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Breast MRI: guidelines from the European Society of Breast Imaging

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Abstract The aim of breast MRI is to obtain a reliable evaluation of any lesion within the breast. It is currently always used as an adjunct to the standard diagnostic procedures of the breast, i.e., clinical examination, mammography and ultrasound. Whereas the sensitivity of breast MRI is usually very high, specificity—as in all breast imaging modalities—depends on many factors such as reader expertise, use of adequate techniques and composition of the patient cohorts. Since breast MRI will always yield MR-only visible questionable lesions that require an MR-guided intervention for clarification, MRI should only be offered by institutions that can also offer a MRI-guided breast biopsy or that are in close contact with a site that can perform this type of biopsy for them. Radiologists involved in breast imaging should ensure that they have a thorough knowledge of the MRI techniques that are necessary for breast imaging, that they know how to evaluate a breast MRI using the ACR BI-RADS MRI lexicon, and most important, when to perform breast MRI. This manuscript provides guidelines on the current best practice for the use of breast MRI, and the methods to be used, from the European Society of Breast Imaging (EUSOBI).

Keywords Breast · Breast neoplasms · Magnetic resonance imaging · Practice guideline

Introduction

The overall aim of breast imaging can be summarized under several general headings. First, it is performed in symptomatic women to exclude breast cancer or other disease that requires immediate treatment. In this respect, it should provide a definitive diagnosis or exclude the presence of a harmful abnormality. Second, in patients with known malignancies, imaging helps in the preoperative staging and subsequent choice of appropriate therapy, either surgical or medical. Third, in patients with known malignancies that are initially treated medically with neoadjuvant chemotherapy, imaging is helpful in the assessment of response to treatment and the evaluation of residual disease afterwards. Fourth, imaging is performed in asymptomatic women to detect breast cancer in its early stages, when it can be better treated, and in this respect imaging increases the prognosis and survival of breast cancer patients. Last, imaging may be used to evaluate foreign bodies within the breast, such as the location of clips and markers or whether breast prostheses are intact.

Magnetic resonance imaging of the breast can be used to pursue any of the above-mentioned goals.

The aim of this paper is to provide guidelines for the performance and use of breast MRI, with respect to both the technical aspects of this procedure and the current indications.

Technical aspects

Patient handling

MRI of the breast is a study that requires the administration of a gadolinium-containing contrast agent during the study [1, 2]. Early studies have shown that breast MRI without contrast agent is not of diagnostic value [3, 4].

The uptake of contrast medium in breast tissue in premenopausal women is also dependent on the phase of the menstrual cycle. It is essential to perform breast MRI in the correct phase of the cycle as enhancing normal breast tissue may otherwise complicate the interpretation of the study. The optimal time in pre-menopausal women to perform a breast MRI is between the 5th and 12th day after the start of the menstrual cycle [5–7].

Placement of an intravenous cathether should be done before positioning the patient on the MR table. A long IV line avoids table and patient movement before the injection. The contrast agent should preferably be given by a power injector.

It is important to position the patient as comfortably as possible in order to avoid motion artifacts.

A dedicated bilateral breast coil is mandatory for this investigation, and the patient should be placed in the prone position with both breasts hanging in the coil loops. The breasts may be supported to further reduce motion artifacts, but should not be compressed.

The position of the breast should be checked before the start of the examination, both breasts must be placed as deeply as possible in the coils with the nipples pointing down. A larger breast coverage is usually obtained by placing both arms at the side of the body and not above the patient's head.

Virtually any MRI scanner can be used to perform contrast-enhanced breast MRI, as long as the system allows image acquisition at a sufficient spatial and temporal resolution (see below). However, scanning protocols need to be adapted to the scanners used, also because the relaxivity of the most commonly used contrast agents decreases at higher field strengths [8, 9]. Breast MRI at low and midfield strength (0.2 T, 0.5 T) depends heavily on parallel imaging to obtain a sufficient resolution. As this further decreases the signal-to-noise ratio (SNR), this is not optimal. In practice, most studies that employed low or midfield scanners did not obtain a sufficient spatial resolution [10, 11]. An increasing field strength (1.5 T, 3 T) allows a higher spatial resolution at a similar temporal resolution and consequently may increase diagnostic confidence [12]. A disadvantage is that, at higher field strengths (e.g. 3 T), inhomogeneity in the B1 field may cause reduced signal in parts of the image and thus less contrast enhancement, which in turn may cause false-negative image interpretation. Two-dimensional acquisitions are particularly sensitive to this effect and are therefore discouraged at 3 T [13].

Sequences

The conventional breast MRI investigation begins precontrast with either T2- or T1-weighted images.

The signal from the body coil can be used to evaluate the position and anatomy of the breasts. Furthermore, both axillae, the supraclavicular fossae, the chest wall and anterior mediastinum can be checked (e.g., for enlarged lymph nodes). However, this is not the purpose of a breast MRI, and this evaluation may also be omitted as there is no evidence of its diagnostic value.

Afterwards the signal from the dedicated double breast coil should be used.

T2-weighted fast spin echo images can be performed as a start.

In the T2-weighted images water-containing lesions or edematous lesions have an intense signal, and in this sequence small cysts and myxoid fibroadenomas are very well identified.

In most cases cancer does not yield a high signal on T2-weighted images; thus, these sequences can be useful in the differentiation between benign and malignant lesions. However, as most of these lesions can also be identified on T1-weighted images, there is no evidence as yet of added value of T2-weighted sequences in breast MRI [14, 15].

The most commonly used sequence in breast MRI is a T1-weighted, dynamic contrast enhanced acquisition. The sequence is called 'dynamic' because it is first performed before contrast administration and is repeated multiple times after contrast administration.

A T1-weighted 3D or 2D (multi-slice) spoiled gradient echo pulse sequence is obtained before contrast injection and then repeated as rapidly as possible for 5 to 7 min after a rapid intravenous bolus of a Gd-containing contrast agent. A 3D pulse sequence offers a stronger T1 contrast and enables thinner slices than 2D; in turn, a 2D sequence suffers less from motion and pulsation artifacts. Both sequences can be performed with and without fat-suppresion [16, 17].

The choice of the image orientation is important. For bilateral dynamic breast MRI, axial or coronal orientations are most frequently used. Coronal imaging has advantages in that it can reduce heart pulsation artifacts, but it is more susceptible to respirational motion and also to flow artifacts because vessels tend to travel perpendicular to the slice-encoding direction. Although bilateral sagittal imaging is possible today, it requires about double the number of slices required for the other orientations. As this hampers the spatio-temporal resolution, such an orientation is currently not feasible.

The optimal dose of the contrast medium is unknown and also depends on the contrast agent used. In literature, applied doses range roughly from 0.05 to 0.2 mmol/kg. One study showed some benefit of 0.16 mmol/kg gadopentetate dimeglumine over 0.1 mmol/kg [18]. However, a more recent evaluation did not find any improve-

ment in diagnostic accuracy using 0.2 mmol/kg gadobenate dimeglumine over 0.1 mmol/kg of the same agent [19]. Consequently, a dose of 0.1 mmol/kg is probably sufficient.

Peak enhancement in the case of breast cancer occurs within the first 2 min after the injection of contrast medium. Therefore, relatively short data acquisition times, in the order of 60–120 s per volume acquisition, are necessary. This allows sampling of the time course of signal enhancement after contrast injection, which is useful because the highly vascularized tumor of the breast shows a faster contrast uptake than the surrounding tissue. More importantly, it enables a detailed analysis of morphologic details, because only in the very early post-contrast phase, the contrast between the cancer and the adjacent fibroglandular tissue is optimal. Tumors may lose signal (a phenomenon referred to as "wash out") as early as 2–3 min after contrast material injection, whereas the adjacent fibroglandular tissue can still exhibit substantial enhancement, resulting in little contrast between the cancer and the fibroglandular tissue. Long acquisition times will be associated with the risk of not resolving fine details of margins and internal architecture; this could have key importance for the differential diagnosis, and may even run the risk of missing cancers altogether because they are masked by adjacent breast tissue.

A dynamic sequence demands at least three time points to be measured, that is, one before the administration of contrast medium, one approximately 2 min later to capture the peak and one in the late phase to evaluate whether a lesion continues to enhance, shows a plateau or shows early wash-out of the contrast agent (decrease of signal intensity) [20]. It is thus recommended to perform at least two measurements after the contrast medium has been given, but the optimal number of repetitions is unknown. However, the temporal resolution should not compromise the spatial resolution. It was shown that an increase in spatial resolution results in higher diagnostic confidence even when the temporal resolution is slightly sacrificed. [21].

The final spatial resolution of the images depends on different factors, especially the size of the imaging volume, defined by the field of view (FOV), the slice thickness and the acquisition matrix. Breast MRI should be capable of detecting all lesions larger than or equal to 5 mm. Therefore, the voxel size should be under 2.5 mm in any direction. Preferably, the in-plane resolution should be substantially higher as morphologic features needed for lesion characterization, such as margin appearance, can only be evaluated when the resolution is sufficiently high. Therefore, the in-plane resolution should be at least 1 mm^{-1} , in other words: pixel size (FOV/matrix) should not be greater than 1×1 mm, which requires a matrix of at least 300×300 in a 300-mm FOV.

Assessment of lesion morphology can be performed directly on the enhanced fat-suppressed images. However, as residual fat-signal (hyperintense at T1-weighted images) may cause difficulties in interpretation, the calculation of subtraction images from the pre- and post-contrast series is recommended [22, 23].

Subtraction suppresses the signal from bright fat because fatty tissue hardly enhances. When subtraction is performed, fat suppression in the acquisition is not needed and is even discouraged, because in the large fields of view that are usually required for axial and coronal imaging, homogenous fat suppression is difficult to obtain. This can be problematic since fat and water resonance frequencies are relatively close at 1.5 T—which implies that with less-than-optimal B0 homogeneity across the field of view, water (rather than fat) suppression can occur. Moreover, fat-suppression increases the noise in the image and usually also compromises spatio-temoral resolution.

Evaluation

Use of both detailed morphological information provided by high spatial resolution images and kinetic information (curve type) provided by at least two repetitions of the high spatial resolution sequence represents the latest trend in acquisition protocols and image interpretation to take into account the increasing importance of detailed morphological information without losing identification of washout enhancement curve types [24].

For the diagnostic interpretation the ACR breast imaging reporting and data system (BIRADS) for breast MRI illustrates many of the morphological findings seen on contrast-enhanced breast MRI. It also includes a lexicon that should be used for uniform reporting of the features seen on MRI [25].

Indications for breast MRI

Inconclusive findings in conventional imaging

Patients referred by their general practitioner or through a nationwide screening program to secondary care are told that there is a chance that they might have breast cancer. In this situation imaging, with or without biopsy, should exclude the presence of a malignancy sufficiently. The sensitivity of breast MRI for the detection of cancer is the greatest of all imaging techniques [26–28], and when the findings of conventional imaging are inconclusive (i.e., BI-RADS 0), MRI can be used as a problem-solving modality. In general, a negative breast MRI excludes malignancy. Only in case of mammographic microcalcifications, MRI is unable to exclude cancer sufficiently, and the decision to perform biopsy should be based on mammographic findings in this specific situation [29].

Preoperative staging

Breast tumors may be solitary, well-circumscribed masses that are well recognized at mammography and/or sonography. However, tumor size may be underestimated severely by mammography and ultrasound, especially in tumors larger than 2 cm [30, 31]. Tumor size of invasive carcinomas on MRI correspond in general well to pathologic sizes [32, 33]. Unfortunately, MRI has a tendency to overestimate the size of pure DCIS lesions [34]. Furthermore, in about 25% of the cases, the tumor is multifocal; in other words, there are more invasive tumors in one quadrant. Moreover, multicentricity, which means one or more invasive foci more than 4 cm from the primary tumor, is present in about 20% of all invasive malignancies. Inadequate size estimation or failure to detect additional foci of disease may thus result in positive resection margins after surgery or early recurrent disease.

The sensitivity of breast MRI is, in the setting of preoperative evaluation, close to 100% [26]. MRI is the most reliable imaging technique to measure the tumor size [35, 36], and it detects additional foci of the tumor in the ipsilateral breast in 10–30% of patients [37–45]. Also the presence of an intraductal component (EIC+) can be better evaluated by MRI than with mammography [36, 46–48]. On MRI this may be seen as an area of contrast enhancement with a dendritic configuration close to the primary tumor. However, approximately 20% of the additional foci detected by MRI are benign [43, 49]. Consequently, before large adjustments to the surgical management are effectuated, histological analysis of MR-detected additional foci should be performed.

Several studies have shown a change in surgical management in about 20% to 30% of all patients undergoing preoperative MRI [26, 37, 39, 49]. Changes were greatest in patients with tumor size greater than 4 cm [50], lobular carcinoma [37] or breast density 4 [49].

However, it is so far unclear whether breast MRI contributes to better control of the disease or survival of all patients with diagnosed breast cancer. Only one study has evaluated such outcomes, and although MRI appears to reduce the incidence of local recurrence (1.2% vs. 6.8%), confounding differences in tumor characteristics between patients treated with and without MRI did occur [51].

The British COMICE trial is a large multicenter trial that randomizes patients between MRI and no-MRI and evaluates the quality of preoperative staging, the differences in outcome, differences in quality of life and cost-effectiveness [52]; the first results are expected in 2008. This study and similar ongoing studies may provide better evaluation of staging in the near future.

Synchronous bilateral breast cancer is reported in about 2–3% of all breast cancer patients [53–55], but it is probably more common. Synchronous contralateral lesions are occult on mammography in about 75% of cases. MRI detects otherwise occult lesions in 3–5% of patients that undergo preoperative MRI [56–58]. Some studies show even more alarming results and report MRI-only detected contralateral breast cancer in 19% [59] and 24% [60]. These lesions would probably have presented as metachronous contralateral carcinomas without MRI, as is also clear from the above-mentioned outcome study. The rate of contralateral carcinomas detected at follow-up decreased from 4% without MRI to 1.7% with MRI [51].

Screening of the contralateral breast in patients with proven unilateral breast cancer is thus a valid indication for the performance of preoperative breast MRI. In practice this means that preoperative MRI is recommended in all patients with histologically proven breast cancer, even though the indication for ipsilateral staging of the cancer is still under investigation.

Especially in the case of dense breasts, MRI is recommended preoperatively. Furthermore, in patients with histologic evidence of invasive lobular carcinoma, a preoperative MRI is strongly recommended as these tumors show a more permeative growth pattern and, consequently, are more difficult to measure [32, 61], are more often multifocal or multicentric (additional foci in 32%) [62, 63] and are more often complicated by concurrent contralateral carcinomas (occult tumors detected in 7%) [62, 64, 65].

Unknown primary

In the case of a carcinoma of unknown primary, metastases are diagnosed, but a primary tumor site cannot be identified. These metastases may either present in the axillary lymph nodes, the supraclavicular lymph nodes, the bones, the liver, the brain or the lungs.

When the mammogram does not show any abnormality, reports in the literature show, in about 50% of the cases, an abnormal MRI [66]. In case of metastatic axillary lymph nodes, MRI is even able to detect a primary breast tumor in 75–85% of patients [67, 68]. MRI thus can subsequently be used to plan the most appropriate treatment as the size of these lesions on MRI is usually concordant with the size at pathology, thus MRI may prevent unnecessary mastectomies or assign patients with large tumors to neoadjuvant protocols.

The evaluation of therapy response in the neoadjuvant chemotherapy setting

Neoadjuvant chemotherapy is the administration of chemotherapy prior to surgical treatment of cancer. Its principal indication is the treatment of unresectable breast cancers, and its goal in this setting is to reduce the tumor to a size that allows resection. However, many studies have shown that the prognosis of breast cancer is equal when chemotherapy precedes or follows after surgery. Because

there are some theoretical benefits in the neoadjuvant setting, and tumor response can be closely evaluated with the tumor in situ, neoadjuvant chemotherapy is also the standard of care in large T2 and T3 tumors. MRI has been shown to be superior to evaluate tumor response to neoadjuvant chemotherapy compared to clinical examination, mammography or ultrasound and is thus the imaging investigation of choice.

If neoadjuvant chemotherapy is given to a patient, the first breast MRI should be performed before the start of chemotherapy. A second MRI, for the evaluation of the effect of chemotherapy on the tumor, should be performed when approximately half of the course of chemotherapy has been administered. A third MRI investigation should be performed after the final course of chemotherapy to evaluate the residual disease. In most hospitals four to six cycles of chemotherapy are given in the neoadjuvant setting.

Response is normally measured using the RECIST criteria [69]. Using these, complete response (CR) is defined as complete vanishing of the tumor, partial response (PR) is defined as decrease of the sum of the longest axes of all individual lesions by more than 30%, progressive disease (PD) is defined as an increase of this sum by more than 25% and the remainder is classified as stable disease (SD). Response to chemotherapy is especially well evaluated in the non-responders (SD, PD) and the good-responder group (CR). The effect of the chemotherapy in partial responders is less well established.

Several studies compared the ability of clinical examination, mammography, ultrasound and MRI in the assessment of final response [70–80]. They showed that MRI measurement after therapy correlated best with the pathological findings and was the best technique for assessing response.

Nevertheless, MRI is unable to detect small residual tumor foci that may persist after neoadjuvant chemotherapy. Radiological complete response is thus no proof for pathological complete response (pCR); therefore, resection of the initial tumor bed is still essential in the treatment of these patients [77, 79].

Observation of response during treatment is important as this is the only measure that justifies the applied chemotherapeutic regimen and is the only response evaluation that allows a change in this regime before its completion. Currently, the performance of MRI halfway during treatment may only change the treatment in clear non-responders and those with progressive disease as there are no other criteria for early response evaluation. This is due to the fact that size of the tumor often does not immediately decrease. Therefore, the performance of MRI earlier in the treatment (e.g., after the first cycle) as is under investigation in several large trials (such as the ACRIN 6657 trial) is currently not recommended, although in one study complete responders had a change in diameter of at least 45% after the first course of chemotherapy [72]. In another study early change in volume was the most predictive of final response [75]. The value of these MRI investigations first should be established, and criteria for early response need to be defined.

Several other techniques, such as MR spectroscopy [81], diffusion imaging [82] and FDG-PET [83–85] show promise in the (early) evaluation of tumor response to therapy. However, none of these techniques have been tested in large-scale prospective studies and can thus not (yet) be recommended for clinical practice. For a more detailed description of the studies so far performed in the evaluation of response to neoadjuvant chemotherapy, we refer to the review by Tardivon et al. [86].

Imaging of the breast after conservative therapy

MRI may be considered after breast-conserving therapy (BCT) in three instances: first as an evaluation tool for residual disease after positive tumor margins, second as a method of evaluating suspected recurrence by either clinical examination, mammography or ultrasound and third as a screening tool in all patients who undergo BCT.

Unfortunately, early postoperative MRI is hampered by strongly enhancing resection margins in response to the surgical intervention. Therefore, MRI is unable to exclude residual tumor at the biopsy cavity sufficiently, and hence does not change the surgical approach consisting in a larger resection of the tumor bed in the direction where pathological analysis of the surgical specimen showed positive margins [87–89].

Although preoperative staging MRI is to be preferred over MRI after initial surgery, it can be performed when surgical margins are badly involved. In such cases, the first acceptable MRI results are not to be expected sooner than a month after surgery [90]. However, as MRI may reveal more widespread disease throughout the breast remote from the lumpectomy site, it can provide valuable information concerning the decision of wider excision versus mastectomy [91–93]. Morakkabati et al. have shown that postradiation changes occur during and up to 3 months after radiation therapy, but do not reduce the accuracy of MRI to identify residual or recurrent tumor compared to patients without radiation therapy [94].

Most local recurrences after BCT and radiotherapy occur within 5 years after the initial surgery, and the annual risk is estimated at 1–2% per year [95–98]. Early detection and treatment of recurrent disease are important as it may still present without distant metastases. Second primary ipsilateral carcinomas in the treated breast can occur at every site and develop on average 7 years after the first primary tumor [99]. The sensitivity of mammography for recurrent disease in the treated breast is limited, but breast MRI can be a valuable complementary tool as explained earlier.

A local recurrence on MRI has the same appearance as a new primary malignancy with strong early enhancement,

while a fibrous scar shows either no enhancement or very slow enhancement. In a treated breast, the specificity of breast MRI is higher than in an untreated breast.

Different studies have shown that MRI is the most sensitive technique in detecting a local recurrence of the disease [36, 100–104]. When a local recurrence is suspected upon clinical findings or abnormalities on mammography or ultrasound, MRI can be used to exclude local recurrence with a high negative predictive value and thus prevent unnecessary biopsies [93, 103, 104].

Analogous to the situation in preoperative staging, MRI is able to detect multifocality and multicentricity unnoticed by conventional imaging. Naturally, in these cases, the evaluation of the contralateral breast is also important.

There is currently not sufficient evidence to recommend or not the screening of patients treated by BCT with MRI. So far, only one small trial has been performed [101], which showed no difference in sensitivity for recurrence between clinical examination combined with mammography and MRI alone. However, the specificity of MRI was much higher (93% vs. 67%), confirming its value as additional investigation. Moreover, in some patients, it can be impossible to image the primary tumor region by mammography after conservative therapy [105]. In these cases breast MRI is mandatory.

The risk of local recurrence is strongly dependent on the age of the patient at the time of diagnosis [106–109]. Patients over 50 have a risk of approximately 4% after 5 years, but this risk is estimated at 12% after 5 years for patients who were under 45 years of age [108] and at 20% after 5 years for patients under 40 [106]. Although additional boost radiotherapy to the tumor bed can reduce this risk to 10% at 5 years, these patients have a lifetime risk that is probably still greater than 20%, which is equal to the lifetime risk demanded for MRI screening in the general population, as described below.

Therefore, annual MRI screening is an option for all patients under 50 at the time of diagnosis of the first primary carcinoma, but this should first be investigated in larger trials.

MRI screening

The high sensitivity for cancer makes breast MRI a desirable technique for screening purposes. Therefore, many countries have performed screening studies in high-risk populations. The American Cancer Society (ACS) has recently issued guidelines for the performance of MR screening based upon the analysis of six of these studies [110]. As the most important of these studies were all performed in Europe (e.g. the Dutch MRISC study [111], The UK-based MARIBS study [112], the German single-center study [113] and the Italian HIBCRIT study [114]), the ACS recommendations apply mostly to the European situation. The overall sensitivity for breast cancer in these high-risk populations is between 71 and 100% for MRI compared to 16–40% for mammography. The specificity ranges from 81 to 99% for MRI and 93 to 99% for mammography, which is illustrative for the higher detection rate of MR and the (almost two times) higher recall rate that unfortunately complicates MR screening.

There is evidence for the value of annual MR screening in BRCA gene mutation carriers, their first degree, untested relatives and all women with a lifetime risk of 20–25% according to models that depend largely upon family history.

Furthermore, MRI screening is advised in patients who received radiation to the chest in their 2nd or 3rd decade (mostly patients with a history of lymphoma) and patients with inherited syndromes, such as LiFraumeni and Cowden syndrome, and their first-degree relatives, although there is no direct evidence for these latter recommendations.

Currently there is not sufficient evidence to recommend MRI or not in women with a lifetimerisk of 15–20%, those with high-risk lesions (LCIS, ALH, ADH) and those with heterogeneously or extremely dense breasts on mammography.

Women with a lifetime risk of less than 15% should currently not be enrolled in MR screening programs.

It is still unclear when to start screening. In most high-risk patients, starting at the age of 30 will probably be sufficient. However, in families where the first carcinomas presented at younger ages, the screening needs to start earlier as well. It seems advisable to follow the guidelines for mammography in this aspect and start screening at an age 5 years younger than the youngest relative that presented with cancer. It is also unclear for how long screening with MR should be continued; in older women the breast density decreases significantly, and the added value of MR might thus decrease. However, at every age, the sensitivity for breast cancer of MRI is higher than that of mammography.

Prosthesis imaging

The evaluation of breast implants, which are either placed for breast augmentation or for breast reconstruction after surgery for breast cancer, can be done with MR. This demands specific sequences that are aimed at the visualization of silicone and provide concurrent suppression of the water signal [115–117]. By using these sequences and specific evaluation criteria [116, 117], MRI is the most accurate modality in the evaluation of implant integrity. Its sensitivity for rupture is between 80 and 90%, and its specificity is approximately 90% [117–119], whereas the sensitivity of mammography is approximately 25% [120, 121].

Nevertheless, the indication for breast MRI is less clear than might be expected. Ten years after insertion, approximately 50% of all breast implants are ruptured [117, 118]. It seems therefore advisable to use breast MR only when there are specific complaints that might be caused by leaking prostheses (e.g., local inflammation or

the formation of silicone granulomas). MRI may then be used to exclude a ruptured prosthesis as the underlying cause of the complaints, and it may also aid explantation surgery as it documents the presence and extent of silicone leakage better than any other imaging modality.

In patients with prosthesis and prior breast cancer, MRI may be used to evaluate suspected recurrent disease or as a postoperative screening modality. The presence of the implant does not seem to decrease the sensitivity of breast MR [122, 123].

MR-guided biopsy and lesion localization

It is clear that the increasing list of indications for the performance of breast MR leads to the detection of many lesions that are neither palpable nor visible on conventional imaging techniques. Although most MR-detected lesions can be found (and biopsied) at second-look ultrasound, many can not. This stresses the importance of the possibility of performing MR-guided biopsies and localizations. Any site that performs breast MR examinations should either be able to perform MR-guided interventions in the breast or should be in close contact with a site that can perform these investigations for them.

However, the exact description of the involved techniques and the minimal requirements that need to be met when performing these interventions are quite extensive and cannot be described in this paper. A separate guideline describing these interventions will be published soon by Heywang-Kobrunner et al.

For adequate performance, some important points should be kept in mind.

- A dedicated bilateral breast coil is mandatory.
- The spatial and temporal resolution must be sufficient.
- A T1-weighted sequence should be obtained for at least three time points, one prior to and two after contrast administration.
- Reporting should be performed by a radiologist with experience in breast MRI, using the ACR BI-RADS MRI Lexicon.
- MRI-guided breast biopsy must be available.

The most important indications currently present are listed below.

- Problem solving in case of inconclusive findings on conventional imaging.
- Screening of the contralateral breast in women with histological evidence of unilateral breast cancer.
- Evaluation of the breasts in case of metastases of an unknown primary carcinoma.
- Evaluation of therapy response in patients treated with neoadjuvant chemotherapy.
- Exclusion of local recurrence after breast-conserving therapy.
- Screening of women with a lifetime risk of 20% or more to develop breast cancer, including mutation carriers.

Conclusion

Breast MRI is no longer an experimental modality, but has attained a solid position in the diagnosis and workup of (suspected) breast lesions.

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