HHS Public Access

Author manuscript

Ann Surg Oncol. Author manuscript; available in PMC 2018 June 01.

Published in final edited form as:

Ann Surg Oncol. 2017 June ; 24(6): 1492–1498. doi:10.1245/s10434-016-5741-y.

Do Calcifications on Mammography after Neoadjuvant Chemotherapy for Breast Cancer Always Need to be Excised?

Yara Felicano, MD[1], **Anita Mamtani, MD**[2], **Monica Morrow, MD**[3], **Michelle M Stempel**[3], **Sujata Patil**[4], and **Maxine S. Jochelson, MD**[5]

[1]Miller School of Medicine, University of Miami, Miami, FL 33136, USA

[2]Department of Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA 02215, USA

[3]Department of Surgery, Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA

[4]Department of Epidemiology and Biostatistics, Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA

[5]Department of Radiology, Memorial Sloan Kettering Cancer Center, New York, NY 10065, USA

Abstract

Purpose—To determine the relationship between mammographic calcifications and MRI tumoral enhancement before and after neoadjuvant chemotherapy (NAC) and assess the impact of these findings on surgical management.

Methods—This IRB-approved, HIPAA-compliant retrospective study involved breast cancer patients who underwent NAC between 2009 and 2015. 90 patients with pre- and post-treatment MRI and mammograms demonstrating calcifications within the tumor bed either at presentation and/or after treatment comprised the study cohort. Data gathered included pre- and post NAC imaging findings and post-NAC histopathology, particularly findings associated with calcifications. Comparisons were made using the Fishers Exact test with p-values < 0.05 considered significant.

Results—Complete resolution of MRI enhancement occurred in 44% and pathologic complete response (pCR) was achieved in 32% of patients. There was no statistically significant correlation between changes in calcifications and MRI (p=0.12). Resolution of enhancement was strongly correlated with pCR (p<.0001). The majority of patients with pCR demonstrated complete resolution of enhancement (23/29, 79%). No statistically significant relationship existed between changes in calcifications and rates of pCR (p=.06). PCR was most frequent in patients with resolution of enhancement and new, increasing, or unchanged calcifications (p<.0001).

Conclusions—Although calcifications seen on post-NAC mammography may be associated with benign disease, loss of MRI enhancement does not predict the absence of residual tumor with sufficient accuracy to leave calcifications in place. Complete excision of tumor bed calcifications

Corresponding author: Maxine S. Jochelson, Department of Radiology, Breast Imaging Section, Memorial Sloan-Kettering Cancer Center, 300 East 66th Street #711, 10065 New York, USA, Tel: 646 888-4507, Fax: 646 888-4912, jochelsm@mskcc.org.

No commercial interest to disclose.

remains standard practice and a substantial limitation to NAC use for downstaging patients to be eligible for BCT.

INTRODUCTION

Neoadjuvant chemotherapy (NAC) is a valuable treatment option for patients with breast cancer.[1-4] NAC can be used to downstage tumor size allowing breast conservation (BCT) in patients who would otherwise require mastectomy and convert unresectable to resectable disease. NAC has also been shown to decrease the need for axillary dissection.[5]

Pre and post-NAC imaging is used to evaluate the patient's response to NAC and guide the surgical approach. This generally includes mammography, ultrasound, and breast MRI. Mammography and breast ultrasound, the most commonly used imaging modalities for evaluating tumor size before and after NAC, have variable accuracy.[6] Several studies have demonstrated that contrast-enhanced MRI is the most accurate breast imaging technique for evaluating the extent of residual disease after NAC.[6-9] De Los Santos et al evaluated the ability of MRI to predict pathologic complete response (pCR) in invasive breast cancer patients receiving NAC and reported an overall accuracy of 74%.[9] However, pCR is not necessary for BCT, and Jochelson et al have demonstrated that 88% of patients determined to be candidates for BCT based on post-NAC MRI were able to be conserved.[8]

After NAC, new mammographic calcifications may develop as tumor cells die, or previously seen calcifications may decrease or increase without clear correlation with enhancement on MRI. The extent of residual calcifications is an unreliable indicator of response to NAC, as not all calcifications represent viable tumor.[10-12] Current treatment guidelines require complete excision of indeterminate or suspicious calcifications[13], sometimes necessitating a larger lumpectomy or a mastectomy for complete removal in a patient who otherwise has responded to NAC. The purpose of this study was to determine the relationship between mammographic calcifications and MRI tumoral enhancement before and after NAC and to assess the impact of these findings on surgical treatment.

MATERIALS AND METHODS

Study population

This was an Institutional Review Board-approved, HIPAA-compliant study involving breast cancer patients who underwent NAC at Memorial Sloan Kettering Cancer Center between April 2009 and October 2015. Patients from 2009 to 2012 were identified retrospectively, while those treated from 2012 onwards were included in a prospectively maintained database. Patients with both pre- and post-NAC MRI as well as mammograms demonstrating calcifications within the tumor bed either at presentation and/or after treatment comprised the study cohort. Those with inflammatory breast cancer, those undergoing axillary surgery only, and those with imaging unavailable for review were excluded.

Variables

Standard clinical and pathologic data were gathered, including both pre-NAC imaging findings and core biopsy results and post-NAC imaging findings and final post-NAC histopathology results (final post-NAC histopathology results included pathologic findings specifically associated with calcifications).Pre and post-operative pathology reports were reviewed in the electronic medical record. These reports routinely include a description of calcifications and their association with malignant or benign (and what type of benign) pathology. Hormone receptor positivity was defined as 1% or more of cells staining for estrogen receptor (ER) or progesterone receptor (PR). Human epidermal growth factor 2 (HER2) positivity was defined as 3+ staining by immunohistochemistry or FISH amplification with value > 2.0.

Imaging

Standard mammography included two views per breast with additional magnification views performed at the discretion of the interpreting radiologist. A single breast radiologist re-reviewed all pre-NAC and post-NAC imaging. The extent of calcifications was measured in centimeters in two dimensions. To assess the change in extent of calcifications post-NAC, the greatest extent of calcifications on post-NAC mammogram was compared to that seen on the pre-NAC mammogram. Mammographic interpretation was reported using the American College of Radiology BI-RADS mammography lexicon.[14]

Breast MRI was performed with the patient prone in a dedicated surface breast coil on a 1.5-T or 3.0-T commercially available system (General Electric Medical Systems, Milwaukee, WI). The standard imaging protocol until 2013 included a localizing sequence followed by sagittal fat-suppressed T2-weighted, sagittal non-fat suppressed T1-weighted, and bilateral sagittal fat-suppressed T1- weighted sequences performed before and three times after intravenous administration of a bolus of 0.1 mmol/L of gadopentetate dimeglumine (Magnevist; Bayer, Wayne, NJ) per kilogram of body weight. Section thickness was 0.3 cm with no gap and a minimum matrix of 256 × 256. Unenhanced images were subtracted from the contrast-enhanced images on a pixel-by-pixel basis producing three subtracted post-contrast subtraction sequences. Maximum intensity projection images were created using the first post-contrast sequence and the first post-contrast subtracted data. After 2013 imaging was performed in the axial plane with sagittal reformatting. Section thickness was reduced to 0.1 cm. On MRI, residual enhancing tumor size after NAC was measured in the longest dimension.

Complete response on MRI was defined as the absence of any residual mass or non-mass enhancement. Similarly, complete response on mammogram was defined as the absence of residual mass and/or calcifications.

The outcomes of interest were the extent of change on imaging after NAC, the correlation between changes on mammogram and MRI, and the correlation between imaging findings and the presence of residual tumor associated with calcifications. The rate of mastectomy due to residual calcifications was also ascertained.

Statistical Analysis

Comparisons were made using the Fishers Exact test. All statistical analysis was done using SAS 9.2 (SAS Institute, Cary, NC) and p-values < 0.05 were considered significant.

RESULTS

From April 2009 to October 2015, 448 patients underwent NAC at our institution. 90 of these women had calcifications identified on pre-and/or post NAC mammography as well as pre- and post-NAC breast MRI with all imaging available for review and comprised the study population. Patient characteristics are summarized in Table 1. The median age was 49 years, median tumor size was 4.0 cm, and the majority of tumors were clinical stage 2 or higher (98%) with ductal histology (98%). HER2+ tumors comprised 49/90 (54%) of cases, while 23/90 (26%) were ER–HER2– and 28/90 (20%) were ER+HER2−. pCR in the breast, defined as the absence of any residual invasive or in situ carcinoma in the breast, was achieved in 29/90 (32%) of patients.

Extent of Change on Imaging after NAC

The median extent of calcifications on the pre-NAC mammograms was 3.1 cm (range 0.0 -11.0 cm), while the median extent of calcifications on the post-NAC mammograms was 3.5 cm (range 0.0 - 10.0). Six patients who did not have any calcifications at presentation (original extent 0) developed calcifications after NAC. In patients presenting with calcifications (n = 84), calcifications resolved completely in 3/84 (4%) patients, decreased in 15/84 (18%) patients, remained stable in 42/84 (50%) patients, and increased in 24/84 (29%) patients (Table 2).

On MRI, tumoral enhancement resolved completely after NAC in 40/90 (44%) patients and decreased in 50/90 (56%) patients. No patients developed increased enhancement or new areas of enhancement in the index breast post-NAC.

Correlation between Changes on Mammogram and MRI

There was no statistically significant correlation between changes in calcifications on mammogram and changes in enhancement on MRI (p=0.12).

However, loss of MRI enhancement was strongly correlated with pCR (p<.0001) and the majority of patients with a pCR demonstrated complete resolution of enhancement on MRI (23/29, 79%). In contrast, there was no statistically significant relationship between changes in calcifications and rates of pCR (p=.06) with the rate of pCR ranging from 24% to 38% among patients with decreased, increased, or stable calcifications. The relationship between the two imaging modalities and rate of pCR is shown in Table 2.

All 3 patients who had calcifications at presentation but who had complete resolution of calcifications after NAC also had complete resolution of MRI enhancement and showed a pCR on final pathology. Among 6 patients who had no calcifications at presentation and developed new calcifications post-NAC, 3/6 (50%) had a pCR. Only 1 of those 3 (33%) also showed complete resolution of enhancement by MRI. The relationship between decreasing or resolved and increasing or stable calcifications, MRI enhancement, and pCR is shown in

Table 3. A statistically significant relationship is noted (p<.0001), with pCR being most frequent in patients with resolution of MRI enhancement and new, increasing, or unchanged calcifications.

Correlation between Imaging Findings and the Presence of Residual Tumor Associated with Calcifications

Calcifications post-NAC were associated with ductal carcinoma in situ (DCIS) or invasive ductal carcinoma (IDC) on final pathology in 34/90 (37.8%) patients, and were benign in 56/90 (62.2%) patients. Table 4 compares characteristics of patients with malignant calcifications to those with benign calcifications. The two groups were demographically similar, but patients with benign calcifications after treatment were significantly more likely to have HER2+ tumors (64% vs. 38%, p = 0.0002).

Among the 34 patients with malignant calcifications, MRI suggested complete response in 6/34 (18%) and partial response in 28/34 (82%). Meanwhile, post-NAC mammogram showed decreased calcifications in 4/34 (11.8%) patients, no change in calcifications in 19/34 (55.9%) patients, and increased/new calcifications in 11/34 (32.4%) patients. None of the patients with malignant calcifications demonstrated complete resolution of calcifications on post-NAC mammogram. Of the 6 patients with malignant calcifications and complete resolution of MRI enhancement, post-NAC mammogram showed no change in calcifications in 3/6 (50%) patients (Figure 1), increased/new calcifications in 2/6 (33%) patients, and decreased calcifications in the remaining 1 (17%) patient.

Among patients with benign calcifications (n=56), only 3/56 (5%) patients had complete resolution of calcifications in the post-NAC mammogram, while 34/56 (61%) patients had completely resolved enhancement on post-NAC MRI.

The Rate of Mastectomy due to Residual Calcifications

Seventy patients (78%) of the total 90 patients in the study were candidates for BCT after NAC. Of these, 57/70 (81%) had BCT and 13/70 (19%) had mastectomy due to the presence of a high-risk mutation or patient preference.

The remaining 20 (22%) of the total 90 patients in the study were not BCT candidates post-NAC. Among these patients, 10/20 (50%) had extensive residual calcifications that precluded BCT; 3/10 (30%) patients had multifocal/multicentric disease, 1/10 (10%) had discordant mammographic and MRI findings, 4/10 (40%) had a cosmetically unfavorable tumor-to-breast size ratio, and 2/10 (20%) progressed on treatment. Of the 10 patients who underwent mastectomy due to extensive residual calcifications, 7/10 (70%) had benign calcifications and 3/10 (30%) had tumor associated with calcifications.

DICUSSION

Downstaging large tumors to allow BCT is a major rationale for the use of NAC in operable breast cancer. In this setting, determination of candidacy for BCT after NAC is dependent upon the post-NAC evaluation of the extent of residual disease. The integration of discordant findings on MRI and mammography remains a significant clinical problem. Several studies

have demonstrated that contrast-enhanced MRI is the most accurate technique for evaluating the extent of residual disease after NAC[6-9], yet indeterminate or malignant appearing calcifications on mammography require surgical excision, regardless of MRI findings. In this study we have demonstrated that the combined assessment of loss of MRI enhancement and changes in calcifications does not predict the presence of pCR with sufficient accuracy to be clinically useful. Although only 38% of calcifications were associated with malignancy after NAC, and neither clinical characteristics, changes in the extent of calcifications, nor the combination of changes in calcifications and loss of MRI enhancement identified a patient subset where calcifications could be safely left in place. Loss of MRI enhancement was the most reliable predictor of pCR, but in 17 cases with resolution of enhancement, there was persistence of viable tumor.

The utility of mammography after NAC in addition to MRI has been questioned. In a study previously published by our institution, MRI alone correctly predicted the ability to perform BCT after NAC in 88% of patients while the combination of MRI and mammography post-NAC correctly predicted the ability to perform BCT in 92% of patients [8], based on using the extent of residual calcifications on the post treatment mammogram to more accurately localize disease extent. The current study emphasizes the importance of identifying the calcifications in planning the appropriate extent of surgical resection.

Meanwhile, others have examined the significance of mammographically detected calcifications after NAC. Weiss et al[11] found that extent of calcifications on mammography correlated poorly with tumor size on final pathology after NAC. Adrada et al[10] reported that of 106 women, 43 (41%) patients had calcifications associated with benign pathology after NAC. Similar to our findings, Kim et al[12] demonstrated that the correlation between residual mammographic calcifications and residual tumor extent was lower than the correlation between MRI findings and residual tumor in all tumor subtypes after NAC. This is not particularly surprising since residual calcifications post NAC may represent necrotic material in the tumor bed area from successfully treated cancer, fat necrosis, or the sequelae of hematoma following biopsy in addition to viable tumor.[15]

Although there is wide agreement that residual calcifications after NAC are often not associated with residual cancer, there is no consensus as to how these calcifications should be handled in part because residual cancer is present in a significant number of cases and in part because following these residual calcifications may prove problematic as they may increase in number on subsequent imaging.

In our study of 90 patients, tumoral enhancement on MRI resolved after neoadjuvant chemotherapy in 40 (44%) patients and decreased in 50 (56%), yet only 29 patients (32%) achieved pCR (defined as no residual invasive disease or DCIS). Correlation of resolution of enhancement with pCR was 74%. However, even in patients with a decrease in calcifications as well as resolution of enhancement, the potential for residual malignancy was high enough that surgery with complete removal of all calcifications in the region of the tumor bed is still required. The need to excise all calcifications resulted in mastectomy in 50% of patients felt to have medical contraindications to BCT after NAC.

This study has several limitations. This was in part a retrospective, single-institution study with a relatively small sample size. However, from 2014 onwards, patients were followed in a prospectively-maintained database. Hormone receptor-negative patients were overrepresented as compared to prior studies, likely due to more frequent selection of these patients for neoadjuvant treatment given a better expected response.

Conclusion

Although it is clear that many of the tumor bed calcifications seen on post-NAC mammography are associated with benign disease, loss of MRI enhancement does not predict the absence of residual tumor with sufficient accuracy to allow calcifications to be left in place. Complete excision of all indeterminate or malignant appearing calcifications remains standard practice and a substantial limitation to the use of NAC to downstage patients to BCT.

Acknowledgments

This study was funded in part through the NIH/NCI Cancer Center Support Grant P30 CA008748.

References

1. Kaufmann M, Hortobagyi GN, Goldhirsch A, 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 : official journal of the American Society of Clinical Oncology. Apr 20; 2006 24(12):1940–1949. [PubMed: 16622270]
2. Teshome M, Hunt KK. Neoadjuvant therapy in the treatment of breast cancer. Surgical oncology clinics of North America. Jul; 2014 23(3):505–523. [PubMed: 24882348]
3. Redden MH, Fuhrman GM. Neoadjuvant chemotherapy in the treatment of breast cancer. The Surgical clinics of North America. Apr; 2013 93(2):493–499. [PubMed: 23464698]
4. Holmes D, Colfry A, Czerniecki B, et al. Performance and Practice Guideline for the Use of Neoadjuvant Systemic Therapy in the Management of Breast Cancer. Annals of surgical oncology. Oct; 2015 22(10):3184–3190. [PubMed: 26224406]
5. Mamtani A, Barrio AV, King TA, et al. How Often Does Neoadjuvant Chemotherapy Avoid Axillary Dissection in Patients With Histologically Confirmed Nodal Metastases? Results of a Prospective Study. Annals of surgical oncology. Oct; 2016 23(11):3467–3474. [PubMed: 27160528]
6. Rosen EL, Blackwell KL, Baker JA, et al. Accuracy of MRI in the detection of residual breast cancer after neoadjuvant chemotherapy. AJR American journal of roentgenology. Nov; 2003 181(5): 1275–1282. [PubMed: 14573420]
7. Yeh E, Slanetz P, Kopans DB, et al. Prospective comparison of mammography, sonography, and MRI in patients undergoing neoadjuvant chemotherapy for palpable breast cancer. AJR American journal of roentgenology. Mar; 2005 184(3):868–877. [PubMed: 15728611]
8. Jochelson MS, Lampen-Sachar K, Gibbons G, et al. Do MRI and mammography reliably identify candidates for breast conservation after neoadjuvant chemotherapy? Annals of surgical oncology. May; 2015 22(5):1490–1495. [PubMed: 25777093]
9. De Los Santos JF, Cantor A, Amos KD. Magnetic resonance imaging as a predictor of pathologic response in patients treated with neoadjuvant systemic treatment for operable breast cancer. Translational Breast Cancer Research Consortium trial 017. Cancer. May 15; 2013 119(10):1776–1783. [PubMed: 23436342]
10. Adrada BE, Huo L, Lane DL, Arribas EM, Resetkova E, Yang W. Histopathologic correlation of residual mammographic microcalcifications after neoadjuvant chemotherapy for locally advanced breast cancer. Annals of surgical oncology. Apr; 2015 22(4):1111–1117. [PubMed: 25287438]

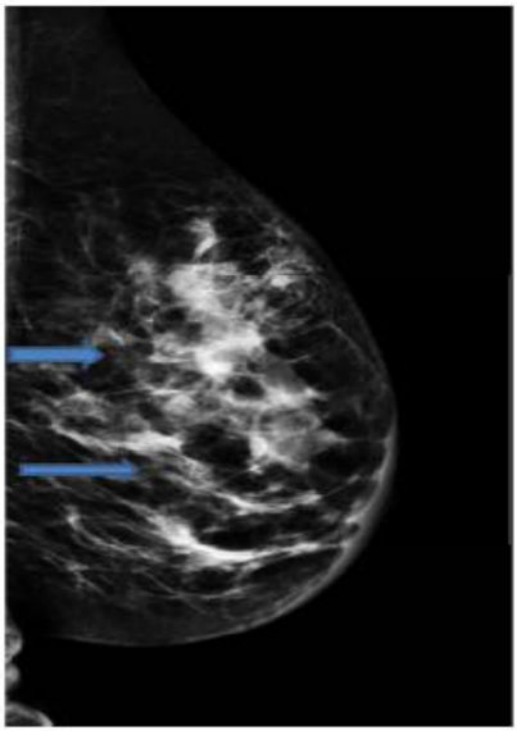
11. Weiss A, Lee KC, Romero Y, et al. Calcifications on mammogram do not correlate with tumor size after neoadjuvant chemotherapy. Annals of surgical oncology. Oct; 2014 21(10):3310–3316. [PubMed: 25056851]

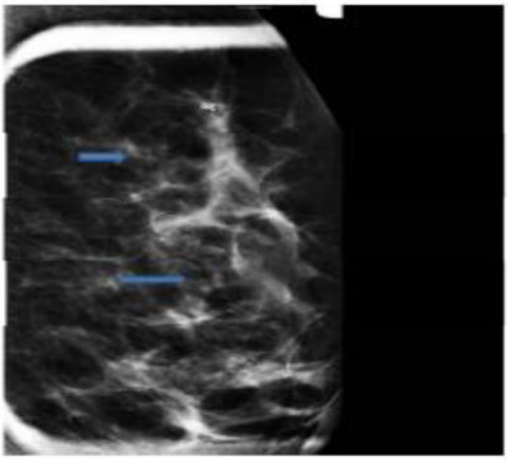
12. Kim YS, Chang JM, Moon HG, Lee J, Shin SU, Moon WK. Residual Mammographic Microcalcifications and Enhancing Lesions on MRI After Neoadjuvant Systemic Chemotherapy for Locally Advanced Breast Cancer: Correlation with Histopathologic Residual Tumor Size. Annals of surgical oncology. Apr; 2016 23(4):1135–1142. [PubMed: 26628432]

13. National Comprehensive Cancer Network. [August 30, 2016] Breast Cancer (Version 2.2016). https://www.nccn.org/professionals/physician_gls/pdf/breast.pdf

14. American College of Radiology (ACR). ACR breast imaging reporting and data system (BI-RADS). 4. Reston, VA: American College of Radiology; 2003.

15. Moskovic EC, Mansi JL, King DM, Murch CR, Smith IE. Mammography in the assessment of response to medical treatment of large primary breast cancer. Clinical radiology. May; 1993 47(5): 339–344. [PubMed: 8508597]





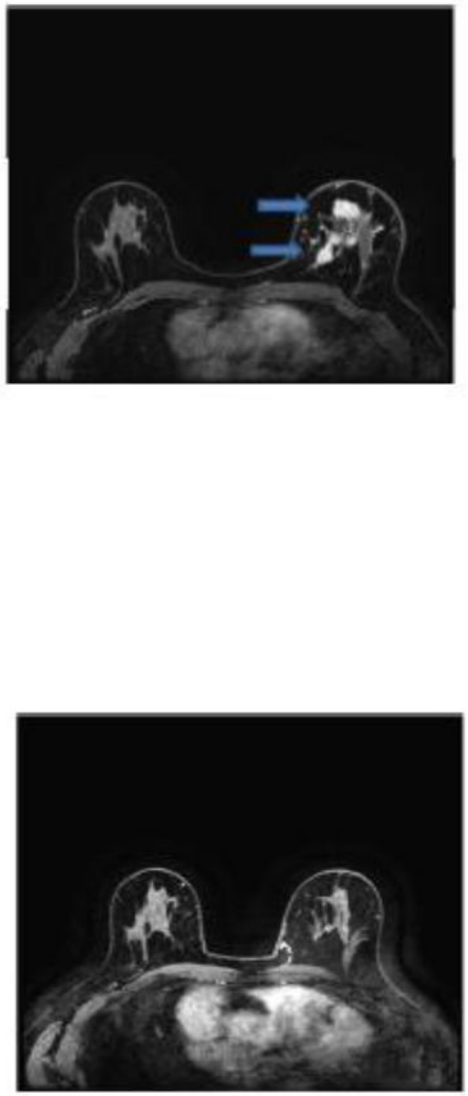


Figure 1.

52-year-old woman presented with a palpable mass in the left upper outer quadrant. Core biopsy demonstrated infiltrating ductal carcinoma (IDC) and ductal carcinoma in situ (DCIS). a. Left mediolateral oblique (MLO) view demonstrates diffuse focal asymmetry with associated calcification spanning 7 cm. b. MRI demonstrates multiple enhancing masses in 2 areas including 2.6 cm mass at 12 o'clock. c. Post-chemotherapy magnification view MLO demonstrates decrease in focal asymmetry with persistent calcifications spanning 7 cm. d. Post-chemotherapy MRI demonstrates complete resolution of enhancement. Patient underwent mastectomy with complete resolution of infiltrating carcinoma but with multiple foci of DCIS within the tumor bed.

Table 1

Patient characteristics

Characteristic	All patients n = 90
Age, years, median (range)	49 (25 – 81)
Clinical tumor size, cm, median (range)	4.0 (2 – 10)
Tumor palpable at presentation, n (%)	88 (98%)
Pre-op core biopsy findings	
Invasive + no DCIS [a]	42 (47%)
Invasive + DCIS [a] present	48 (53%)
Receptor subtype, n (%)	
ER+ HER2-	18 (20%)
HER2+	49 (54%)
TNBC	23 (26%)
Clinical stage, n (%)	
IA	2 (2%)
IIA	27 (30%)
IIB	39 (43%)
IIIA	22 (24%)
Histology, n (%)	
Ductal	88 (98%)
Lobular	2 (2%)
LVI [b], n (%)	23 (26%)
Breast tumor response, n (%)	
pCR [c] (no residual invasive or DCIS [a])	29 (32%)
Residual DCIS [a] only	7 (8%)
Residual invasive only	11 (12%)
Residual invasive + DCIS [a]	43 (48%)
Size of residual invasive if present, cm, median (range)	1.6 (rare cells – 6.5)

[a] Ductal Carcinoma in Situ

[b] Lymphovascular invasion

[c] Pathologic complete response

Table 2

Correlation between changes in calcification on mammogram, changes in enhancement on MRI, and rates of pathologic complete response (pCR)

Change in calcifications on mammography	Change in MRI enhancement		pCR
	Resolved	Decreased	
Resolved n = 3	3 (100%)	0 (0%)	3 (100%)
Decreased n=15	5 (33%)	10 (67%)	4 (27%) [a]
No change n=42	16 (38%)	26 (62%)	10 (24%) [b]
Increased n=24	14 (58%)	10 (42%)	9 (38%) [c]
New n=6	2 (33%)	4 (67%)	3 (50%) [d]

[a] 1 of 4 had resolved MRI enhancement, 3 of 4 had decreased MRI enhancement

[b] 9 of 10 had resolved MRI enhancement, 1 of 10 had decreased MRI enhancement

[c] 9 of 9 had resolved MRI enhancement

[d] 1 of 3 had resolved MRI enhancement, 2 of 3 had decreased MRI enhancement

Table 3

Table of calcifications (decrease/resolve vs new/increase/unchanged) and MRI enhancement (decrease vs resolved) by pathologic complete response (pCR) P=<.0001 by Fisher's exact test

Group	Number of patients n=90	Breast pCR	
		No n=61	Yes n=29
decr/reso - Decreased	10 (11.11%)	7 (7.78%)	3 (3.33%)
decr/reso - Resolved	8 (8.89%)	4 (4.44%)	4 (4.44%)
new/incr/unch -Decreased	40 (44.44%)	37 (41.11%)	3 (3.33%)
new/incr/unch - Resolved	32 (35.56%)	13 (14.44%)	19 (21.11%)
Total	90 (100.00%)	61 (67.78%)	29 (32.22%)

Table 4

Characteristics stratified by post-NAC calcification pathology

Characteristic	Calcifications associated with DCIS [a]/IDC[b] n = 34	Calcifications benign n = 56
Age, years, median (range)	50 (27 – 81)	47 (25 – 71)
Clinical tumor size, cm, median (range)	4.0 (2.0 – 10.0)	4.0 (2.0 – 9.0)
Tumor palpable at presentation, n (%)	34 (100%)	54 (96%)
Receptor subtype, n (%)		
ER+ HER2-	14 (41%)	6 (11%)
HER2+	13 (38%)	36 (64%)
TNBC	7 (21%)	14 (25%)
Clinical stage, n (%)		
IA	1 (3%)	1 (2%)
IIA	7 (21%)	20 (36%)
IIB	17 (50%)	22 (39%)
IIIA	9 (26%)	13 (23%)
Change in calcifications on MMG [c]		
Resolved	0 (0%)	3 (5%)
Decreased	4 (12%)	11 (20%)
No change	19 (56%)	23 (41%)
Increased/new	11 (32%)	19 (34%)
Change in enhancement on MRI		
Resolved	6 (18%)	34 (61%)
Decreased	28 (82%)	22 (39%)
Breast tumor response, n (%)		
pCR [d]	0 (0%)	29 (52%)
Residual DCIS [a] only	3 (9%)	4 (7%)
Residual invasive only	1 (3%)	10 (18%)
Residual invasive + DCIS [a]	30 (88%)	13 (23%)
Size of residual invasive if present, cm	2.3 (rare cells – 6.5)	0.65 (rare cells – 3.4)

[a] Ductal Carcinoma in Situ

[b] Invasive ductal carcinoma

[c] Mammogram

[d] Pathologic complete response: no residual invasive cancer or DCIS