Section A-Research paper

An Overview about Role of Magnetic Resonance Imaging in breast cancer

Mostafa Mohamad Assy, Ahmed Sabry Ragheb, Amany Abd Elhafez Ahmed Hafez, Marwa Elsayed Abd Elhamed

Radiodiagnosis Department, Faculty of Medicine, Zagazig University, Egypt

Email: hafezamany2020@gmail.com

Article History: Received 10th June, Accepted 5th July, published online 10th July 2023

Abstract

Background: Breast MRI is an indispensable modality, along with mammography and US. Its main indications are staging of known cancer, screening for breast cancer in women at increased risk, as part of the routine post-treatment follow-up, being considered more sensitive than conventional imaging investigations in discriminating between postsurgical tissue modifications and tumor relapse and evaluation of response to neoadjuvant chemotherapy. As opposed to mammography and US, MRI is a functional technique. Heywang et al and Kaiser and Zeitler independently introduced this technique in the 1980s. Contrast material–enhanced MRI evaluates the permeability of blood vessels by using an intravenous contrast agent (gadolinium chelate) that shortens the local T1 time, leading to a higher signal on T1-weighted images. The underlying principle is that neoangiogenesis leads to formation of leaky vessels that allow for faster extravasation of contrast agents, thus leading to rapid local enhancement. Despite improvements in the technique of breast MRI, this principle is still the basis of all clinical MRI protocols. However, most MRI protocols nowadays are multiparametric. The standard breast MRI performed in clinical routine relies on both morphologic and dynamic contrast enhancement of lesions. Advanced imaging techniques have been proposed and increasingly used in the last few years. One such technique is diffusion-weighted (DW)-MRI, providing an evaluation of tissue cellularity and integrity of cell membranes. Another technique is the pharmacokinetic analysis of contrast uptake, providing a quantitative assessment of the contrast agent exchange between the vascular and interstitial compartments.

Keywords: Magnetic Resonance Imaging, breast cancer

DOI: 10.53555/ecb/2023.12.Si12.295

Introduction

Breast MRI is an indispensable modality, along with mammography and US. Its main indications are staging of known cancer, screening for breast cancer in women at increased risk, as part of the routine post-treatment follow-up, being considered more sensitive than conventional imaging investigations in discriminating between postsurgical tissue modifications and tumor relapse and evaluation of response to neoadjuvant chemotherapy **(1)**.

As opposed to mammography and US, MRI is a functional technique. Heywang et al and Kaiser and Zeitler independently introduced this technique in the 1980s. Contrast material–enhanced MRI evaluates the permeability of blood vessels by using an intravenous contrast agent (gadolinium chelate) that shortens the local T1 time, leading to a higher signal on T1-weighted images. The underlying principle is that neoangiogenesis leads to formation of leaky vessels that allow for faster extravasation of contrast agents, thus leading to rapid local enhancement. Despite improvements in the technique of breast MRI, this principle is still the basis of all clinical MRI protocols. However, most MRI protocols nowadays are multiparametric **(2).**

The standard breast MRI performed in clinical routine relies on both morphologic and dynamic contrast enhancement of lesions. Advanced imaging techniques have been proposed and increasingly used in the last few years. One such technique is diffusion-weighted (DW)-MRI, providing an evaluation of tissue cellularity and integrity of cell

membranes. Another technique is the pharmacokinetic analysis of contrast uptake, providing a quantitative assessment of the contrast agent exchange between the vascular and interstitial compartments **(1)**.

Components of multiparametric breast MRI protocol:

Breast MRI has evolved from a primarily contrast-enhanced technique to a multiparametric technique, In general, the protocol is begun with the non-contrast-enhanced acquisitions (T2-weighted and diffusion-weighted imaging [DWI]). This is followed by a native T1-weighted acquisition and subsequently the contrast-enhanced series (ultrafast [UF] imaging and regular T1-weighted imaging) **(2).**

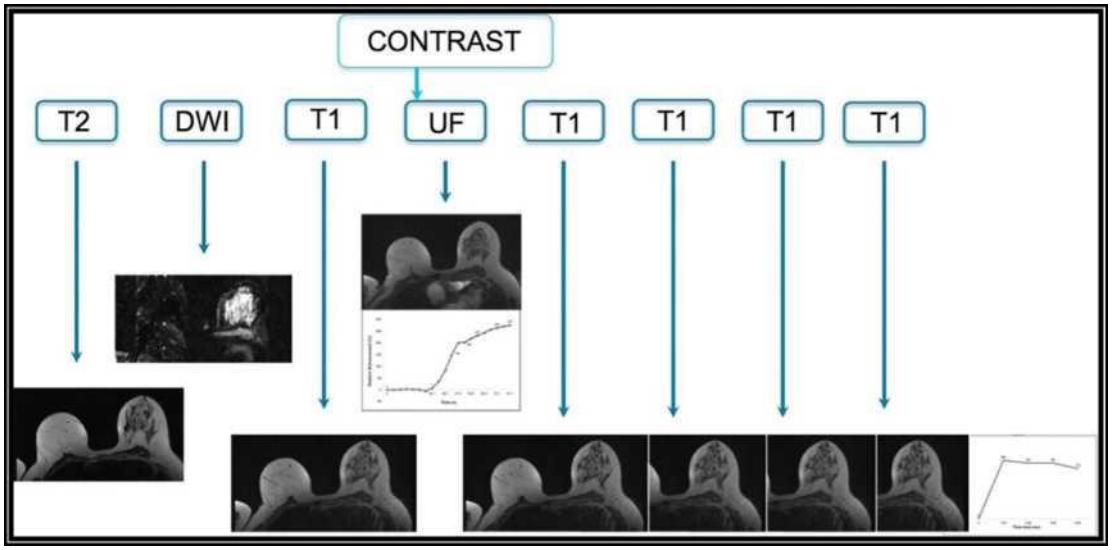


Figure 1. Components of the basic multiparametric breast MRI protocol **(2).**

Ultrafast Breast MRI:

Ultrafast MRI is a sequence developed to capture early contrast material wash-in at high temporal resolution (typically ≤ 6-7 seconds). An ultrafast sequence allows rapid sequential imaging within the first 2 minutes after contrast material injection to render an early wash-in kinetic curve, as opposed to the conventional delayed washout kinetic curve **(3).**

Malignancies enhance both earlier and faster than benign lesions. Consequently, the first lesion that enhances in the breast is the most suspicious. Most breast cancers start to enhance within 10 seconds after the arrival of contrast material in the major vessels, whereas benign lesions, on average, enhance later (>15 seconds) (**4).**

\

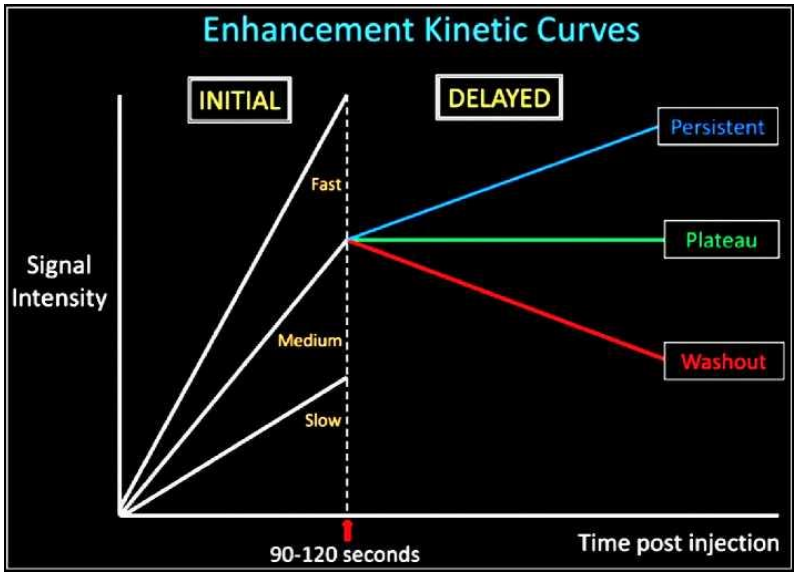


Figure 2. Conventional dynamic contrast-enhanced MRI typically acquires at least three postcontrast series to generate a delayed kinetic curve, with the first postcontrast time point at 90-120 seconds. A washout delayed kinetic curve (red line) is highly associated with malignancy. The initial contrast material wash-in kinetics (within the first 120 seconds), which are not available at conventional MRI, can now be acquired with ultrafast MRI **(3).**

Ultrafast imaging is not readily feasible with all commercially available imaging units because specific MRI coil and sequence requirements needed to achieve diagnostic spatial resolution at high temporal resolution are not universally available. The technique depicts early arterial enhancement highly specific for breast carcinoma **(3).**

Breast lesion evaluation at breast MRI

Reporting of breast MRI is standardized in the American College of Radiology Breast Imaging Reporting and Data System (BI-RADS). A standard report contains the clinical indication, the MRI sequences and postprocessing methods that were used, and the amount and type of contrast agent administered. Subsequently, the composition of the breast and the amount of background parenchymal enhancement (BPE) should be stated. For both measures, a higher fraction is associated with a higher likelihood of malignancy being present. Still, the correlation between the amount of fibroglandular tissue, amount of BPE, and breast cancer risk in the future is incompletely understood. A higher fraction of BPE leads to a higher risk of false-positive findings **(5)**.

The morphologic and kinetic features of findings are divided into three main groups: focus or foci, masses, and non-mass-like enhancements. Focus and foci are enhancements measuring less than 5 mm that cannot be otherwise specified. They are often unchanged on follow-up images and may be related to hormonal changes. They are mostly benign, especially when multiple and symmetric. However, they should be considered malignant when they are located in the same quadrant as an invasive breast cancer.

1. Masses are space-occupying lesions within the breast, described in terms of shape, margins, and internal enhancement characteristics.

    a. Shape. A mass can be round, oval, lobulated, or irregular, Lobulated masses are characterized by an undulating contour, and irregular masses , show an uneven shape that cannot be characterized as round, oval, or lobulated. The shape analysis should be performed on the early post-contrast images to avoid washout and progressive enhancement of the surrounding breast tissue, which can impair lesion analysis.
    b. Margins are described as smooth, irregular, or spiculated, For adequate margin assessment, a high spatial resolution is required. For instance, irregular borders can appear relatively smooth when insufficient resolution is used or when the tumour is small. On the other hand, as time elapses after contrast agent administration, the periphery of the lesion may become more indistinct.
    c. Internal enhancement characteristics have been conventionally divided into 6 types:

1. Homogeneous enhancement is uniform throughout the mass, It can also be suggestive of a benign process.
2. Heterogeneous enhancement is non-uniform and varies within the mass. It is more characteristic of malignant lesions.
3. Rim enhancement is mainly concentrated at the periphery of the mass, This finding is particularly suspicious for malignancy, being most frequently a feature of high-grade invasive ductal cancer. However, benign findings including fat necrosis and cysts with inflammation may show rim enhancement.
4. Non-enhanced internal septations within an enhanced lesion are characteristic of fibroadenomas, especially when the lesion has smooth or lobulated borders. However, they are only seen in a minority of cases; when present, masses can be considered benign with a high degree of certainty (>95%).
5. Enhanced internal septations are usually a feature of malignant lesions, although these signs occur less commonly.
6. Central enhancement is an enhancing nidus within a mass that is usually more pronounced than the rest of the enhanced mass. Central enhancement has been associated with high-grade ductal cancer and vascular breast tumours.

2. Non-masslike enhancements are areas of enhancement that do not belong to a space-occupying lesion and do not have distinct mass characteristics. Features of non-masslike enhancement are categorized by distribution, internal enhancement pattern, and symmetric or asymmetric enhancement:

    a. Distribution. A focal area is described in the presence of an enhancement occupying less than 25% of a breast quadrant, showing fat or normal glandular tissue between abnormally enhanced components. This type of enhancement may present as clumped, irregular contrast enhancement. Linear enhancement is an enhancement that does not follow the shape of a ductal system. In contrast, ductal enhancement follows the shape of a ductal system, pointing towards the nipple. Segmental enhancement has a conical appearance and probably represents one or more ductal systems. Ductal and segmental distribution of enhancement may be associated with in situ ductal cancer (DCIS) or invasive ductal cancer, atypical ductal hyperplasia, papillary neoplasms, or sclerosing adenosis. Regional enhancement does not correspond to a single duct system and may be within multiple ducts. Diffuse contrast enhancement is uniform enhancement of the entire parenchyma of the breast. Regional enhancement and diffuse enhancement are more characteristic of benign disease such as proliferative changes, although multicentric DCIS may have this appearance **(6)**.

ii. Internal enhancement patterns are homogeneous, heterogeneous, clumped, stippled or punctate, and reticular or dendritic. Clumped refers to a cobblestonelike enhancement, with occasional confluent areas. Punctate or stippled refers to multiple punctate foci approximately 1–2 mm in size. They are often distributed in an area of the breast that does not usually conform to a duct. Punctate or stippled enhancement is more characteristic of benign normal variant parenchymal enhancement or fibrocystic changes. In the reticular or dendritic pattern, the normal fat–glandular tissue interface is lost; this finding is usually associated with inflammatory breast cancer or lymphatic involvement **(7).**

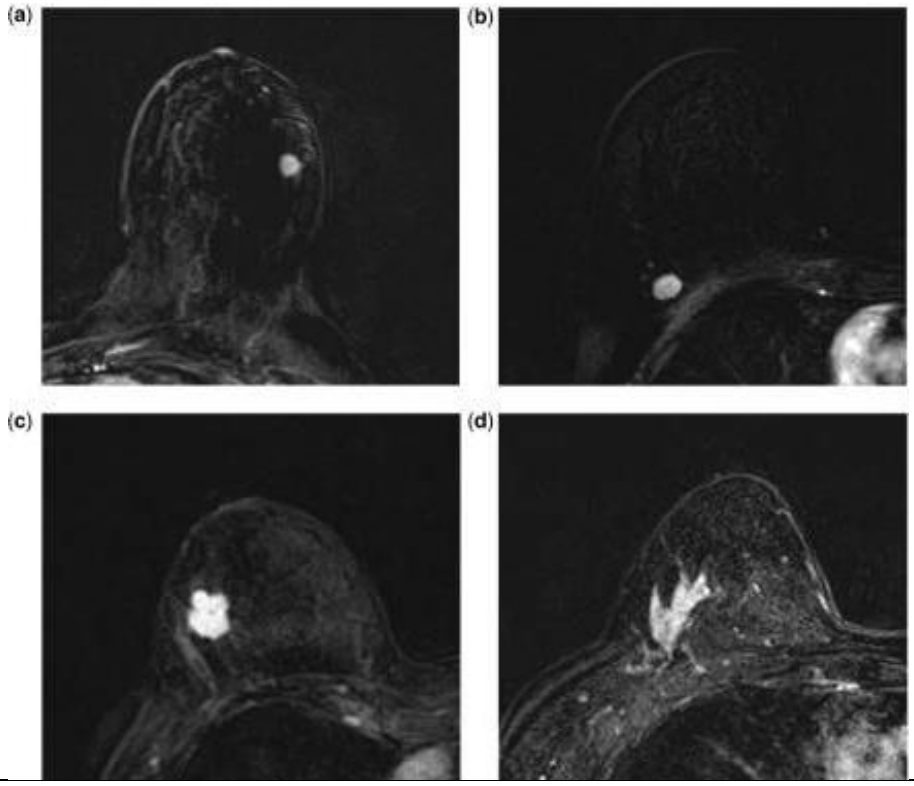


Fig. 3. Axial subtracted image showing mass-enhancing lesions, with (a) round, (b) oval, (c) lobulated, and (d) irregular shape **(8)**.

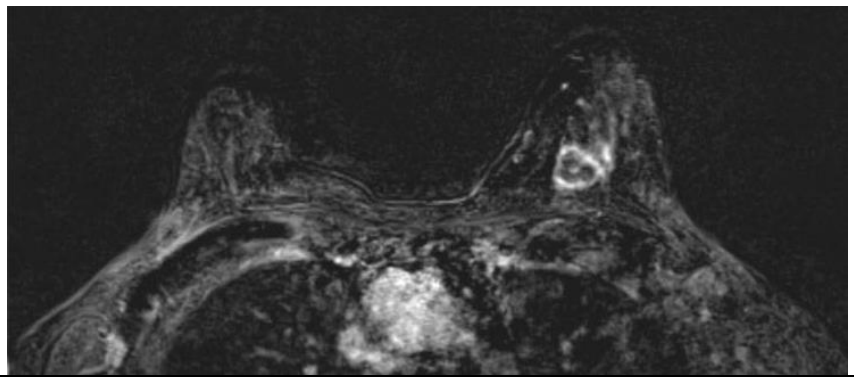


Fig. 4. Axial subtracted image showing mass-enhancing lesion of the left breast with rim enhancement **(8)**.

Approximately two-thirds to three-quarters of cancers manifest as a mass, including most invasive ductal cancers; the remainder are visible as areas of NME, including the majority of cases of DCIS. Typical malignant masses have an irregular size and margin, heterogeneous or rim enhancement patterns, and show washout. Classic malignant areas of NME have a segmental distribution and a clumped or clustered ring pattern of internal enhancement, While most cancers are easily recognizable by their morphologic features alone, smaller lesions are more difficult to assess. In general, the features of NME are less specific than those of masses. Foci have a likelihood of malignancy of 2.9%–6% **(9)**.

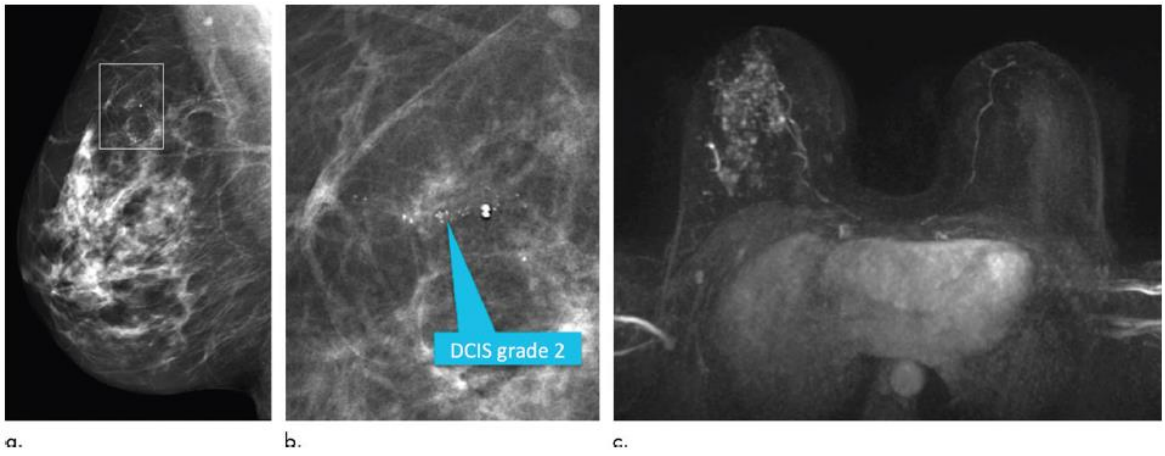


Fig. 5. **(a)** Mediolateral oblique view from a screening mammogram in a 54-year-old woman shows a small cluster of microcalcifications in the upper outer quadrant of the right breast. A detailed spot magnification view is given in (**b**). Stereotactic biopsy revealed grade 2 ductal carcinoma in situ (DCIS). **(c)** Maximum intensity projection from subsequent staging MRI shows a large area of segmental clumped non-mass enhancement in the right breast, representing the actual extent of disease **(2).**

On the basis of the above analysis of morphologic and kinetic features, the radiologist assigns a final assessment, or BI-RADS score, from 0 to 6. However, unlike the Prostate Imaging Reporting and Data System, or PI-RADS, lexicon, the BI-RADS lexicon does not provide information on the associated "likelihood of malignancy" of the individual findings. It provides descriptor terms—not an interpretation guideline. To aid in the classification, a tree flowchart has been developed in which a decision rule assigns the levels of suspicion to specific combinations of imaging features. The decision tree may standardize reporting and improve the discrimination between benign and malignant lesions. It incorporates some of the BI-RADS descriptors as well as the presence or absence of a root sign and edema. A root sign is a spicule-like extension from the lesion margin, even when the rest of the margin is smooth; its presence strongly increases the likelihood of malignancy. Study results show the decision tree improved the diagnostic accuracy of inexperienced readers and reduced the number of benign findings at biopsy by more than 25% **(10)**.

Although findings from ultrafast acquisitions and DWI have not been incorporated into the decision tree, many studies have shown that the combination of ultrafast acquisitions, T2-weighted imaging, and DWI improves the diagnostic accuracy of discriminating benign from malignant masses. Late and slow initial enhancement, high T2 signal, and high ADC substantially decrease the likelihood of malignancy and may be used to avoid biopsy. In particular, ADCs greater than 1.4×10^{-3} mm^2/sec are exceptionally rare in cancers. On the other hand, early and fast enhancement, a low T2 signal, the presence of edema, and a low ADC increase the level of suspicion. A specificity of 90% has been reported with use of a multiparametric approach. BI-RADS and supplemental descriptors **(11)**.

Table. 1. BI-RADS and Supplemental Descriptors for the Evaluation of Lesions at Breast MRI **(2).**

Sequence and Description	Descriptor	Terms
T1 native		
Breast composition	Fibroglandular tissue	Almost entirely fatty; scattered; heterogeneous; extreme
T1 postcontrast (approximately 90 sec)/SUB		
Background signal	Background parenchymal enhancement	Minimal; mild; moderate; marked
Lesion	Lesion type	Focus; mass; non-mass
Mass		
	Shape	Round; oval; irregular
	Margin	Circumscribed; irregular; spiculated
	Internal enhancement pattern	Homogeneous; heterogeneous; rim enhancement; dark internal septations
Non-mass enhancement		
	Distribution	Focal; linear; segmental; regional; multiple regions; diffuse
	Internal enhancement pattern	Homogeneous; heterogeneous; clumped; clustered ring
T1 dynamic		
Signal intensity vs time curve	Initial enhancement (relative enhancement at 90 sec)	Slow, <50%; medium, 50%–100%; fast, >100%
	Delayed phase (relative enhancement compared with peak)	Persistent, >10% increase; plateau, –10% to +10%; washout, >10% decrease
Ultrafast		
Inflow curve	Time to enhancement (sec)	Early, <10; intermediate, 10–15; late, >15
	Maximum slope (%/sec)	Slow, <6.4; intermediate, 6.4–13.3; rapid, >13.3
T2		
Lesion T2 signal intensity	Signal intensity	High; intermediate, low
Edema	Presence	Absent; perifocal; prepectoral; unilateral diffuse; bilateral diffuse
DWI		
Lesion diffusion level	ADC (mm^2/sec)	Very low, <0.9; low, 0.9–1.3; intermediate, 1.3–1.7; high, 1.7–2.1; very high, > 2.1

Note.—ADC = apparent diffusion coefficient, BI-RADS = Breast Imaging Reporting and Data System, DWI = diffusion-weighted imaging, SUB = subtraction.

BI-RADS classification of MRI of the breast

Seven categories are distinguished, whereby the categories BI-RADS 0 and BI-RADS 6 are of special significance. The BI-RADS assessment categories 1 to 5 are used to encode the probability that an abnormality is a malignant process; these prescribe concrete recommendations for the further course of action **(12)**.

- BIRADS 0 = incomplete, additional imaging evaluation is needed.
- BIRADS 1 = negative, no abnormalities.
- BIRADS 2 = benign findings.
- BIRADS 3 = probably benign findings (short-term follow-up within 6 months recommended; needle biopsy may be performed only in special cases, such as on patient request or high-risk patients).
- BIRADS 4 = suspected malignancy (needle biopsy recommended).
- BIRADS 5 = highly suspected malignancy (needle biopsy recommended).
- BIRADS 6 = already histologically proven cancer (typically reserved for MRI scans made for cancer staging or in the case of neoadjuvant chemotherapy) **(2).**

MRI for breast cancer postoperative complications

Breast cancer is the most common malignancy in women worldwide. The introduction of mammographic screening programs has led to an increase in the number of breast cancer cases diagnosed at an early stage, often as non-palpable lesions, that can be treated with breast-conserving surgery (BCS), as also described for sarcomatous breast lesions. BCS followed by radiation treatment represents the standard of care in patients with early-stage breast cancer. Several studies confirmed that this procedure shows equivalent survival rates (more than 20 years) compared to mastectomy. Breast oncoplastic surgery (BOS) comprises the surgical excision of breast cancer that allows oncologically safe breast conservation and breast remodeling, reducing postoperative deformities **(13)**.

Local tumor recurrence is the most important issue after BOS and is directly related to the presence of residual tumor cells in the remaining breast parenchyma. In fact, most cases of isolated local recurrence (i.e., without systemic

metastases) usually occur in the first 2-3 years after surgery. Moreover, after surgery and radiation therapy, several changes occur in the breast tissue which may cause difficulties in image interpretation during the follow-up period, especially when local recurrence is suspected. Unfortunately, early postoperative MRI is affected by the strong enhancement of resection margins in response to inflammatory postoperative reactions. Therefore, MRI is unable to exclude possible residual tumor until at least 12-18 months after completion of breast-conserving therapy **(14)**.
However, in the clinical setting, MRI is often used as part of the routine post-treatment follow-up, being considered more sensitive than conventional imaging investigations in discriminating between postsurgical tissue modifications and tumor relapse with a high negative predictive value and a sensitivity of 90-100% and a specificity of 89-92%, preventing unnecessary biopsies. **(6)**.

1) Fat necrosis

Breast fat necrosis (FN) is a common benign inflammatory process resulting from aseptic fat saponification. Common causes of FN include surgery, radiotherapy, or trauma, especially in association with anticoagulation therapy. These influences cause blood vessel rupture with subsequent activation of lipolytic enzymes. Normal adipose tissue is composed of cells containing triglycerides. Fatty acids, released from triglycerides into the interstitial space, form a complex with calcium, liquefying the tissue and causing aseptic fat saponification. Fat necrosis frequently occurs in the subcutaneous fat tissue and in the subareolar region, both of which have a predominantly adipose composition **(15)**.

A recent study by Dolan et al. compared imaging and biopsy results after BOS and breast lumpectomy. The rate of fat necrosis after oncoplastic BCS was 18% on clinical and 15% on US examination, and 7% were confirmed by pathology, showing that patients undergoing BOS require significantly more US examinations and subsequent biopsies than patients undergoing lumpectomy. This was mainly due to FN developing after BOS in the majority of cases **(16)**.

FN is usually asymptomatic; however, sometimes patients may present with a palpable mass, ecchymosis, erythema, or skin thickening. The mammographic image is usually clear, showing a radiolucent rounded image surrounded by a thin radiopaque rib. However, the possible presence of calcifications may lead to the suspicion of disease relapse. The US image may also be misleading, showing an apparent hypoechoic area with blurred margins and posterior acoustic shadowing. On MRI, FN has different presentations depending on the stage of the process. The most common MRI image is a round or oval mass showing high signal intensity on T1-weighted non-fat-saturated images, which appears hyperintense on T2-weighted non-fat-saturated and hypointense on fat-saturated images **(17)**.

In particular, T1-weighted fat-suppressed sequences are helpful to differentiate fat from blood which also shows high-signal intensity on T1-weighted images. As fat-containing lesions are extremely uncommon in malignant conditions, the presence of fat is extremely useful for differentiating FN from a malignant lesion. A fat-fluid level may be present. In post-contrastographic images, FN shows several degrees of enhancement, depending on the stage (acute or chronic) of the inflammatory process. More recent lesions present with irregular contours and may have variable enhancement surrounding the lesion, while older lesions show marked irregularity, retraction, and fibrosis, and generally do not enhance **(13)**.

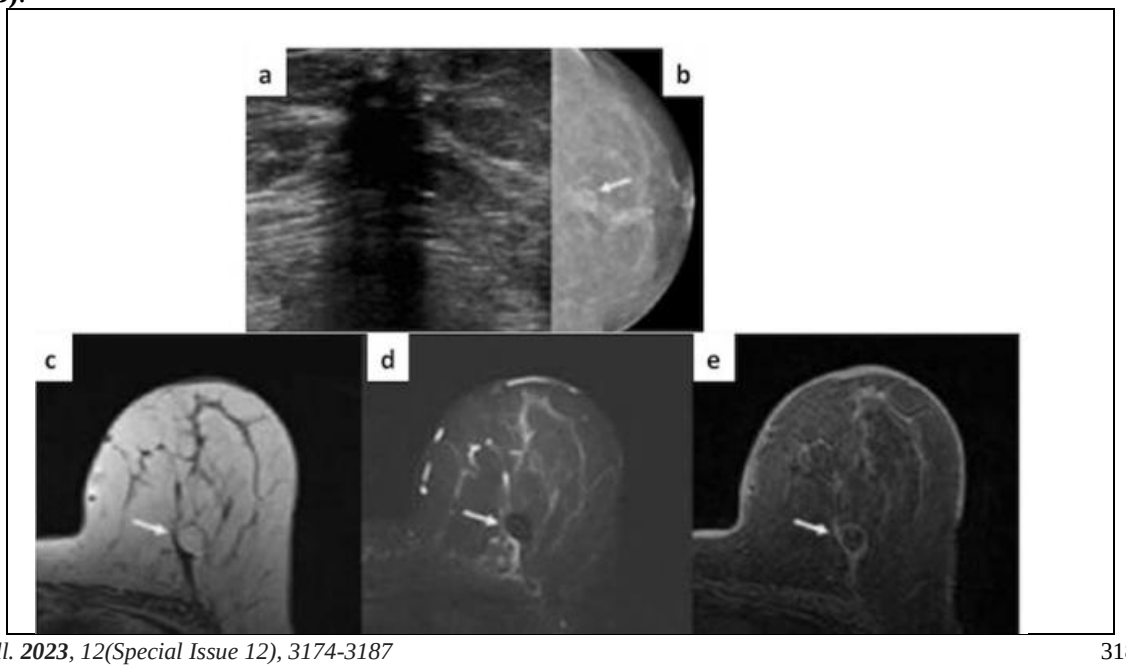


Fig. 6. Patient having previously undergone breast oncoplastic surgery (BOS). **a** Mammographic examination showing a typical radiolucent rounded image surrounded by a thin radiopaque rib. **b** Ultrasound image documenting a hypoechoic area with blurred margins and posterior acoustic shadowing. **c, d, e** Magnetic resonance imaging findings documenting a round focal lesion with high signal intensity in T1 non-fat-saturated sequence (c), and low intensity in T2 short tau inversion recovery (d) and T1 fat-saturated sequence (e). The morphological and signal intensity findings are suggestive of fat necrosis **(13)**.

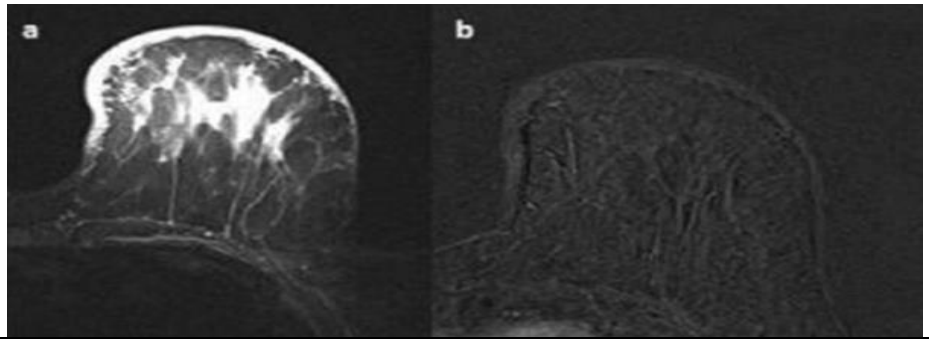


Fig. 7. Patient having recently undergone conservative surgery and radiotherapy for cancer in the lower quadrants of the right breast. **a** Axial T2 short tau inversion recovery sequence showing widespread edema of the breast and diffuse skin thickness; **b** post-contrastographic image showing no pathologic enhancement **(13)**.

2) Seroma

A seroma is a serous fluid collection that may develop in the postsurgical space after breast cancer surgery. On Tl-weighted sequence (precontrast) seroma appears as a more or less circumscribed area usually demonstrating a hypointense signal in comparison to surrounding parenchyma. On T2-weighted sequence it appears as hyperintense areas of fluid retention within the parenchyma. On TI-weighted sequence (contrast-enhanced) enhancement usually takes place in the immediate postoperative period. Seromas can form after lumpectomy, mastectomy or axillary surgery with variable frequency. They have been described as being more common in older and obese patients. MRM is more frequently associated with seroma formation than lumpectomy. Postsurgical seroma after MRM occurs in 20–50% of patients compared with 9–20% of patients after lumpectomy. The use of electrocautery is associated with increased incidence of seroma formation. Although usually self-limited and not a serious postoperative complication, a seroma can impair healing and increase patient discomfort, particularly in mastectomy patients **(18)**.

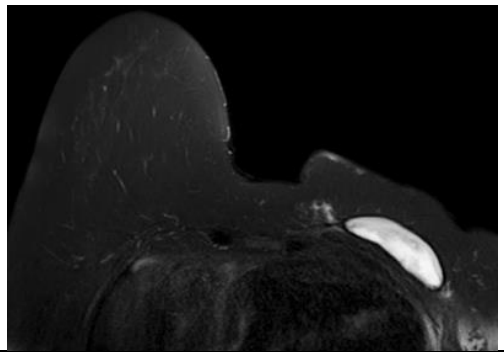
Surgical drains are routinely placed after mastectomy to prevent and evacuate a potential postoperative seroma. However, there is a lack of definite data regarding the length of time a drain should remain in place. Drains are removed when the drain output has diminished and as the skin flaps heal and adhere to the chest wall. Treatment of a seroma is dependent on the clinical situation. If asymptomatic, seromas are often left untreated in lumpectomy patients. If treatment is indicated, seromas can be managed with percutaneous aspiration and pressure. Postoperative seromas do not necessarily delay adjuvant treatment.. **(19)**.

3) Hematoma:

A hematoma is a less common postsurgical complication, with a reported incidence of 2–10% of breast cancer surgery cases. Hematoma is thought to originate from uncauterized vessels. The size and clinical presentation can be variable, with smaller volume hematomas sometimes presenting clinically as skin ecchymosis, whereas larger hematomas can be painful and necessitate surgical evacuation. Patients who consume aspirin; nonsteroidal antiinflammatory drugs; or certain over-the-counter supplements, such as fish oil, may be at higher risk for hematoma formation as are patients

with known bleeding diatheses. Small hematomas carry low morbidity and usually require no treatment. However, large or rapidly developing hematomas may necessitate surgical evacuation **(20)**.

On MRI, hematomas show variable signal intensity on T1-weighted and T2-weighted sequences depending on blood product evolution. Postoperative hematomas may show a low-signal-intensity rim of hemosiderin on the T2-weighted sequence high signal intensity in the fluid collection on the unenhanced T1-weighted sequence and a fluid-fluid layer (hematocrit level). There should be no solid-tissue component or internal enhancement in a postoperative hematoma **(18)**.



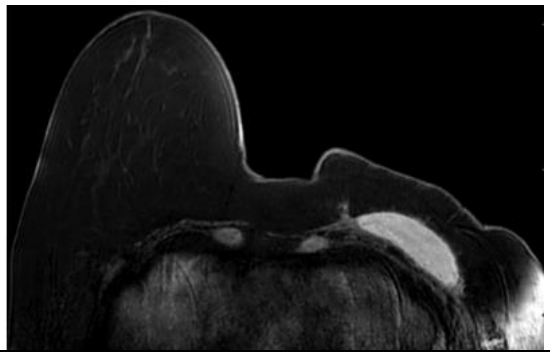
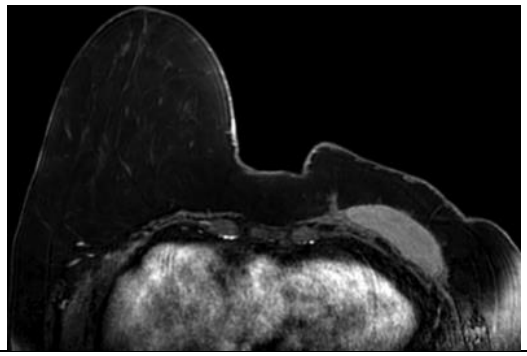


Fig. 8. 64-year-old woman with history of breast cancer who was treated with left modified radical mastectomy, adjuvant hormone therapy, and left chest wall radiation who presented with persistent pain due to hematoma. Fat-saturated T2-weighted image shows hyperintense heterogeneous fluid collection. Although not seen in this image, hematocrit level may also be seen with hematomas (At the left). Unenhanced fat-saturated T1-weighted image shows that fluid collection has high T1 signal intensity, suggestive of hematoma (At the right) **(18)**.



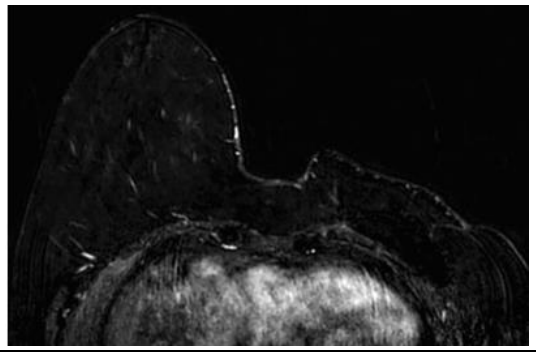


Fig. 9. 64-year-old woman with history of breast cancer who was treated with left modified radical mastectomy, adjuvant hormone therapy, and left chest wall radiation who presented with persistent pain due to hematoma. Contrast-enhanced fat-saturated T1-weighted image (At the left) shows no evidence of internal enhancement of fluid collection **(18)**.

4) Infection:

Postoperative infection manifesting as cellulitis or abscess is another potential complication of breast surgery. The rate of postoperative infection is variable, ranging from 1% to 20%. No consistent correlation between the risk of infection and the type of breast cancer surgery has been identified. Diabetes, obesity, older age (> 65 years), and nicotine use are associated with an increased risk of postoperative infection. Abscess appears on Tl-weighted sequence (precontrast) as a round, or ovoid lesion, less commonly polygonal, with hyperintense signal due to high protein content (in comparison to the parenchyma) Usually demonstrates strong enhancement within the capsule and smooth inner walls, with no enhancemnt uptake within fluid contents. Signs such as smooth well-defined internal wall, strong enhancement of

surrounding tissue (indicating reactive hyperemia), the only criteria differentiating it from seroma, and intermediate enhancement of the thickened capsule favor the diagnosis of an abscess rather than necrotic carcinoma **(21)**.

A postsurgical infection may be complicated by abscess formation, usually within 1 to 2 weeks after surgery, presenting as a fluctuant tender mass at the surgical site. Ultrasound evaluation is usually performed as the first imaging test at the site of concern and may show a complex hypoechoic or isoechoic fluid collection. Mobile debris within the fluid collection and hypervascularity of the adjacent breast tissue may also be seen. Definitive abscess management usually requires surgical or percutaneous drainage depending on the size and clinical scenario **(18)**.

5) Breast Edema and Skin Thickening

After BOS, breast edema and skin thickening are often found due to small vessel damage. Edema of the mammary gland post-surgery usually occurs close to the incision area, while edema after radiation therapy usually encompasses the entire breast. The clinical examination reveals all the signs of inflammation such as skin that is warm to the touch and reddened, tissue stiffness, and soreness. Skin thickening and breast edema can cause diagnostic difficulties in the mammographic examination because of the increase in breast density **(22)**.

In these cases, the US image shows diffuse structural dishomogeneity and edematous imbibition, together with evidence of skin thickening. This modification may be better evaluated through MRI on T2-weighted sequences with fat suppression if the skin is thicker than 4 mm, and it is best appreciated when compared to the contralateral breast. No enhancement is found after contrast administration. These alterations are more evident during the first 6 months after radiation therapy and usually become reduced and stabilized over a 2-3-year period in the majority of patients. An increase in skin thickening or breast edema after this period warrants further investigation, being suspicious for inflammatory breast cancer **(22)**.

6) Fibrosis, architectural distortion, and skin retraction

Fibrosis is a radiologic finding of the late phase after BOS. The mammographic imaging of the breast scar is usually a focal distortion of the normal parenchymal architecture, while the US imagine may appear as an interruption of the normal tissue together with structural alterations. On MRI, fibrosis has a heterogeneous signal, appearing hypointense on T1/T2-weighted images and showing variable degrees of enhancement in the earliest phase of the process and no enhancement in the late phase **(23)**.

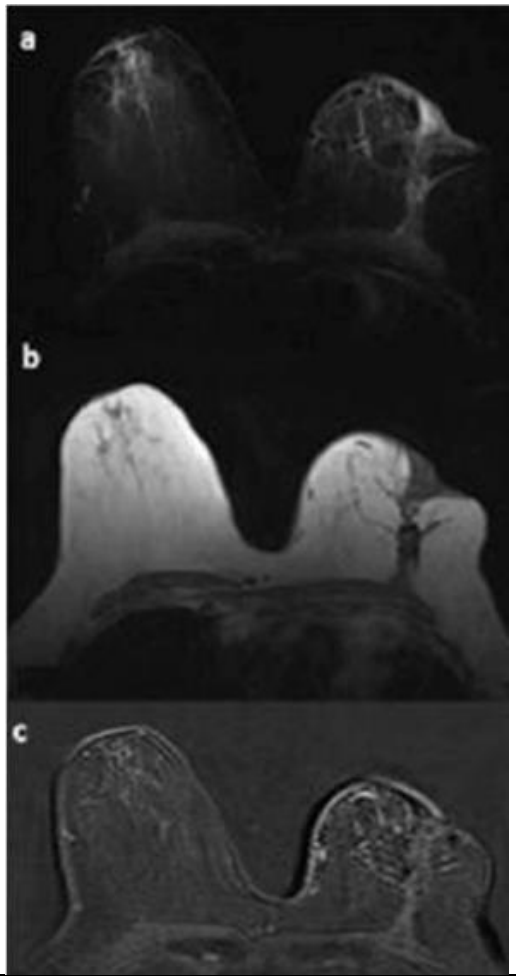


Fig.10. Patient having previously undergone breast oncoplastic surgery (BOS). **a** Axial T2 short tau inversion recovery and **b** T1 non-fat-saturated image showing the surgical scar and alteration of the surrounding parenchyma. **c** After injection of contrast, no enhancement of the scar is detectable **(13)**.

Architectural distortion and skin retraction are usually the result of different processes including postsurgical scar consolidation, FN, and severe fibrosis with disorganization of the collagen production. The typical MRI finding in the morphologic sequences without fat suppression is a spiculated irregular tissue area associated with changes in the contour of the skin. These alterations can mimic a malignant recurrence. The distinction is based on the dynamic enhancement pattern on contrast-enhanced MRI **(24)**.

Tumor recurrence

Local tumor recurrence is the relapse, after a variable period of time, of tumor cells in the original tumor site despite surgical treatment, while regional tumor recurrence is the additional spread of the primary cancer outside the breast, frequently involving the axillary lymph nodes. Breast cancer recurrence following conservative surgery and radiotherapy usually occurs during the first 5 years after treatment, with a peak incidence after 2 years. The risk of local tumor relapse in patients having undergone BOS is higher than in patients after mastectomy, in particular in premenopausal women and in the case of an invasive cancer with an extensive intraductal component **(25)**.

The rate of local recurrence is 2% per year. One of the most important current indications for performing an MRI study is to distinguish, after BOS, a tumor recurrence from scar tissue, with a sensitivity of 75-100%. The sensitivity of MRI is higher at least 12-18 months after breast surgery compared to that of mammography (35-40%). MRI is a useful tool in the case of suspected recurrence when the conventional imaging techniques (i.e., mammography and US) are

inconclusive or in conflict with the physical examination or other clinical indicators. Moreover, MRI is accurate in assessing the residual tumor extent in women after lumpectomy with close or positive resection margins **(26)**.

Some categories of patients, including those whose primary tumor was occult on mammography and those with infiltrating lobular cancer, should undergo a follow-up course based on MRI because of concerns that ipsilateral recurrent tumors will be difficult to detect through first-step breast investigations (i.e., mammography and US) **(6)**.

Dynamic contrast-enhanced MRI more accurately reveals the presence, location, and extent of tumor recurrence compared to breast US or mammography. The main advantage of MRI is the rapid contrast enhancement of malignant lesions compared to benign postoperative breast modifications. On DWI, the tumor relapse shows diffusion restriction, while in post-contrastgraphic sequences it presents rapid and intense contrast enhancement. In contrast, most scars does not show diffusion restriction and does not significantly enhance. Considering the diagnostic radiologic findings, if a suspicious enhancement is identified in the surgically treated breast gland, we believe that a core needle biopsy is indicated to confirm the suspected recurrence before performing surgery **(27)**.

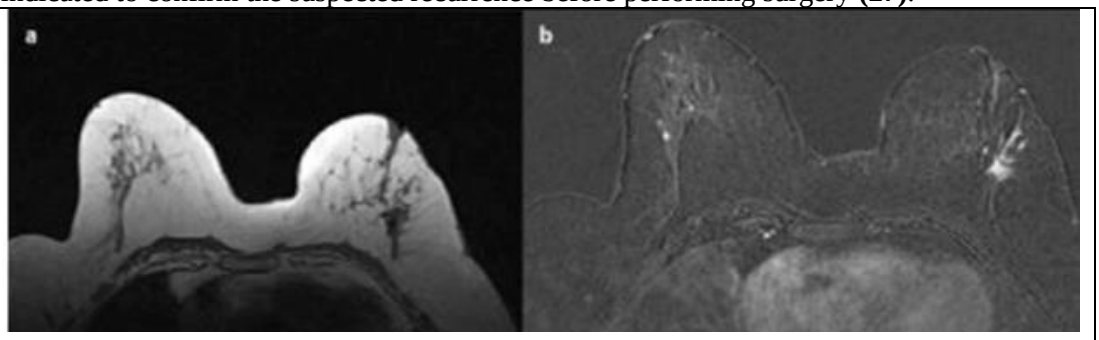


Fig. 11. Axial T2 non-fat-saturated imaging **a** showing parenchymal distortion post-surgery. **b** After contrast administration, a mass-like enhancement near the surgical scar is evident, suggestive for local tumor recurrence **(13)**.

Conclusion

Dynamic MRI appeared to be a valuable technique for differentiation of post-treatment changes from recurrent carcinoma and for guiding the histological confirmation. Its high negative predictive value may have an impact on follow-up of treated breast.

References

1. Barkhausen, J., Bischof, A., Haverstock, D., et al. (2021). Diagnostic c of contrast-enhanced breast MRI versus X-ray mammography in women with different degrees of breast density. Acta Radiol, 62, 586–593.
2. Mann, R.M., Cho, N., and Moy, L. (2019a). Breast MRI: State of the Art. Radiology, 292, 520–536.
3. Gao, Y. and Heller, S. L. (2020). Abbreviated and Ultrafast Breast MRI in Clinical Practice. Radiographics : a review publication of the Radiological Society of North America, Inc, 40(6), 1507–1527.
4. Onishi, N., Kataoka, M., Kanao, S., et al. (2018). Ultrafast dynamic contrast-enhanced mri of the breast using compressed sensing: breast cancer diagnosis based on separate visualization of breast arteries and veins. Journal of magnetic resonance imaging: JMRI, 47(1), 97–104.
5. Ray, K.M., Kerlikowske, K., Lobach, I.V., et al. (2018). Effect of Background Parenchymal Enhancement on Breast MR Imaging Interpretive Performance in Community-based Practices. Radiology, 286, 822–829.
6. Sardanelli, F., Trimboli, R.M., Houssami, N., et al. (2020). Solving the preoperative breast MRI conundrum: design and protocol of the MIPA study. Eur Radiol, 30, 5427–5436.
7. Spak, D. A., Plaxco, J. S., Santiago, L., et al. (2017). BI-RADS® fifth edition: A summary of changes. Diagnostic and interventional imaging, 98(3), 179–190.
8. Petralia, G., Bonello, L., Priolo, F., et al. (2011). Breast MR with special focus on DW-MRI and DCE-MRI. Cancer Imaging 11, 76–90.
9. Kawai, M., Kataoka, M., Kanao, S., et al. (2018). The Value of Lesion Size as an Adjunct to the BI-RADS-MRI

2013 Descriptors in the Diagnosis of Solitary Breast Masses. Magn Reson Med Sci, 17, 203–210.

10. Woitek, R., Spick, C., Schernthaner, M., et al. (2017). A simple classification system (the Tree flowchart) for breast MRI can reduce the number of unnecessary biopsies in MRI-only lesions. Eur Radiol 27, 3799–3809.

11. Pinker, K., Mann, R., and Partridge, S. (2022). Breast MRI: State of the Art and Future Directions, Advances in Magnetic Resonance Technology and Applications, 5. Academic Press.

12. Fischer, U., Baum, F., and Luftner-Nagel, S. (2017). Breast cancer: diagnostic imaging and therapeutic guidance. Thieme, Stuttgart; New York.

13. Gigli, S., Amabile, M.I., Pastena, F.D., et al. (2017). Magnetic Resonance Imaging after Breast Oncoplastic Surgery: An Update. BRC 12, 260–265.

14. Piper, M., Peled, A.W., Price, E.R., et al. (2021). Mammographic Changes After Oncoplastic Reduction Mammoplasty. Annals of Plastic Surgery.

15. Taboada, J.L., Stephens, T.W., Krishnamurthy, S., et al. (2009). The many faces of fat necrosis in the breast. AJR Am J Roentgenol, 192, 815–825.

16. Dolan, R., Patel, M., Weiler-Mithoff, E., et al. (2015). Imaging Results Following Oncoplastic and Standard Breast Conserving Surgery. Breast Care (Basel), 10, 325–329.

17. Kerridge, W.D., Kryvenko, O.N., Thompson, A., et al. (2015). Fat Necrosis of the Breast: A Pictorial Review of the Mammographic, Ultrasound, CT, and MRI Findings with Histopathologic Correlation. Radiol Res Pract, 2015, 613139.

18. Neal, C.H., Yilmaz, Z.N., Noroozian, M., et al. (2014). Imaging of Breast Cancer–Related Changes After Surgical Therapy. American Journal of Roentgenology 202, 262–272.

19. Okada, N., Narita, Y., Takada, M., et al. (2015). Early removal of drains and the incidence of seroma after breast surgery. Breast Cancer 22, 79–83.

20. Jesinger, R.A. (2014). Breast anatomy for the interventionalist. Tech Vasc Interv Radiol. 17, 3–9.

21. Zieliński, J., Jaworski, R., Irga, N., et al. (2013). Analysis of selected factors influencing seroma formation in breast cancer patients undergoing mastectomy. Arch Med Sci, 9, 86–92.

22. Chansakul, T., Lai, K.C. and Slanetz, P.J. (2012). The postconservation breast: part 1, Expected imaging findings. AJR Am J Roentgenol, 198, 321–330.

23. Leung, J.W.T. (2010). MR imaging in the evaluation of equivocal clinical and imaging findings of the breast. Magn Reson Imaging Clin N Am 18, 295–308, ix–x.

24. Tse, G.M.K., Chaiwun, B., Wong, K.-T., et al. (2007). Magnetic resonance imaging of breast lesions--a pathologic correlation. Breast Cancer Res Treat, 103, 1–10.

25. Bosma, S.C.J., van der Leij, F., van Werkhoven, E., et al. (2016). Very low local recurrence rates after breast-conserving therapy: analysis of 8485 patients treated over a 28-year period. Breast Cancer Res Treat, 156, 391–400.

26. Yin, J., Yang, J., Han, L., et al. (2015). Quantitative discrimination between invasive ductal carcinomas and benign lesions based on semi-automatic analysis of time intensity curves from breast dynamic contrast enhanced MRI. J Exp Clin Cancer Res, 34, 24.

27. Rinaldi, P., Giuliani, M., Belli, P., et al. (2010). DWI in breast MRI: role of ADC value to determine diagnosis between recurrent tumor and surgical scar in operated patients. Eur J Radiol, 75(2), e114-123.