Evaluation of Neoadjuvant Chemotherapy Response with Dynamic Contrast Enhanced Breast Magnetic Resonance Imaging in Locally Advanced Invasive Breast Cancer

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ABSTRACT

Objective: The reliability of traditional methods such as physical examination, ultrasonography (US) and mammography is limited in determining the type of treatment response in patients with neoadjuvant chemotherapy (NAC) application for locally advanced breast cancer (LABC). Dynamic contrast-enhanced magnetic resonance imaging (MRI) is gaining popularity in the evaluation of NAC response. This study aimed to compare NAC response as determined by dynamic contrast-enhanced breast MRI in patients with LABC to histopathology that is the gold standard; and evaluate the compatibility of MRI, mammography and US with response types.

Materials and Methods: The US, mammography and MRI findings of 38 patients who received NAC with a diagnosis of locally advanced breast cancer and surgical treatment were retrospectively analyzed and compared to histopathology results. Type of response to treatment was determined according to the "Criteria in Solid Tumors Response Evolution 1.1" by mammography, US and MRI criteria. The relationship between response types as defined by all three imaging modalities and histopathology were evaluated, and the correlation of response type as detected by MRI and pathological response and histopathological type of breast cancer was further determined. For statistical analysis, the chi-square, paired t test, correlation and kappa tests were used.

Results: There is a statistical moderate positive correlation between response type according to pathology and MRI (kappa: 0.63). There was a weak correlation between response type according to mammography or US and according to pathology (kappa: 0.2). When the distribution of treatment response by MRI is stratified according to histopathological types, partial response was higher in all histopathological types similar to the type of pathologic response. When compared with pathology MRI detected treatment response accurately in 84.2% of the patients.

Conclusion: Dynamic contrast-enhanced breast MRI appears to be a more effective method than mammography or US in the evaluation of response to neoadjuvant chemotherapy. MRI evaluation of LABC is accepted as the appropriate radiological approach.

Key words: Cancer, chemotherapy, breast, MRI, neoadjuvant, response

Introduction

Tumors with a diameter above 5 centimeters, skin and chest wall involvement, involvement of ipsilateral supraclavicular, infraclavicular, internal mammary or fixed axillary lymph nodes are defined as locally advanced breast cancer (LABC). These characteristics are compliant with stage 3A and B tumors in general. LABC can be classified as operable and inoperable. Neoadjuvant chemotherapy (NAC) is the standard method of treatment in patients with inoperable LABC and increases both disease-free and overall survival (1). In operable patients, it permits breast conserving surgery rather than mastectomy (2-7). In a meta-analysis consisting of 5500 patients, NAC and surgery combination was compared to surgery and adjuvant chemotherapy (4). Although survival was similar in both groups, the rate of mastectomy as well as the incidence of side effects was significantly lower in patients treated with the combination of NAC and surgery (4).

However, a pathological complete response to neoadjuvant chemotherapy cannot be achieved in all patients. The early detection of patients with complete or near-complete response is of great significance in the follow-up and survival of patients (2, 3). The timely identification of patients who are unresponsive to treatment is important for the planning of new treatment regimens with different chemotherapeutic agents as soon as possible, reducing toxicity and complications (1). Disease-free and overall survivals have a clear correlation with NAC response (8).

Physical examination, ultrasonography (US), mammography, magnetic resonance imaging (MRI) and molecular imaging can detect response to neoadjuvant therapy in the early period. The reliability of traditional methods such as physical examination, ultrasonography and mammography is limited, thus dynamic contrast-enhanced MRI is being increasingly used for the evaluation of response to treat-

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ment (9, 10). The MRI, unlike physical examination and mammography, is also able to distinguish between fibrosis and tumor tissue in dense breasts (3). It reflects tumor size more accurately and is more reliable than ultrasound, mammography or physical examination in predicting the size of residual disease after neoadjuvant chemotherapy. In patients receiving neoadjuvant chemotherapy, antiangiogenic effects of cytotoxic chemotherapy agents decrease tumor vasculature, thereby reducing contrast enhancement. Viable residual tumor tissue will show contrast enhancement on dynamic contrast-enhanced breast MRI, and can be distinguished more easily. The sensitivity of MRI in the evaluation of response to neoadjuvant chemotherapy is reported as 50% - 100% (2). This high sensitivity depends on the ability of MRI to distinguish between fibroglandular tissue and untreated hypervascular tumors within the breast tissue.

This study aimed to compare NAC response as determined by dynamic contrast-enhanced breast MRI in patients with LABC to histopathology that is the gold standard; and evaluate the compatibility of MRI, mammography and US with response types.

Materials and Methods

The radiology images of patients who were referred to Dokuz Eylül University Medical Faculty Hospital Radiology Department between January 2002 to October 2011 for evaluation of their treatment response after receiving NAC with a diagnosis of LABC have been retrospectively reviewed. Patients without an MRI either before or after NAC, who did not undergo surgery and without histopathological results were excluded from the study. The US, mammography and dynamic contrast-enhanced MRI investigations of the 38 included patients before and 1-3 months after NAC were evaluated and compared to histopathological results. The ethical permission was obtained from "Dokuz Eylül University Non-Interventional Research Ethics Board".

The chemotherapy regimens used combination of anthracycline and taxane group chemotherapeutic drugs and received 4 +4 cycles of treatment. In addition, in 8 patients with c-erb-B2 receptor-positivity, trastuzumab was added to the treatment.

The mammography examinations were conducted with a digital mammography device (Lorad Selenia; Hologic, Danbury, USA) with low kVp and high mAs protocol, in the routine craniocaudal and mediolateral-oblique positions. Additional positional views were added if needed. The breast US examinations were carried out with Philips HDI-11 SA ultrasound device (Koninklijke Philips Electronics, the Netherlands) using a high-resolution linear probe, simultaneously with the mammography examinations.

Dynamic contrast-enhanced breast MRI of all patients was performed in our department with a 1.5 Tesla MRI device (Gyrosan Achieva; Philips, Best, the Netherlands) with a SENSE- Breast coil, in the axial plane. In the reports of breast imaging, the classification by Breast Imaging Reporting and Data System (BIRADS) was

used. As routine magnetic resonance parameters, the turbo spin echo (TSE) T1-weighted (repetition time (TR): 476 ms, echo time (TE): 8.0 ms, flip angle: 90, matrix: 288, field of view (FOV): 400, rectangular FOV: 100, slice thickness: 3 mm, gap: 0 mm, number of excitation (NEX): 2) and T2-weighted (TR: 5726 ms, TE: 120 ms, flip angle: 90, matrix: 448, FOV: 400, rectangular FOV: 100, slice thickness: 3 mm, gap: 0 mm, NEX: 2), dynamic contrast-enhanced fat-suppressed THRIVE (TR/TE: 5.6/2.7, flip angle: 10, matrix: 448, FOV: 400, rectangular FOV: 100, slice thickness: 3 mm, NEX: 2) and post-contrast fat-suppressed T1-weighted axial sequences (TR: 550 ms, TE: 8.0 ms, flip angle: 90, matrix: 288, FOV: 400, rectangular FOV: 100, slice thickness: 3 mm, gap: 0 mm, number of excitation (NEX): 2) were applied in all patients. After obtaining pre-images for all sections, patients were injected gadopentetate dimeglumine at a dose of 0.1 mmol/kg via a venous access, and repetitive images with 30 sec intervals were obtained. Upon completion of imaging, subtraction images were created by using the Standard subtraction function of the device that subtracts early and late contrast-enhanced images from non-contrast images. The pharmacokinetic curves of the images were created by View Forum and recorded with the PACS system.

The tumor size determined by mammography and US before and after NAC, was compared to the measured tumor size by MRI. For the measurements, the largest single diameter, or the sum of the long axes of all target lesions in multifocal multicentric lesions were used according to "Response Criteria in Solid Tumors Evolution" (RECIST 1.1 criteria). When assessing magnetic resonance images, number and propagation of the mass, multicentricity, shape, contour features, presence of necrosis, time / intensity curve type (Type 1, 2, 3), enhancement pattern (homogeneous, heterogeneous, point, reticulated, branching, cobblestone, peripheral glossy - dark interior region) and enhancement speed (fast, medium and slow) were recorded. In addition, breast parenchyma type, accompanying signs (pectoral muscle invasion, microcalcifications, skin edema) and axillary lymph node status were evaluated. The tumor size in pathology reports has been accepted as the gold standard in the evaluation of residue after NAC, and was compared to tumor size as determined by each of the three methods (mammography, breast US, breast MRI) after the operation. The histopathological type of breast cancer was also recorded.

According to RECIST 1.1 criteria, the NAC response was grouped into complete response, partial response, stable disease and progressive disease. The absence of contrast-enhancing lesions on MRI, the complete disappearance of mass lesions on mammography and breast US examination were accepted as complete response. The absence of invasive focus on pathology evaluation was considered as pathological complete response. Table 1 summarizes NAC response types according to RECIST 1.1 criteria.

In the statistical evaluation, the tumor size detected by mammography and breast US prior to chemotherapy was compared to the size de-

Table 1. Type of response to neoadjuvant chemotherapy according to RECIST 1.1 criteria

Complete response	Disappearance of all target lesions
Partial response	30% and higher decrease in tumor longitudinal diameter
Progressive disease	20% and higher increase in tumor longitudinal diameter - 5 mm increase in tumor size – new lesion formation
Stable disease	Less than 25% increase or less than 30% decrease in tumor size

Table 2. Pre-post treatment tumor size detected by MRI / Mammography / US

Method	Pre-treatment tumor size (cm)		Post-treatment tumor size (cm)	
	Min/Max	Mean*	Min/Max	Mean *
Mammography	0/16	4.1±3.0	0/10	2.4±2.6
US	0/16	3.9±3.1	0/10	2.6±2.7
MRI	0.8/16	5.2±2.8	0/6	2.07±1.6

*Mean value ± Standard deviation
 US: Ultrasonography; MRI: magnetic resonance imaging; cm: centimeters; min: minimum; max: maximum

tected by breast MRI and after chemotherapy the tumor size detected radiologically was compared to the size stated in the pathology report and their correlation was assessed. The correlation of response types and mammography, breast US, and breast MRI were determined. The relation of response types detected with MRI and pathologic evaluation with histopathological type of breast cancer were also considered. Statistically, chi-square, paired t test, correlation and kappa tests were used. Data were reported as mean ± standard deviation (SD) or as percentages where appropriate. P value of <0.05 was considered statistically significant. Statistical analyses were performed using SPSS (version 15.0, SPSS, Inc., Chicago, IL, USA).

Results

The mean age of 38 patients was 49.84 (SD 17.12) years and the breast parenchyma was classified as BIRADS 1 in 6, as BIRADS 2 in 14, as BIRADS 3 in 14, and as BIRADS 4 in 4 patients. All patients received tru-cut biopsy and dynamic contrast-enhanced breast MRI examinations prior to treatment. Two patients had no pre-treatment mammography and US evaluations.

According to pathology results, 10 cases had dominant invasive ductal carcinoma component, and in 12 patients the invasive lobular carcinoma component was evident. In five patients invasive ductal carcinoma+ invasive lobular carcinoma, in 3 patients medullary-like invasive ductal carcinoma, in 1 patient mixed invasive breast cancer and in 1 patient inflammatory breast cancer was observed. In six patients, the histopathologic type was reported as invasive breast carcinoma.

The properties of mass lesions viewed on MRI were as follows: 14 multicentric and heterogeneously enhancing, 4 diffuse growing and heterogeneously enhancing; 6 spicular edged and homogeneous enhancing, 3 irregular margined, 2 peripheral enhancing, 2 nodular enhancing, 4 compatible with inflammatory cancer (skin edema and mass lesions tendency to coalesce). Two patients had breast edema and regional enhancement findings. In one case, the lesion had irregular margins and central necrotic areas were observed. In two cases there was invasion of the skin and pectoral muscles.

The pre-treatment mean tumor diameter detected by mammography was 3 cm, the mean tumor diameter detected by US was 3.1 cm, and the mean tumor diameter detected by MRI was 5.2 cm. The mean tumor diameter detected by MRI, mammography and US after treatment were 1.6 cm, 2.6 cm and 2.7 cm, respectively. Table 2 summarizes pre-treatment and post-treatment tumor size detected by each of the three imaging modalities.

Mammography and US showed statistically high level of correlation in terms of lesion diameter by Pearson's correlation test ($r=0.9$,

$p<0.005$), but mammography and MRI ($r=0.7$, $p<0.005$) and US ($r=0.6$, $p<0.005$) were moderately correlated. Tumors were measured by US as compared to MRI. US did not detect any tumor in two patients, and in four patients the tumor diameter was measured larger than MRI. Statistically, there was moderate correlation between MRI and pathology in terms of tumor size after treatment ($r=0.4$, $p=0.007$). MRI predicted residual tumor diameter correctly in 26 of 38 cases. There was no statistical correlation between mammography and pathology ($r=0.2$, $p=0.1$) or US and pathology ($r=0.1$, $p=0.4$).

On the pharmacokinetic evaluation before treatment, type 2 (44.7%) and type 3 (55.3%) curves were observed and after treatment the most common finding was type 2 curve (65.8%). In four cases (10.5%) type 1 benign curve was observed that was not detected before treatment and there was a significant decrease in the rate of type 3 curves. Most of the mass lesions showed heterogeneous (70%) and fast (60.5%) contrast enhancement prior to treatment, whereas the contrast enhancement rate significantly decreased after treatment and rapid enhancement was seen in only 10.5%. However, significant differences in enhancement pattern were not detected. In five cases, the MRI did not reveal a mass lesion due to complete response. In one patient, although there was not significant contrast enhancement, a mass lesion in the localization of the lesion was found in other sequences that were considered compatible with a partial response to treatment. Contrast enhancement pattern has not been evaluated in six cases. The dynamic contrast-enhanced MRI findings before and after NAC treatment are summarized in Table 3.

The cases were fairly homogenous in terms of the chemotherapy protocol. Anthracycline and taxane group chemotherapeutic drugs are used in combination and 4+4 cycles of treatment were given. Only one patient received 6 cycles of treatment. Eighteen out of 38 cases were c-erb-B2 receptor positive and trastuzumab was added to the treatment in 7 of them. Chemotherapy regimens are summarized in Table 4.

After NAC all 38 patients had a dynamic contrast-enhanced breast MRI, 22 had mammography and 19 underwent US examination. There was statistical high-level positive correlation between mammography or US and response type (kappa: 0.9). MRI type of response and mammography or US response type showed poor statistical compatibility (kappa: 0.1). The type of pathologic response after treatment with mammographic or US response type showed poor statistical compatibility with kappa test (kappa: 0.2). Figure 1-5 show radiological examinations of a case that was evaluated as "partial" NAC response type by mammography but was considered as "complete response" by MRI and histopathological evaluation.

The pathological complete response rate of 38 patients after treatment was 15.8%, and the complete response rate in MRI was 13.2%. MRI

Table 3. MRI findings pre- and post-neoadjuvant chemotherapy

		Pre-treatment	Post-treatment*
		n (%)	n (%)
Pharmacokinetics curve	Type 1	0 (0)	4 (10.5)
	Type 2	17 (44.7)	25 (65.8)
	Type 3	21 (55.3)	3 (7.9)
Contrast-enhancement pattern	Homogenous	9(23.7)	4 (10.5)
	Heterogeneous	27 (70)	26 (68.4)
	Peripheral	2 (5.3)	2 (5.3)
Contrast-enhancement speed	Slow	3 (7.9)	7 (18.4)
	Medium	12 (31.6)	21 (55.3)
	Fast	23 (60.5)	4 (10.5)

*Pharmacokinetic evaluation could not be performed in 6 cases in whom there were no focal lesions with contrast-enhancement on post-treatment images.

MRI: Magnetic resonance imaging

Table 4. Neoadjuvant chemotherapy protocols

Treatment (*)	Number	%
4 cycle FEC + 4 cycle D / P	23	60.5
4 cycle EC + 4 cycle D / P	8	21
4 cycle FEC + 4 cycle DT	6	16
6 cycle TAC	1	2.5
Total	38	100

*F: 5-Fluorourasil; E: epirubicin; C: cyclophosphamide; D: dosetaxel; P: pakli-taxel; A: adriamisin

Figure 1. a-c. Pre-treatment mammography and US examinations of a 55-year-old patient (case 1) with a mass in the left breast. Mammographic craniocaudal and mediolateral oblique views of the left breast (a, b). US image of the left breast (c). Mass lesions located in the left breast UOQ-LOQ junction with extension to UOQ, showing cystic-solid components on US, with lobulated borders are visualized. There is left axillary lymphadenopathy. Results were interpreted as multicentric-multifocal breast tumor

identified type of NAC response correctly in 32 (84.2%) of 38 patients as compared to pathology. Pathological response type and MRI response type showed a statistical moderate positive correlation with the kappa test (kappa: 0.63). Table 5 shows the type of NAC response detected by all three imaging methods and identified by pathology.

Following NAC, 17 of 38 cases underwent breast conserving surgery, 16 modified radical mastectomy (MRM) and 5 simple mastectomy. Patients

Figure 2. a, b. Mammographic craniocaudal and mediolateral oblique views of Case 1 after treatment. Compared to the previous views, a significant reduction in the size of the mass is observed (a, b). Mammography response type was evaluated as "partial response".

who underwent breast-conserving surgery after NAC had less than 4cm of residual tumor as detected by MRI and their axillary lymph nodes disappeared after treatment. In 16 of these patients, the MRI response type was consistent with the type of pathologic response and the difference between residual tumor size between MRI and pathology were maximum 1 cm except two patients. Figures 6-10 show radiological examination of a patient who was evaluated as "stable disease" after NAC by MRI but had "partial response" on histopathological evaluation.

Complete response was detected in 25% of patients with invasive lobular carcinoma, in 7% of invasive ductal carcinoma, in 16% of invasive

Figure 3. a-c. Dynamic contrast-enhanced MRI and pharmacokinetic curve of Case 1 before treatment. The subtraction image revealed a 6.5 cm, lobulated, irregularly contoured, necrotic mass lesion with skin invasion in the left breast outer quadrant (a, b). Various foci with similar morphologic and kinetic features, the largest reaching 2 cm in diameter, are detected (b). Pharmacokinetic evaluation is compatible with type 3 curve (c).

Figure 4. Post-treatment subtraction MRI images of Case 1 MRI not showing any pathological mass lesion or enhancement in the left breast. MRI response type was evaluated as "complete response"

ductal + invasive lobular carcinoma and in 7% of other pathological types. The histopathological distribution according to pathologic response types revealed that partial response was more frequent in all types, with a partial response in 73.7% of patients. One out of 14 patients with invasive ductal carcinoma had a pathological complete response. Three out of 12 patients with invasive lobular carcinoma had complete response. Out of the 12 patients who have been grouped as other types involved invasive breast cancer, invasive ductal + invasive lobular carcinoma, and inflammatory carcinoma, two patients showed

Figure 5. The histopathological examination of modified radical mastectomy specimen of Case 1 after NAC showed chemotherapy-induced changes, diffuse fibrosis, and lobular atrophy areas. Tumor cells were not detected with 'complete response'. Pathologic and MRI response types are compatible.

pathologic complete response. When the histopathological distribution according to MRI response type is evaluated, partial response is detected the most in all histopathological types similar to pathological response type.

Discussion and Conclusions

Currently NAC is the standard treatment of choice in LABC. The clinical and pathological response of the primary tumor to NAC has been reported as a prognostic factor that can be used as an indicator of long-term survival and disease management (11, 12). Early tumor response to chemotherapy during treatment can provide the opportunity of patient-specific treatment protocols (13). One of the major advantages of this treatment is the opportunity of BCS in patients who were initially unsuitable for BCS due to disappearance or shrinkage of the tumor in some selected cases (14). Singletary and colleagues (15) from MD Anderson Cancer Center reported that according to pathology results of mastectomy specimens of 143 LABC patients after neoadjuvant chemotherapy, 23% became suitable for BCS. Afterwards, Bonadonna and colleagues (16) showed that the rate of breast conserving surgery increases with neoadjuvant chemotherapy. In our study, 17 patients (44.7%) underwent breast conserving surgery after neoadjuvant chemotherapy.

In order to ensure negative surgical margins in breast-conserving surgery, proper detection of residual tumor size is crucial. However, there are limitations of mammography in the assessment of response to NAC. Dense breast parenchyma, increase in intensity due to edema, not being able to view the borders of diffuse growing lesions can be stated among these limitations. Similarly, due to edema the breast cannot be compressed at optimum quality and inability to obtain appropriate quality images are among the challenges. Based on all these reasons, physical examination and mammography cannot differentiate neoplastic tissue from fibrosis. In recent years studies are done in order to develop normograms that estimate the size of residual tumor after neoadjuvant chemotherapy and determine whether patients are eligible for breast conserving surgery or not (14, 17).

In our study, MRI correctly identified residual tumor size in 26 of 38 cases and the superiority of MRI over mammography or US in deter-

Table 5. Response type following neo-adjuvant treatment

	Complete response n (%)	Partial response n (%)	Stable disease n (%)	Progressive disease n (%)	Total n (%)
Pathology	6 (15.8)	28 (73.7)	3 (7.9)	1 (2.6)	38 (100)
MRI	5 (13.2)	28 (73.7)	4 (10.5)	1 (2.6)	38 (100)
Mammography	7 (18.4)	5 (13.2)	8 (21.1)	2 (5.3)	22 (58)
US	5 (13.2)	4 (10.5)	8 (21.1)	2 (5.3)	19 (50.1)

US: Ultrasonography; MRI: magnetic resonance imaging

Figure 6. a-c. Mammographic craniocaudal and mediolateral oblique views of a 48-year-old patient (Case 2) with a left sided mass (a, b). US image of the left breast (c). A diffuse growing tumor with indistinguishable boundaries and that cannot be measured in size is located in the UOQ of the left breast, it cannot be clearly assessed by US, the hypoechoic heterogeneous mass lesion was evaluated as BIRADS -5

mining residual tumor size after NAC was shown by correlating with histopathology. The difference in maximum residual tumor diameter between MRI and pathology was 1 cm in 15 of 17 patients who underwent breast-conserving surgery. It should be kept in mind that pathology accepts the tumor size as the entire width of the lesion therefore, in patients with millimetric tumor foci pathology determines a larger tumor size than MRI. In some patients, there might be no contrast enhancement on MRI while a few invasive cells might be detected on pathology. In two of our cases, 1-2 mm of invasive tumor tissue type was detected in some foci, resulting in a mismatch between MRI and pathologic response.

The difference in the widest diameter is important by itself in evaluation of NAC response. However, only using diameter measurement for assessment of response to treatment with MRI has some limitations. It is difficult to determine the actual size of the tumor in lesions with originally multiple nodular contrast enhancements that show partial – patchy response after NAC. Also in lesions with necrosis, the size can appear larger in MRI although the residual viable tumor tissue has decreased. Parallel to the literature in our study, MRI was found to be superior to mammography and US in terms of tumor size after NAC, its statistical correlation with pathologic diameter was moderate. MRI was able to determine the residual tumor size accurately in only 26 of 38 cases. For all these reasons, there is a need for other parameters in evaluation of response to treatment. Total tumor volume, changes in signal enhancement pattern and changes in peak signal enhancement can be stated as such parameters (10).

It is reported that in cases with response to NAC, type 3 pharmacokinetic curves with wash-out either flatten (type 1) or form a plateau

Figure 7. The histopathology result of tru-cut biopsy of Case 2 before treatment showed invasive lobular carcinoma, and 8 cycles of chemotherapy were administered. Treatment response type with mammography was considered as “stable disease”

(type 2) (18, 19). Balu Maestro and colleagues (20) accepted disappearance of early and initial contrast enhancement in the tumor after treatment as pathological complete response. Rieber et al. (18) determined that flattening or disappearance of the kinetic curve segment in the pharmacokinetic curve after the first course of chemotherapy or absence of enhancement after four cycles of chemotherapy indicate pathological complete response. In our patients, type 3 pharmacoki-

Figure 8. Pharmacokinetic curve of pre-treatment dynamic contrast-enhanced MRI of Case 2 before treatment. A 5x6 cm, diffusely growing mass mainly located in the middle and outer quadrant of the left breast, radiating from the lower to the upper quadrant was evaluated as BIRADS-5. The left breast skin is thick in appearance

Figure 9. Pharmacokinetic curve of post-treatment dynamic contrast-enhanced MRI of Case 2. Mass lesion in the left breast showed approximately 40% reduction in dimension, the pharmacokinetic curve type shifted from type 3 to type 1. The MRI response type was considered as "partial response"

Figure 10. a, b. The histopathological examination of modified radical mastectomy specimen of Case 2 after neoadjuvant chemotherapy showed invasive lobular carcinoma and chemotherapy-induced changes (a low magnification, b: high magnification) are detected in histopathological examination. The pathological response type was evaluated as "partial response" and is compatible with the MRI results.

netic curve ratio decreased from 55.3% to 7.9% with treatment. In patients with partial response to treatment, type 1 and type 2 curves are in the majority. It was observed that mass lesions showing rapid enhancement pattern before treatment, show medium and slow enhancement after treatment and that contrast enhancement rates decrease.

It is reported that there is a strong correlation between MRI and pathology in determining tumor response to NAC in LABC patients (correlation coefficient: 0.75 to 0.93) (21). The accuracy rate of MRI in detecting response to neoadjuvant chemotherapy as compared to pathology have been reported as 63.3%, 69%, 94.8%, and 80% (10, 18, 20). These publications include 15 to 60 patients and their chemotherapy and MRI protocols are different. In our study, MRI detected response to treatment accurately in 84.21% of the patients, and it was superior to mammography and US.

One of the limitations of our study is the difficulty in assessing tumor diameter in patients with inflammatory breast cancer with diffuse growth. MRI has limitations in detecting scattered small tumors and in showing residual tumor with slight contrast enhancement. The pathologic residual tumor size was different from the residual tumor size detected by MRI in three of our patients who were clinically compatible with inflammatory breast cancer. In these cases, MRI detected the size of the tumor smaller than its actual size due to edema. Another limitation was that diffusion-weighted images could not be obtained for each patient during MRI and thus it could not be used as a parameter in the evaluation of NAC response. The limited number of cases included is another limitation of our study.

There are three main stages in the radiographic evaluation of LABC patients who underwent neoadjuvant CT. The first is to diagnose the tumor and to determine its extent, the second is to accurately evaluate response to treatment therefore enabling implementation of appropriate chemotherapy protocol, and the third is to detect residual tumor size and its extent for exact surgical planning, and if breast conserving surgery is to be made to ensure tumor free surgical margins.

Traditional methods may not be accurate in assessing the true extent of the disease because of chemotherapy-induced fibrosis. MRI is more advantageous in assessing the true extent of the disease by evaluation of tissue vascularization and the ability to distinguish viable tumor from fibrotic tissue. It reflects tumor size more accurately and is more reliable than mammography or US in predicting residual disease after NAC. Similarly in our study, when compared to histopathological findings, contrast-enhanced dynamic breast MRI was determined as a more effective method than either mammography or US in the evaluation of response to neoadjuvant chemotherapy. Evaluation of locally advanced breast cancer by MRI is appropriate due to its not being invasive, ability of performing re-measurements and guiding future treatment.

Ethics Committee Approval: Ethics committee approval was received for this study.

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