATIONS

Diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC), neoadjuvant systemic therapy (NAST), necrosis volume (NV), dynamic contrast-enhanced imaging (DCE), pathological complete response (pCR).

STUDY LIMITATIONS

The study had some limitations. First, it was performed in a single institution and further assessment by the selection of a larger population from multiple centers will be recommended. Second, all types of breast cancer were included in our study. Third, we have had used the 30 and 20% on imaging, as a reference for regression and progression state of the tumour volume and the necrotic component depending on RECIST criteria, instead of the longest dimension of the tumour size which is traditionally used in RECIST criteria.

DECLARATIONS

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Written informed consent was signed by all patients before the examination. The study was approved by the Research Ethics Committee (REC) of the Faculty of Medicine, Ain Shams University, FMASU R49/2024 and experiments were conducted in accordance with the ethical guidelines.

CONSENT FOR PUBLICATION

All patients included in this research were fully conscious and older than 16-year old and gave written informed consent to publish the data contained within this study.

AVAILABILITY OF DATA AND MATERIAL

All the datasets used and analyzed in this study are available with the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they have no competing interests

FUNDING

Not applicable (no funding received for this study).

AUTHORS CONTRIBUTIONS

- H.I.K: editor of the manuscript, image interpretation, performed the statistical analysis, and data collection.
- N.T.E: has followed the results of chemotherapy and share in data collection.
- KM: responsible for operative details and data collection.
- BMM: put the idea of research and shared in the design of the study and image interpretation.
- All authors read and approved the final manuscript.

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Not applicable

Dear Prof. Dr:

It is a great honor and pleasure to submit our work titled “Role of diffusion MRI, volumetry and tumor necrosis in assessment of response of breast cancer after neoadjuvant systemic therapy (NAST)” to your distinguished journal to be considered for publication. We choose you journal as this is a new tool for management of breast cancer which is prevalent in Egypt. This has never been submitted or published before.

All patients signed a well-informed consent.

All authors have approved the publication.

We agree that all copyright ownership is transferable to the Association of University Radiologists when the manuscript is accepted for publication in the Ain Shams Medical Journal

We certify that the submitted article will not constitute "Redundant Publication”.

This study is not previously published nor submitted elsewhere and the methods employed respect the Helsinki Declaration of 1975, as revised in 1983.

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دور التصوير بالرنين المغناطيسي المنتشر وقياس الحجم ونخر الورم في تقييم استجابة سرطان الثدي بعد العلاج الكيميائي الجهازي المساعد الجديد (NAST)

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المقدمة: لقد أظهر العقدان الأخيران تغييراً في استراتيجية علاج سرطان الثدي باستخدام العلاج الكيميائي النظامي قبل الجراحة بدلاً من اتباع الجراحة لهؤلاء المرضى المؤهلين للعلاج الكيميائي النظامي. يلعب التصوير بالرنين المغناطيسي دورًا مهمًا في الكشف عن سرطان الثدي، وخاصةً لفحص المرضى المعرضين لمخاطر عالية، وتحديد مراحل المرض وتقييم مدى تطوره لدى المرضى الذين تم تشخيص إصابتهم بسرطان الثدي مؤخرًا. يمكن أن يوفر التصوير بالرنين المغناطيسي تقييمًا مناسبًا لسرطان الثدي والمكون النخري المرتبط به، والذي قد يعكس استجابة الورم .

الهدف من البحث: تقييم العلاقة بين نتائج معايير التصوير بالرنين المغناطيسي الجماعية لسرطان الثدي بالإضافة إلى المكون النخري بعد العلاج الكيميائي المساعد الجديد وعلاقتها بالاستجابة في سرطان الثدي.

المرضى و طرق الدراسة: أجريت هذه الدراسة على ٩٤ مريضة مصابة بسرطان الثدي من المرحلة الثانية إلى الثالثة والتي تم تأكيدها من خلال التقييم النسيجي المرضي، قبل بداية NAST وبعد انتهائها. باستخدام التصوير بالرنين المغناطيسي المنتشر، قياس الحجم والرنين المغناطيسي المعزز بالتباين الديناميكي.

النتائج: أكمل الدراسة ٨٨ مريضًا فقط، بمتوسط عمر ٥٦ عامًا. ومن بين هؤلاء المرضى، تم تصنيف ٧٢ مريضًا على أنهم مجيبون و١٦ على أنهم غير مستجيبين. كانت تغييرات معايير الإشارة لقيم DCE وDWI ، بالإضافة إلى حجم الورم، كبيرة بين المشاركين الذين لديهم قيمة p كبيرة <٠,٠٠١. لا يوجد ارتباط كبير بين حجم نخر الورم والاستجابة المرضية الكاملة (قيمة P =٠,٩٦).

الخلاصة: يؤدي الجمع بين DCE والحجم والانتشار بالإضافة إلى تغييرات ADC إلى زيادة قدرة وقوة فحص التصوير بالرنين المغناطيسي كأداة لتقييم أورام الثدي الخبيثة بعد NAST.