

The value of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) in the prediction of neoadjuvant chemotherapy response in breast cancer: A Meta-Analysis

H. Abed Dakhil¹, A. Arian², N. Ahmadinejad^{3*}, R.A. Bustan^{1,4}, M.A. Sahib¹,
M. Anjomrooz⁵

¹Medical Imaging Techniques, Department of Radiology Technologies, College of Health & Medical Technology, Al-Ayen Iraqi University, Thi-Qar, Iraq

²Radiology-TUMS (Cancer Institute-ADIR), Tehran University of Medical Sciences (TUMS), Tehran, Iran

³Radiology-Medical Imaging Center, Cancer Research Institute, Imam Khomeini Hospital Advanced Diagnostic and Interventional Radiology Research Center (ADIR), Tehran University of Medical Sciences (TUMS), Tehran, Iran

⁴Radiology Department, College of health and medicine technology, Al-Ayen University, Thi-Qar, Iraq

⁵Radiology Department, Shariati Hospital, Tehran University of Medical Sciences (TUMS), Tehran, Iran

ABSTRACT

► Review article

*Corresponding author:

N. Ahmadinejad

E-mail:

naahmadinejad@TUMS.ac.ir

Received: September 2022

Final revised: May 2023

Accepted: June 2023

Int. J. Radiat. Res., July 2024;
22(3): 749-755

DOI: 10.61186/ijrr.22.3.749

Background: The Breast dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is utilized for screening breast cancer (BC) in women with a total lifetime BC risk of greater than 20-25%. This study aimed to assess the DCE-MRI value in predicting response to neoadjuvant chemotherapy (NAC) in BC patients. **Materials and Methods:** International databases, including Medline, PubMed, Embase, and Science Direct, were searched with appropriate keywords. Using the binomial distribution formula, the variance of each study was calculated, and the data were analyzed using Stata 14. Finally, the results of the studies were inputted into the random-effect meta-analysis. **Results:** Sixteen studies, with no recognized publication bias by Begg's test, comprising 1868 patients were involved in this study. The sensitivity of DCE-MRI was 0.693, whereas its specificity was 0.754, with 95% confidence intervals (CI) of 0.560-0.826 and 0.605-0.903, respectively. Based on the random-effect model, the results revealed a pooled positive and negative predictive value of 0.458 and 0.901, with 95% CI of 0.339-0.577 and 0.829-0.972, respectively. The pooled DCE-MRI accuracy in predicting pathologic complete response to NAC was 0.768 (95% CI: 0.720-0.817). Finally, a meta-analysis of 10 reports, revealed a pooled AUC 0.779 (95% CI: 0.702-0.856). **Conclusion:** Overall, the findings of our study revealed that the DCE-MRI is a sensitive and specific method with an acceptable NPV for predicting response to NAC in BC cases.

Keywords: Early prediction, DCE-MRI, Neoadjuvant chemotherapy, Breast cancer.

INTRODUCTION

Breast cancer (BC), a prevalent cancer type among women, is currently the main reason for mortality from cancer among women and is thought to account for 15% of cancer fatalities ⁽¹⁻³⁾. It was reported that the healing ratio of breast lesions detected at an early stage is dramatically higher than other breast lesions ⁽⁴⁾. BC which is progressed locally is now commonly treated with neoadjuvant chemotherapy (NAC). NAC is a systemic, cytotoxic medication treatment for patients with advanced BC that can minimize the tumor size before performing surgery. This can lead to an increased probability of conserving the breast ⁽⁵⁾. The effectiveness of NACT is reliant on the specific treatment plans employed. The most effective chemotherapy regimens for breast cancer patients

are anthracyclines and taxanes ⁽⁶⁾. Anthracyclines consist of doxorubicin and epirubicin, while taxanes include docetaxel or paclitaxel. Furthermore, these medications are typically administered in conjunction with other drugs such as fluorouracil and cyclophosphamide ⁽⁶⁾.

In BC patients, molecular markers can predict the response to the NAC. For example, human epidermal growth factor receptor 2 (HER2), and proliferation index (Ki-67) are considered prognostic factors of response to NAC ^(7, 8). Early examination of NAC therapy for BC can result in clinical counseling for treatment choice adjustments, suitable timing for surgery, and a reduction in unnecessary overtreatment ⁽⁹⁻¹¹⁾. The strongest indicator of a good long-term result is achieving a minimal residual tumor. The reliable assessment of the treatment

response to NAC is essential for surgical planning, decision-making, and the prediction of ultimate results⁽¹²⁾.

High clinical response rates (70-98 %) after NAC can lead to a pathologically complete response in a small subset of patients^(13,14). Previous studies have shown that people receiving NAC had an equal chance of surviving as individuals receiving adjuvant chemotherapy, while they had a decreased probability of needing a mastectomy, meaning that they are more likely to be eligible for breast conservation therapy⁽¹⁵⁻¹⁷⁾.

Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) of the breast is employed to screen BC in women with a total lifetime BC risk of greater than 20-25%. principle of the DCE-MRI approach is the fast diffusion of a contrast agent with low molecular mass via the fenestration found in these aberrant microcapillaries. Studies have revealed that the vascular density of the lesion is related to changes in signal intensity. These studies also demonstrated that vascular fenestrations and functional permeability, as well as the interstitial environment that affects the diffusibility determine enhancement rate^(18,19). Parameters linking to the permeability of microvascular vessel wall, and tissue perfusion from the analysis of the signal intensity-time curves can help characterize the underlying pathology⁽²⁰⁻²²⁾. Although the uncertainty of the pathophysiological mechanism gives rise to alterations in DCE-MRI parameters, these changes can be utilized to indicate treatment response, although it appears to be correlated to changes in the density of microvessels and the anti-angiogenic impacts of chemotherapy⁽²⁰⁾. MRI images before and after chemotherapy in BC patients show in figure 1.

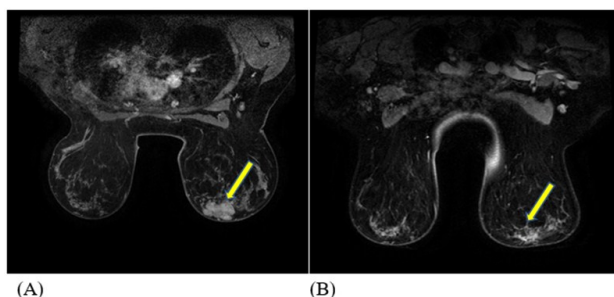


Figure 1. A patient with a moderately differentiated IDC has partial imaging and a pathologic response. A heterogeneous irregular tumour with enhancement in the center of the left breast is visible in (A) axial contrast-enhanced T1-weighted MRI taken prior to therapy (arrow). After therapy, axial contrast-enhanced T1-weighted MRI results show residual non-mass enhancement that is smaller and less intense (arrow), which is consistent with a partial response.

Some studies have already evaluated the performance of DCE-MRI in predicting the response to NAC among BC patients^(15,23,24). However, high-quality studies, are either insufficient, and there are controversies in their findings. Moreover, as

mentioned above, the prediction of the response to NAC is of great importance for treatment-related choices. Also, there is not a systematic review and meta-analysis which comprehensively pooled the results of each studies in this topic. Thus, this study aimed to evaluate the DCE-MRI value in predicting response to NAC in BC patients.

MATERIALS AND METHODS

Publication search strategy

Herein, a literature search was accomplished in July 2022 to identify studies providing data on the value of DCE-MRI, for the prediction of the response to NAC among BC cases. One author searched WoS, Medline, Embase, and Google Scholar databases using the following keywords as well as their synonyms, abbreviations, Mesh terms, and all the possible combinations: “Dynamic Contrast-Enhanced Magnetic Resonance Imaging”, “Breast neoplasm” and “Neoadjuvant chemotherapy”.

Study selection

The following criteria were considered to include studies in our review: 1) original articles written in english, 2) studies that compared the results of DCE-MRI with a reference standard, and 3) the results of the histopathological analysis were considered the reference standard. Also, our exclusion criteria were as follows: 1) review articles, editorial articles, book chapters, and case reports, 2) articles that used imaging modalities other than DCE-MRI and 3) studies that evaluated response in BC patients, after receiving NAC.

Screening and data extraction

Two authors independently assessed the identified articles considering inclusion and exclusion criteria. Initially, titles and abstracts were screened. Then, the same two authors evaluated the full text of the selected articles. The articles that were selected by both authors were included in the study, while the ones selected by only one author were evaluated further by a third reviewer. Finally, out of all included studies, the required data were extracted by two authors, independently. The extracted data entailed the first author, his/her country of affiliation, study design, year of publication, gender and age of the patient(s), sample size, complete pathological response, regimen of neoadjuvant chemotherapy, specificity, sensitivity, accuracy, positive and negative predictive value (PPV and NPV, respectively), and area under the curve (AUC). Likewise, when there was a disagreement between the extracted data, all discrepant items were assessed by a third author.

Risk of bias in included studies (Quality assessment)

Using QUADAS criteria, one author assessed the

quality of selected studies. QUADAS is a quality assessment tool evaluate the risk of bias, and the applicability of primary diagnostic accuracy studies. The quality evaluation of the included studies was carried out in the following domains: patient selection, index test(s), reference standard, and flow and timing.

Risk of bias across studies

To estimate publication bias, we applied the Begg's and Egger tests.

Statistical analysis

The effect size and the 95% confidence intervals (CI) were calculated by Stata 14. The heterogeneity of each group was also measured using the inconsistency index (I^2). An I^2 greater than 50% or a p -value smaller than 0.05 was recognized as significant heterogeneity. In case of high heterogeneity, we used a random-effect model for calculating the pooling effect and the 95% CI. Otherwise, the fixed-effect model was applied. The DCE-MRI value in predicting the NAC pathological response among BC cases was also determined by calculating pooled specificity, sensitivity, PPV, NPV, accuracy, and AUC with 95% CI.

RESULTS

Study selection

At the end of a comprehensive search, 1529 studies were identified. Then, 522 duplicate articles and 896 other articles were excluded by assessing their titles and abstracts. In the next step, 111 remaining articles were fully screened, upon which 99 articles were excluded and 12 articles remained. Noteworthy, the reference lists of eligible articles were also cross-checked, and four articles were included among them. In the end, we selected 16 articles for our investigation (figure 2).

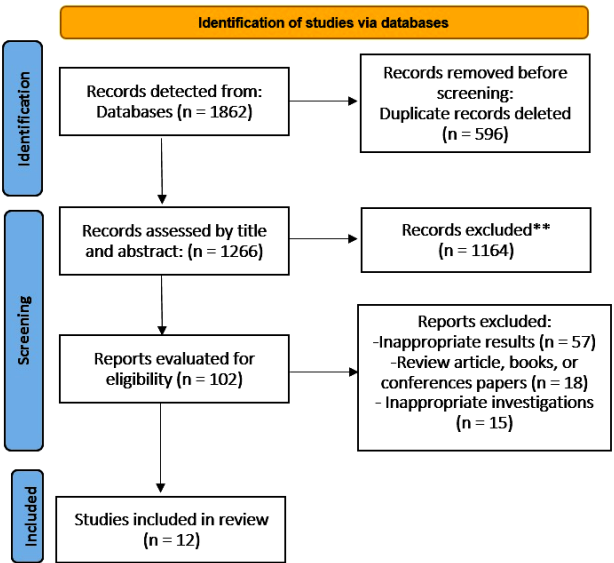


Figure 2. A flow chart of studies selection in this study.

Characteristics of included studies

Characteristics of all selected studies, including 1868 patients, are provided in table 1. In 12 studies, BC cases were enrolled retrospectively, and in the remaining four, patients were enrolled prospectively.

Quality assessment of studies

Using the quality assessment tool, QUADAS-2, we assessed the quality of included studies in four main domains (figure 3). The unclear risk of bias, both in the reference standard and index text domains, emerged from the ambiguity in the manuscript around the reference standard or index test or whether the investigators were blinded to the study or not. Additionally, in two studies, the selection process of patients was unclear and at risk of bias, and in one other study, the bias risk was unclear in the “flow and timing” domain.

	Risk of Bias				Applicability Concerns		
	Patient Selection	Index Test	Reference Standard	Flow and Timing	Patient Selection	Index Test	Reference Standard
Bufl et al. 2015	+	?	+	+	+	+	+
Chen et al. 2020	+	+	+	?	+	+	+
Craciunescu et al. 2009	?	+	?	+	+	+	+
De Los Santos et al. 2011	+	+	?	+	+	+	+
Dongfeng et al. 2012	+	+	+	+	+	+	+
Fan et al. 2021	+	?	?	+	+	+	+
Gampenrieder et al. 2019	+	+	+	+	+	+	+
Huang et al. 2016	+	+	-	+	+	+	+
Li et al. 2020	+	+	+	+	+	+	+
Moon et al. 2008	+	+	+	+	+	+	+
Pesapane et al. 2021	+	?	?	+	+	+	+
Schott et al. 2005	+	+	+	+	+	+	+
Tateishi et al. 2012	+	+	?	+	+	+	+
Tokuda et al. 2021	+	+	?	+	+	+	+
Zhao et al. 2021	?	+	+	+	+	+	+
Zhou et al. 2020	+	+	+	+	+	+	+

High

Unclear

Low

Figure 3. Studies Quality assessment using QUADAS-2.

Evaluation of DCE-MRI diagnostic performance

The DCE-MRI value in predicting response to NAC was assessed in selected articles. To this end, the data around specificity, sensitivity, accuracy, AUC, NPV, and PPV were pooled using meta-analysis. The pooled data of 14 out of 16 articles on DCE-MRI sensitivity and specificity were 0.693 and 0.754, with 95% CI of 0.560-0.826 and 0.605-0.903, respectively (figures 4 and 5). The meta-analysis of the data from six articles showed a pooled PPV of 0.458 and a

pooled NPV of 0.90, with 95% CI of 0.339-0.577 and 0.829-0.972, respectively. The pooled DCE-MRI accuracy of six articles to predict pathologic complete response (pCR) to NAC was 0.768 (95% CI 0.720-0.817). Finally, our meta-analysis of 10 surveys that reported AUC, revealed a pooled AUC of 0.779 (95%

CI: 0.702-0.856) (figure 6).

Publication bias

After the evaluation, according to Begg's test, there was no publication bias. The results of Begg's test and Begg's funnel plot are presented in figure 7.

Table 1. Characteristics of studies included in the present survey.

Study	Year	No. of patients	Age (year), mean	Study design	MRI	Preoperative therapy (drugs used in regimens)	Receptor status
Bufl et al. (7)	2015	225	47	Retrospective	1.5 T	doxorubicin, taxane, cyclophosphamide	143 Luminal, 37 Triple negative, 17 HER2+, 28 Hybrid
Li et al. (42)	2020	384	49	Retrospective	-	paclitaxel, anthracycline, cyclophosphamide, trastuzumab	162 HR+/HER2-, 60 HR+/HER2+, 30 HR-/HER2+, 132 HR-/HER2- (triple negative)
Zhou et al. (43)	2020	55	50.4	Retrospective	3.0 T	taxol, 5-fluorouracil, epirubicin, cyclophosphamide, doxorubicin	22 Luminal A, 9 Luminal B, 13 HER2+, 11 Triple negative
Gampenrieder et al. (44)	2019	246	50	Retrospective	3.0 T	anthracycline, taxane, trastuzumab, pertuzumab	57 Luminal A, 29 Luminal B, 33 HER2+/HR-, 37 HER2+/HR+, 90 Triple negative
Pesapane et al. (45)	2021	83	47.26	Retrospective	1.5 T	Chemotherapy, hormone therapy	44 ER+, 41 PR+, 31 HER2+
Chen et al. (46)	2020	28	48.48	Retrospective	3.0 T	doxorubicin, cyclophosphamide, docetaxel, trastuzumab	19 ER+, 11 PR+, 15 HER2+
Dongfeng et al. (47)	2012	60	55.4	Retrospective	3.0 T	paclitaxel, pirarubicin	31 ER+
Fan et al. (48)	2021	114	48	Retrospective	3.0 T	N/A	12 Luminal A, 58 Luminal B, 20 Basal-like, 24 HER2+
Huang et al. (36)	2016	59	-	Retrospective	-	N/A	N/A
Zhao et al. (49)	2021	87	-	Retrospective	3.0 T	taxane, anthracyclines, cyclophosphamide, carboplatin, trastuzumab	37 HR+/HER2-, 36 HER2+, 14 Triple Negative
Tateishi et al. (50)	2012	142	57	Prospective	3.0 T	5-fluorouracil, epirubicin, cyclophosphamide, doxorubicin, paclitaxel, herceptin, docetaxel	100 ER+, 82 PR+, 111 HER2+
Tokuda et al. (40)	2021	29	55	Prospective	3.0 T	paclitaxel, trastuzumab, 5-fluorouracil, epirubicin, cyclophosphamide	7 Luminal A, 13 Luminal B, 3 HER2+, 6 Triple Negative
De Los Santos et al. (51)	2011	81	50	Retrospective	1.5 T	doxorubicin, paclitaxel, cyclophosphamide	45 HR+, 23 HER2+
Moon et al. (41)	2008	212	45.5	Prospective	1.5 T	taxane, anthracyclines, trastuzumab	101 ER+, 68 PR+, 63 HER2+
Craciunescu et al. (37)	2009	20	46.5	Retrospective	1.5 T	paclitaxel, liposomal doxorubicin, hormone therapy	N/A
Schott et al. (52)	2005	43	48	Prospective	1.5 T	doxorubicin, docetaxel	25 ER+

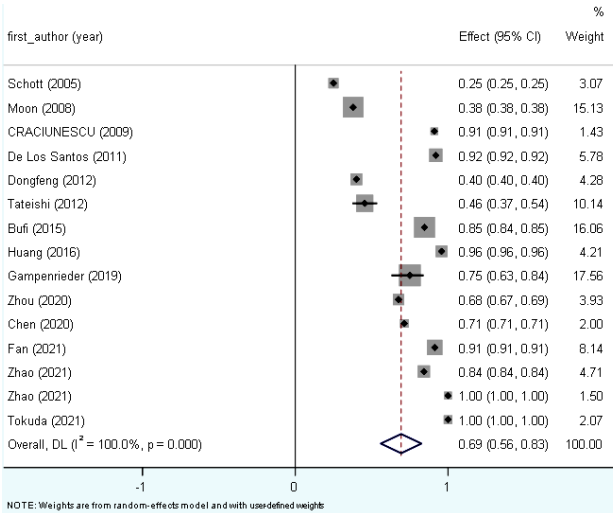


Figure 4. Forest plot of the DCE-MRI sensitivity for the prediction of response to NAC among BC patients.

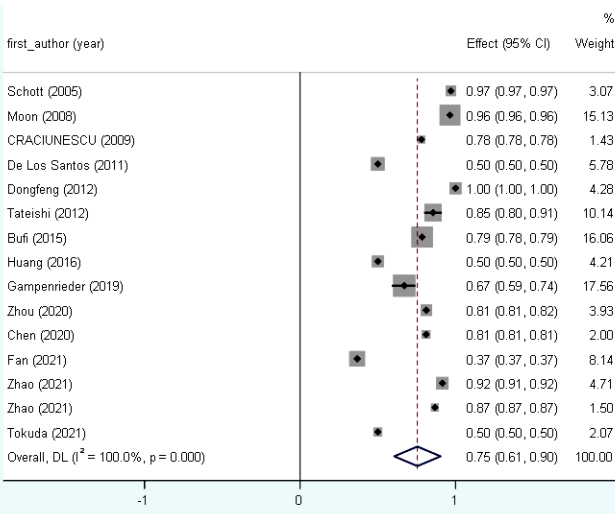


Figure 5. Forest plot of the DCE-MRI specificity for the prediction of response to NAC among BC patients.

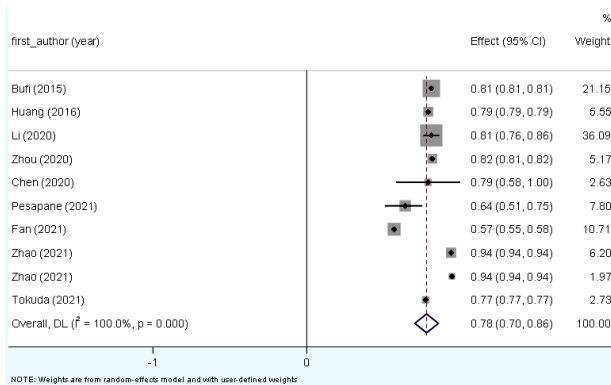


Figure 6. Forest plot of the diagnostic AUC of DCE-MRI for the prediction of response to NAC among BC patients.

DISCUSSION

NAC has been standardized to decrease the size of breast tumors or downstaging the BC, which can decline the progression of cancer, enhance the survival of BC cases, and improve their life quality^(25, 26). Previous studies showed that the clinicopathological findings and improvements upon NAC were various in different types of invasive BCs⁽²⁷⁾. Therefore, we evaluated the DCE-MRI value in predicting the NAC response in BC patients. Our findings showed that the pooled specificity of DCE-MRI to predict the reaction to NAC in BC patients was 75%, while the DCE-MRI sensitivity was 69%. Furthermore, we observed that the pooled NPV of DCE-MRI was 90%.

Multiple studies have already evaluated the DCE-MRI performance in assessing the pathological response to NAC in BC cases^(5,28-30). According to a meta-analysis by Jun *et al.*⁽⁵⁾, DCE-MRI is capable of monitoring NAC for BC with high sensitivity and specificity despite a high degree of heterogeneity in published studies. In another meta-analysis, Cheng *et al.*⁽³¹⁾ pooled the surveys assessing the value of DCE-MRI in the evaluation of the response to NAC in patients with BC. However, in the current study, we pooled the data reporting the predictive DCE-MRI value in BC cases receiving NAC. However, Prevos *et al.*⁽³²⁾ showed that the value of MRI in this regard is still unclear. In the study of Li *et al.*⁽³³⁾, the signal enhancement ratio washout volume, as well as k_{ep} of DCE-MRI, successfully predicted the response of BC after one cycle of NAC. Also, Atuegwu *et al.*⁽³⁴⁾ reported that the radiomics features of DCE-MRI and Diffusion-Weighted Imaging (DWI-MRI) could be utilized for the prediction of the treatment response in BC cases at the end of chemotherapy. Finally, a study by Marinovich *et al.*⁽³⁵⁾ determined that the heterogeneity of the study method precluded definitive conclusions. Notably, many differences were observed between mentioned studies in their clinicopathological details such as tumor type, NAC regimen, pathological reaction, imaging like time

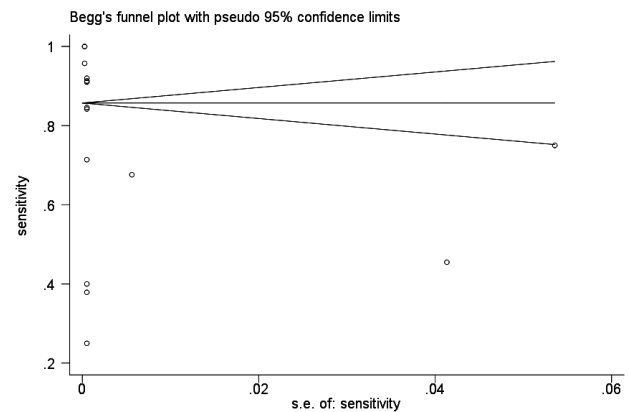


Figure 7. Publication bias test using Begg's funnel plot test.

point testing, and analysis methods, including pharmacokinetic models.

Our study, like other investigations, suffers from some limitations. First, in the studies reviewed in our study, the data was not reported based on the pathological types of BC, and since NAC treatment may produce different responses relative to the pathological type of BC, it may cause heterogeneity in the results. Second, the stage of BC was not reported in some studies^(36,37), and those revealed did not clearly report their data based on the stage of BC. Third, various NAC regimens were applied in different studies. Fourth, some studies^(14,38,39) reported the predictive value of some radiomics features of DCE-MRI, which cannot be presented in our study. Finally, some studies^(40,41) reported the predictive value of DCE-MRI using different indices. Therefore, further studies need to be performed to overcome these limitations.

CONCLUSION

To sum up, the findings of our study revealed that the DCE-MRI is not only a sensitive but also a specific method with an acceptable NPV for predicting the response to NAC in BC cases. Thus, a clinician can make a decision on a treatment regimen before NAC and treat some patients who do not benefit from NAC with another appropriate regimen.

ACKNOWLEDGMENTS

The authors extend their gratitude to the Tehran University of Medical Sciences.

Availability of data and materials: All data generated or analyzed during this study are included in this published article.

Authors' contributions: H.D, A.A, and N.A contributed to the study concept and design; H.D, R.A, M.A, and M.S collected the data; A.A and N.A carried out analysis and interpretation of data; H.D performed drafting of the manuscript; H.D, R.A, and M.S performed critical revision of the manuscript for

important intellectual content. All authors read and approved the final manuscript.

Ethics approval and consent to participate: Not applicable.

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

Funding: No funding.

REFERENCES

- Watkins EJ. Overview of breast cancer. *Journal of the American Academy of PAs*. 2019;**32**(10):13-7.
- Naseem U, Rashid J, Ali L, Kim J, Haq QEU, Awan MJ, et al. An automatic detection of breast cancer diagnosis and prognosis based on machine learning using ensemble of classifiers. *IEEE Access*. 2022;**10**:78242-52.
- Ghayoumi Zadeh H, Masoumzadeh S, Nour S, Kianersi S, Eyvazi Zadeh Z, Joneidi Shariat Zadeh F, et al. Breast cancer diagnosis by thermal imaging in the fields of medical and artificial intelligence sciences. *Tehran University Medical Journal TUMS Publications*. 2016;**74**(6):377-85.
- Milosevic M, Jankovic D, Milenkovic A, Stojanov D. Early diagnosis and detection of breast cancer. *Technology and Health Care*. 2018;**26**(4):729-59.
- Jun W, Cong W, Xianxin X, Daqing J. Meta-analysis of quantitative dynamic contrast-enhanced MRI for the assessment of neoadjuvant chemotherapy in breast cancer. *The American Surgeon*. 2019;**85**(6):645-53.
- Pathak M, Dwivedi SN, Deo S, Thakur B, Sreenivas V, Rath G. Neoadjuvant chemotherapy regimens in treatment of breast cancer: a systematic review and network meta-analysis protocol. *Systematic reviews*. 2018;**7**(1):1-8.
- Bufl E, Belli P, Costantini M, Cipriani A, Di Matteo M, Bonatesta A, et al. Role of the apparent diffusion coefficient in the prediction of response to neoadjuvant chemotherapy in patients with locally advanced breast cancer. *Clinical Breast Cancer*. 2015;**15**(5):370-80.
- Moradi B, Gity M, Etesam F, Borhani A, Ahmadijeh N, Kazemi MA. Correlation of apparent diffusion coefficient values and peritumoral edema with pathologic biomarkers in patients with breast cancer. *Clinical Imaging*. 2020;**68**:242-8.
- Kim J, Oktay K, Gracia C, Lee S, Morse C, Mersereau JE. Which patients pursue fertility preservation treatments? A multicenter analysis of the predictors of fertility preservation in women with breast cancer. *Fertility and sterility*. 2012;**97**(3):671-6.
- Pilewski M, Zabor EC, Mamtani A, Barrio AV, Stempel M, Morrow M. The optimal treatment plan to avoid axillary lymph node dissection in early-stage breast cancer patients differs by surgical strategy and tumor subtype. *Annals of surgical oncology*. 2017;**24**:3527-33.
- de Munck L, Sonke G, van Dalen T, van Diest P, van den Bongard H, Peeters P, et al. Population based study on sentinel node biopsy before or after neoadjuvant chemotherapy in clinically node negative breast cancer patients: Identification rate and influence on axillary treatment. *European journal of cancer*. 2015;**51**(8):915-21.
- Bear HD, Anderson S, Brown A, Smith R, Mamounas EP, Fisher B, et al. The effect on tumor response of adding sequential preoperative docetaxel to preoperative doxorubicin and cyclophosphamide: preliminary results from National Surgical Adjuvant Breast and Bowel Project Protocol B-27. *Journal of Clinical Oncology*. 2003;**21**(22):4165-74.
- Kaufmann M, Hortobagyi GN, Goldhirsch A, Scholl S, Makris A, Valagussa P, et al. Recommendations from an international expert panel on the use of neoadjuvant (primary) systemic treatment of operable breast cancer: an update. *Journal of Clinical Oncology*. 2006;**24**(12):1940-9.
- Ah-See MLW, Makris A, Taylor NJ, Harrison M, Richman PI, Burcombe RJ, et al. Early changes in functional dynamic magnetic resonance imaging predict for pathologic response to neoadjuvant chemotherapy in primary breast cancer. *Clinical Cancer Research*. 2008;**14**(20):6580-9.
- Abramson RG, Li X, Hoyt TL, Su P-F, Arlinghaus LR, Wilson KJ, et al. Early assessment of breast cancer response to neoadjuvant chemotherapy by semi-quantitative analysis of high-temporal resolution DCE-MRI: preliminary results. *Magnetic resonance imaging*. 2013;**31**(9):1457-64.
- Almahariq MF, Quinn TJ, Siddiqui ZA, Thompson AB, Jawad MS, Chen PY, et al. Post-mastectomy radiotherapy is associated with improved overall survival in T3N0 patients who do not receive chemotherapy. *Radiotherapy and Oncology*. 2020;**145**:229-37.
- Cassidy MR, Zabor EC, Stempel M, Mehrara B, Gemignani ML. Does response to neo-adjuvant chemotherapy impact breast reconstruction? *The breast journal*. 2018;**24**(4):567-73.
- Gubern-Mérida A, Martí R, Melendez J, Hauth JL, Mann RM, Karssemeijer N, et al. Automated localization of breast cancer in DCE-MRI. *Medical image analysis*. 2015;**20**(1):265-74.
- Ahmadijeh N, Azhdeh S, Arian A, Eslami B, Mehrabinejad M-M. Implementation of abbreviated breast MRI in diagnostic and screening settings. *Acta Radiologica*. 2022;0284185122114434.
- Knopp M, Weiss E, Sinn H, Mattern J, Junkermann H, Radeleff J, et al. Pathophysiologic basis of contrast enhancement in breast tumors. *Journal of Magnetic Resonance Imaging: An Official Journal of the International Society for Magnetic Resonance in Medicine*. 1999;**10**(3):260-6.
- Turnbull LW. Dynamic contrast-enhanced MRI in the diagnosis and management of breast cancer. *NMR in Biomedicine: An International Journal Devoted to the Development and Application of Magnetic Resonance In Vivo*. 2009;**22**(1):28-39.
- Gordon Y, Partovi S, Müller-Eschner M, Amarteifio E, Bäuerle T, Weber MA, et al. Dynamic contrast-enhanced magnetic resonance imaging: fundamentals and application to the evaluation of the peripheral perfusion. *Cardiovascular diagnosis and therapy*. 2014;**4**(2):147.
- Johansen R, Jensen LR, Rydland J, Goa PE, Kvistad KA, Bathen TF, et al. Predicting survival and early clinical response to primary chemotherapy for patients with locally advanced breast cancer using DCE-MRI. *Journal of Magnetic Resonance Imaging: An Official Journal of the International Society for Magnetic Resonance in Medicine*. 2009;**29**(6):1300-7.
- Fan M, Wu G, Cheng H, Zhang J, Shao G, Li L. Radiomic analysis of DCE-MRI for prediction of response to neoadjuvant chemotherapy in breast cancer patients. *European journal of radiology*. 2017;**94**:140-7.
- Wolmark N, Wang J, Mamounas E, Bryant J, Fisher B. Preoperative chemotherapy in patients with operable breast cancer: nine-year results from National Surgical Adjuvant Breast and Bowel Project B-18. *JNCI Monographs*. 2001;**2001**(30):96-102.
- Mauri D, Pavlidis N, Ioannidis JP. Neoadjuvant versus adjuvant systemic treatment in breast cancer: a meta-analysis. *Journal of the National Cancer Institute*. 2005;**97**(3):188-94.
- Nagao T, Kinoshita T, Hojo T, Tsuda H, Tamura K, Fujiwara Y. The differences in the histological types of breast cancer and the response to neoadjuvant chemotherapy: the relationship between the outcome and the clinicopathological characteristics. *The Breast*. 2012;**21**(3):289-95.
- Hahn SY, Ko EY, Han BK, Shin JH, Ko ES. Role of diffusion-weighted imaging as an adjunct to contrast-enhanced breast MRI in evaluating residual breast cancer following neoadjuvant chemotherapy. *European Journal of Radiology*. 2014;**83**(2):283-8.
- An YY, Kim SH, Kang BJ, Lee AW. Treatment response evaluation of breast cancer after neoadjuvant chemotherapy and usefulness of the imaging parameters of MRI and PET/CT. *Journal of Korean medical science*. 2015;**30**(6):808-15.
- Li X, Abramson RG, Arlinghaus LR, Kang H, Chakravarthy AB, Abramson VG, et al. Multiparametric magnetic resonance imaging for predicting pathological response after the first cycle of neoadjuvant chemotherapy in breast cancer. *Investigative radiology*. 2015;**50**(4):195-204.
- Cheng Q, Huang J, Liang J, Ma M, Ye K, Shi C, et al. The diagnostic performance of DCE-MRI in evaluating the pathological response to neoadjuvant chemotherapy in breast cancer: a meta-analysis. *Frontiers in Oncology*. 2020;**10**:93.
- Prevos R, Smidt M, Tjan-Heijnen V, van Goethem M, Beets-Tan R, Wildberger J, et al. Pre-treatment differences and early response monitoring of neoadjuvant chemotherapy in breast cancer patients using magnetic resonance imaging: a systematic review. *European radiology*. 2012;**22**:2607-16.
- Li X, Arlinghaus LR, Ayers GD, Chakravarthy AB, Abramson RG, Abramson VG, et al. DCE-MRI analysis methods for predicting the response of breast cancer to neoadjuvant chemotherapy: Pilot study findings. *Magnetic resonance in medicine*. 2014;**71**(4):1592-602.

34. Atuegwu NC, Arlinghaus LR, Li X, Chakravarthy AB, Abramson VG, Sanders ME, et al. Parameterizing the logistic model of tumor growth by DW-MRI and DCE-MRI data to predict treatment response and changes in breast cancer cellularity during neoadjuvant chemotherapy. *Translational oncology*. 2013;**6**(3):256-64.
35. Marinovich M, Sardanelli F, Ciatto S, Mamounas E, Brennan M, Macaskill P, et al. Early prediction of pathologic response to neoadjuvant therapy in breast cancer: systematic review of the accuracy of MRI. *The Breast*. 2012;**21**(5):669-77.
36. Huang L, Fan M, Li L, Zhang J, Shao G, Zheng B, editors. Association between dynamic features of breast DCE-MR imaging and clinical response of neoadjuvant chemotherapy: a preliminary analysis. *Medical Imaging 2016: PACS and Imaging Informatics: Next Generation and Innovations*; 2016: SPIE.
37. Craciunescu OI, Blackwell KL, Jones EL, MacFall JR, Yu D, Vujaskovic Z, et al. DCE-MRI parameters have potential to predict response of locally advanced breast cancer patients to neoadjuvant chemotherapy and hyperthermia: a pilot study. *International Journal of Hyperthermia*. 2009;**25**(6):405-15.
38. Bian T, Wu Z, Lin Q, Wang H, Ge Y, Duan S, et al. Radiomic signatures derived from multiparametric MRI for the pretreatment prediction of response to neoadjuvant chemotherapy in breast cancer. *The British Journal of Radiology*. 2020;**93**:20200287.
39. Cavallo Marincola B, Telesca M, Zaccagna F, Riemer F, Anzidei M, Catalano C, et al. Can unenhanced MRI of the breast replace contrast-enhanced MRI in assessing response to neoadjuvant chemotherapy? *Acta Radiologica*. 2019;**60**(1):35-44.
40. Tokuda Y, Yanagawa M, Fujita Y, Honma K, Tanei T, Shimoda M, et al. Prediction of pathological complete response after neoadjuvant chemotherapy in breast cancer: comparison of diagnostic performances of dedicated breast PET, whole-body PET, and dynamic contrast-enhanced MRI. *Breast Cancer Research and Treatment*. 2021;**188**(1):107-15.
41. Moon HG, Han W, Lee J, Ko E, Kim EK, Yu JH, et al. Age and HER2 expression status affect MRI accuracy in predicting residual tumor extent after neo-adjuvant systemic treatment. *Annals of oncology*. 2009;**20**(4):636-41.
42. Li W, Newitt DC, Gibbs J, Wilmes LJ, Jones EF, Arasu VA, et al. Predicting breast cancer response to neoadjuvant treatment using multi-feature MRI: results from the I-SPY 2 TRIAL. *NPI breast cancer*. 2020;**6**(1):1-6.
43. Zhou J, Lu J, Gao C, Zeng J, Zhou C, Lai X, et al. Predicting the response to neoadjuvant chemotherapy for breast cancer: wavelet transforming radiomics in MRI. *BMC cancer*. 2020;**20**(1):1-10.
44. Gampenrieder SP, Peer A, Weismann C, Meissnitzer M, Rinnerthaler G, Webhofer J, et al. Radiologic complete response (rCR) in contrast-enhanced magnetic resonance imaging (CE-MRI) after neoadjuvant chemotherapy for early breast cancer predicts recurrence-free survival but not pathologic complete response (pCR). *Breast Cancer Research*. 2019;**21**(1):1-11.
45. Pesapane F, Rotili A, Botta F, Raimondi S, Bianchini L, Corso F, et al. Radiomics of MRI for the prediction of the pathological response to neoadjuvant chemotherapy in breast cancer patients: a single referral centre analysis. *Cancers*. 2021;**13**(17):4271.
46. Chen X, Chen X, Yang J, Li Y, Fan W, Yang Z. Combining dynamic contrast-enhanced magnetic resonance imaging and apparent diffusion coefficient maps for a radiomics nomogram to predict pathological complete response to neoadjuvant chemotherapy in breast cancer patients. *Journal of Computer Assisted Tomography*. 2020;**44**(2):275-83.
47. Dongfeng H, Daqing M, Erhu J. Dynamic breast magnetic resonance imaging: pretreatment prediction of tumor response to neoadjuvant chemotherapy. *Clinical Breast Cancer*. 2012;**12**(2):94-101.
48. Fan M, Chen H, You C, Liu L, Gu Y, Peng W, et al. Radiomics of tumor heterogeneity in longitudinal dynamic contrast-enhanced magnetic resonance imaging for predicting response to neoadjuvant chemotherapy in breast cancer. *Frontiers in molecular biosciences*. 2021;**8**:622219.
49. Zhao R, Lu H, Li YB, Shao ZZ, Ma WJ, Liu PF. Nomogram for early prediction of pathological complete response to neoadjuvant chemotherapy in breast cancer using dynamic contrast-enhanced and diffusion-weighted MRI. *Academic Radiology*. 2022;**29**:S155-S63.
50. Tateishi U, Miyake M, Nagaoka T, Terauchi T, Kubota K, Kinoshita T, et al. Neoadjuvant chemotherapy in breast cancer: prediction of pathologic response with PET/CT and dynamic contrast-enhanced MR imaging—prospective assessment. *Radiology*. 2012;**263**(1):53-63.
51. De Los Santos J, Bernreuter W, Keene K, Krontiras H, Carpenter J, Bland K, et al. Accuracy of breast magnetic resonance imaging in predicting pathologic response in patients treated with neoadjuvant chemotherapy. *Clinical breast cancer*. 2011;**11**(5):312-9.
52. Schott AF, Roubidoux MA, Helvie MA, Hayes DF, Kleer CG, Newman LA, et al. Clinical and radiologic assessments to predict breast cancer pathologic complete response to neoadjuvant chemotherapy. *Breast cancer research and treatment*. 2005;**92**(3):231-8.

