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PICTORIAL ESSAY

Dynamic Contrast-enhanced Breast Magnetic Resonance Imaging: Clinical Practice, Techniques, and Challenges in Local Chinese Population

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ABSTRACT

Breast cancer is the most common malignancy and the third most common cause of cancer death in Hong Kong women. Ultrasound imaging and contrast-enhanced magnetic resonance imaging are useful adjuncts to mammography. The advantage of breast magnetic resonance imaging is its high sensitivity for invasive breast cancer. Therefore indications for and use of breast magnetic resonance imaging have increased over the past decade. In this article, we illustrate the current protocol for dynamic contrast-enhanced breast magnetic resonance imaging in our centre, by reference to cases with different indications for such imaging. We also review the common artefacts and pitfalls in breast magnetic resonance imaging. Contrast-enhanced breast magnetic resonance imaging is a powerful imaging modality for breast diseases. An awareness of proper technique, potential pitfalls, and artefacts is critical to achieving accurate image interpretation. When breast magnetic resonance imaging is performed with the required technical finesse and in the appropriate clinical setting, it is a highly sensitive and reasonably specific means of detecting breast cancer.

Key Words: *Artifacts; Breast neoplasms; Carcinoma in situ; Magnetic resonance imaging; Mass screening*

中文摘要

本地華籍病人的動態增強乳房磁共振造影：臨床實踐、技術及挑戰

衛頴莊、趙朗峰、杜德信、黎國鴻、蕭志偉、郭啟欣、陳慈欽

乳癌是最常見的惡性腫瘤，亦是香港婦女第三大最常見的癌症死因。超聲及增強磁共振造影均為乳房攝影檢查的輔助性工具。對於侵襲性乳癌，乳房磁共振造影的優點是有高敏感度，因此這技術在過去十年間被廣泛應用。本文根據過往不同的病例，展示本中心使用動態增強乳房磁共振造影的常規，並探討有關乳房磁共振造影常見的圖像偽差及陷阱。增強乳房磁共振造影是很有效果的一種成像方法。只有認識正確的技術操控以及圖像偽差的可能性和陷阱，才可以達到準確的圖像闡釋。在適當的臨床環境中正確運用乳房磁共振造影，是一種高敏感度及特異性可靠的偵察檢出乳癌方法。

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INTRODUCTION

Breast cancer is the most common malignancy and the third most common cause of cancer deaths in Hong Kong women.[1] The number of breast cancer cases diagnosed in Hong Kong has doubled from 1152 in 1993 to 2616 in 2008.[2] Although mammography is the primary imaging technique for detection of early breast cancer, it has limited sensitivity and specificity.[3] Ultrasound imaging and contrast-enhanced magnetic resonance imaging (MRI) are reported to be useful adjuncts to mammography. The advantage of breast MRI is its high sensitivity for invasive breast cancer,[4] and is quoted to be up to 95 to 100%.[3,4] Therefore indications for and use of breast MRI have increased over the past decade. This article describes technical and practical issues in attaining high-quality breast MR images by reviewing the appropriate indications, as well as the common artefacts and pitfalls of such imaging. We also illustrate our current protocol for dynamic contrast-enhanced breast MRI examination, by reference to cases involving different indications for breast MRI.

CLINICAL INDICATIONS

Radiologists have a role in educating referring surgeons and oncologists about the appropriate clinical indications for breast MRI. Breast MRI is a highly sensitive means of detecting abnormalities that are not evident clinically, mammographically, or sonographically. The American College of Radiology has published guidelines on appropriated indications for breast MRI.[5] The Table and Figures 1 to 3 summarise the relevant indications.

Because MRI can miss some mammographically detectable cancers such as malignant micro-calcifications and ductal carcinoma in-situ, it is not a substitute for screening mammograms. Moreover, due to its increased costs, breast MRI is not recommended for screening women in the general population with average risk, as this would provide a very low yield.[6]

Table. Current indications for breast magnetic resonance imaging.

Procedure	Indications
Screening	- Screening of high-risk patients (>20% lifetime risk of breast cancer)
	- Screening of the contralateral breast in patients with a new breast malignancy
	- Breast augmentation — postoperative reconstruction and free injections (Figure 1)
Extent of disease	- Invasive carcinoma and ductal carcinoma in-situ
	- Invasion deep to fascia of breast carcinoma prior to surgical treatment (Figure 2)
	- Post-lumpectomy with positive margins in the evaluation of residual disease
	- Neoadjuvant chemotherapy: before, during, and / or after chemotherapy to evaluate treatment response and the extent of residual disease prior to surgical treatment
Additional evaluation of clinical or imaging findings	- Recurrence of breast cancer
	- Metastatic cancer when the primary is unknown and suspected to be of breast origin (Figure 3)
	- Lesion characterisation when other imaging examinations, such as ultrasound and mammography, and physical examination are inconclusive for the presence of breast cancer
	- Postoperative tissue reconstruction in the evaluation of suspected cancer recurrence
	- Guidance of interventional procedures, e.g. vacuum-assisted biopsy and preoperative wire localisation for lesions

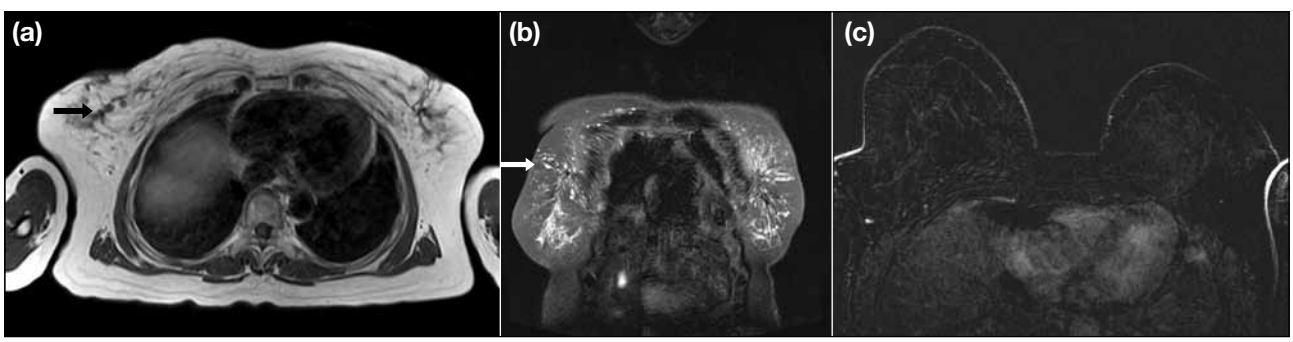

Figure 1. Bilateral breast augmentation by free injection of unknown materials. (a) An axial T1 image using a body coil showing multiple subcentimeter hyperintense foci representing injected materials in breast glandular tissue (arrow). (b) Coronal T2 turbo inversion recovery magnitude using the body coil demonstrates hyperintense foci representing injected materials (arrow). (c) A fully subtracted post-contrast axial T1-weighted image with breast dedicated coil does not show any tumour. The injected materials do not affect the accuracy of magnetic resonance imaging.

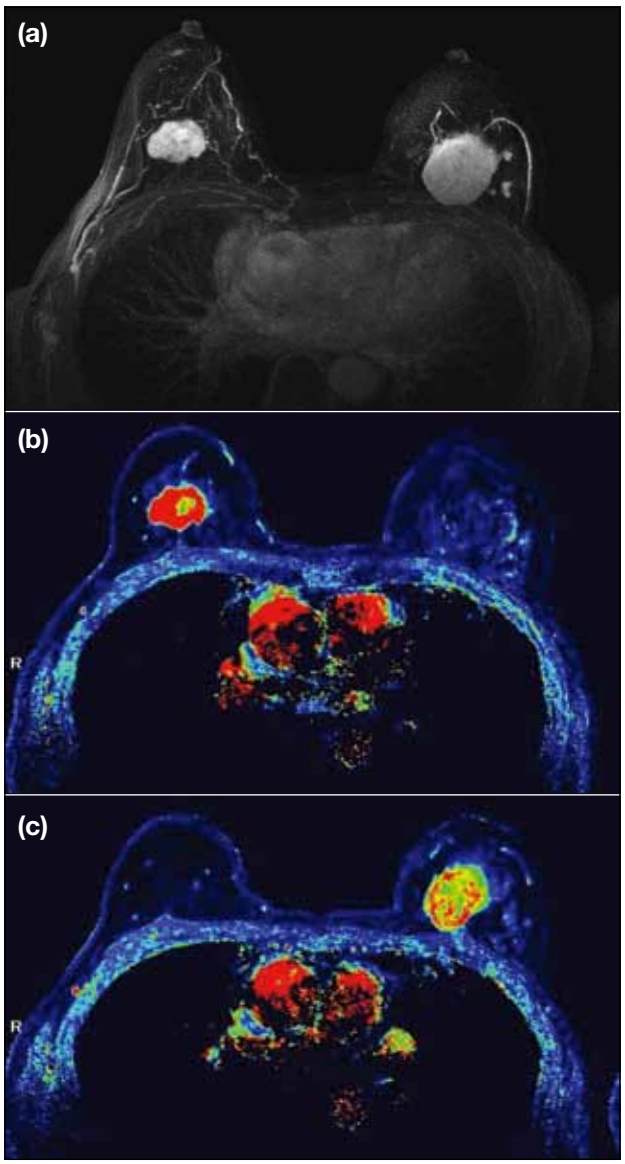

Figure 2. Advanced stage of carcinoma of left breast with synchronous right breast carcinoma. (a) Axial full maximum intensity projection (MIP) from the first post-contrast subtraction image reveals bilateral breast cancer with increased vascularity. (b and c) Colour overlying perfusion images correspond to the rapid enhancement and washout kinetics of both tumours. The most vascular part of each tumour (shown in red) is illustrated separately.

Due to its high sensitivity, breast MRI can detect both benign and malignant lesions, but inappropriate use increases unnecessary patient anxiety and interventional procedures.

PRECAUTIONS

Notably, MRI does not have a 100% sensitivity for excluding breast carcinomas, so in the face of suspicious clinical or imaging findings, biopsy, surgery or other investigations should still proceed. Increased parenchymal enhancement has been observed normally during the secretory phase of the menstrual cycle, which can give rise to false-positive MRI results. Therefore, in pre-menopausal women, all contrast-enhanced studies should be performed between day 7 and 14 of the menstrual cycle.[7] However, this is usually not practical and for this reason, radiologists have to learn the patterns of physiological breast enhancement.

TECHNICAL CONSIDERATIONS

The selection of field strength is of the utmost importance in breast MRI. A 1.5-Telsa magnet has generally been considered as a minimum technical requirement due to the relationship between field strength and spatial resolution.[8] Low field strength can give inadequate homogeneity in the magnetic field, which prevents chemically selected fat saturation and affects the image quality.[9]

Multi-channel breast dedicated coils are essential (Figure 4). They can provide a higher signal-to-noise ratio and more uniform image intensity across both breasts. Mild compression may be applied to the breast in a lateral to medial direction so as to decrease the amount of tissue imaged (Figure 4b), which also decreases motion artefacts during and between sequences.[10] However, excessive compression can inhibit the contrast uptake into breast tissue. Simultaneous bilateral imaging should be performed to allow assessment of symmetry and for comparison, which can also aid in detection of synchronous or occult cancer in the contralateral breast in about 3 to 5% of women with a known diagnosis of breast cancer.[11,12]

High spatial and temporal resolution is needed to detect and characterise small abnormalities in MRIs. Section thickness determines how small a breast lesion can be identified. The slice thickness should be 3 mm or less and in plane pixel resolution should be 1 mm or less, so as to minimise volume averaging effects.[13]

Gadolinium chelate injection increases the sensitivity for detection of malignancies due to the tumour angiogenesis.[14] In practical clinical settings, the contrast should be administered as an intravenous bolus as a standard dose of 0.1 mmol/kg of body weight, followed by a saline flush of at least 10 ml to ensure that all the contrast is cleared from the tubing and in the circulation.[15] Peak contrast enhancement in malignant lesions typically occurs between 90 and 180 seconds

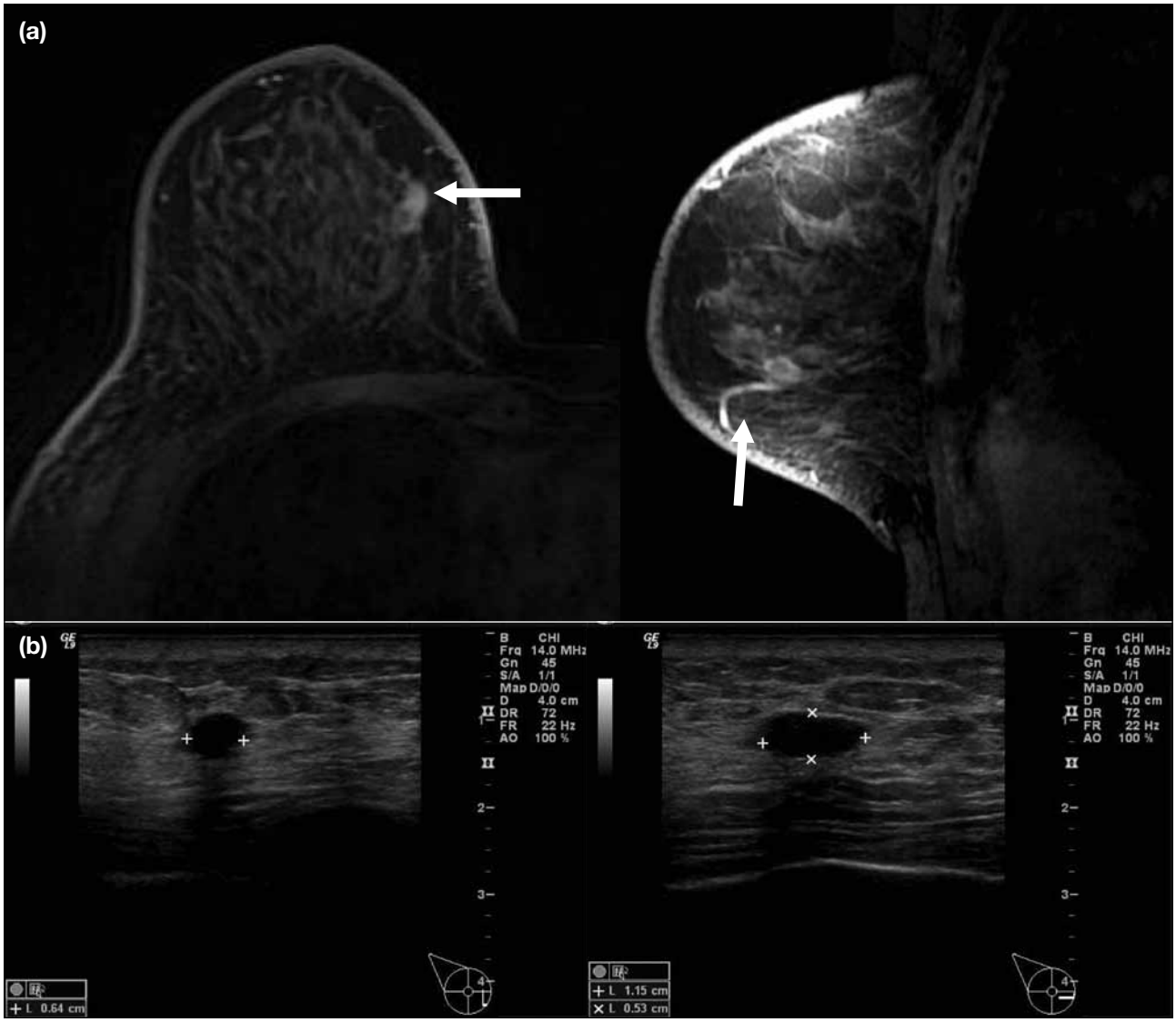

Figure 3. This patient with a history of carcinoma of breast and left mastectomy, was found to have right metastatic axillary lymph nodes of breast in origin. Private mammography and ultrasound of the right breast were normal. (a) Axial and sagittal contrast-enhanced T1-weighted subtracted images show an abnormal peripheral rim-enhancing mass at the inner lower quadrant of right breast (arrows). (b) A second-look ultrasound reveals the corresponding mass outlined by calipers.

after injection. Both breasts must be imaged within that time. Imaging for approximately 5 to 6 minutes after contrast injection is sufficient to determine the type and shape of the enhancement kinetic curve.[16]

LOCAL EXPERIENCE IN CHINESE PATIENTS

Records of all patients who underwent dynamic contrast-enhanced breast MRI examination in our centre between January 2011 and July 2011 were retrospectively reviewed. Clinical data and radiological images were retrieved from the electronic patient record, Radiology Information System, and Picture Archiving and Communication System. All these examinations were approved by radiologists specialised in breast imaging, based on American College of Radiology Practice guidelines, which specified the proposed indications for breast MRI.

The current protocol adds imaging with body coil from the base of neck through the breasts with the patient in a supine position, with axial T1 turbo spin echo and coronal T2 turbo inversion recovery magnitude. This can enhance the complete nodal staging prior to operation or chemotherapy, which is deficient in the breast dedicated coil (Figure 5). Then, a 16-channel

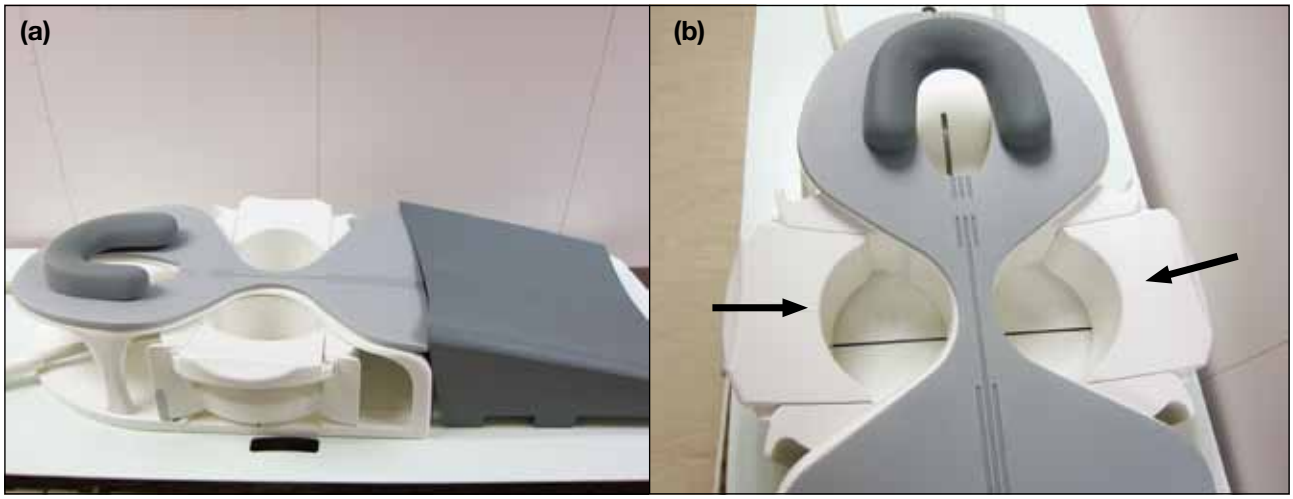

Figure 4. (a) A 16-channel–dedicated breast coil allows simultaneous imaging of both breasts in all directions; cushions for resting of head and body increase comfort so as to decrease patient movement. (b) Mild mediolateral compression (arrows) showing decreased amounts of imaged tissue and decreased the motion artefacts during and between sequences.

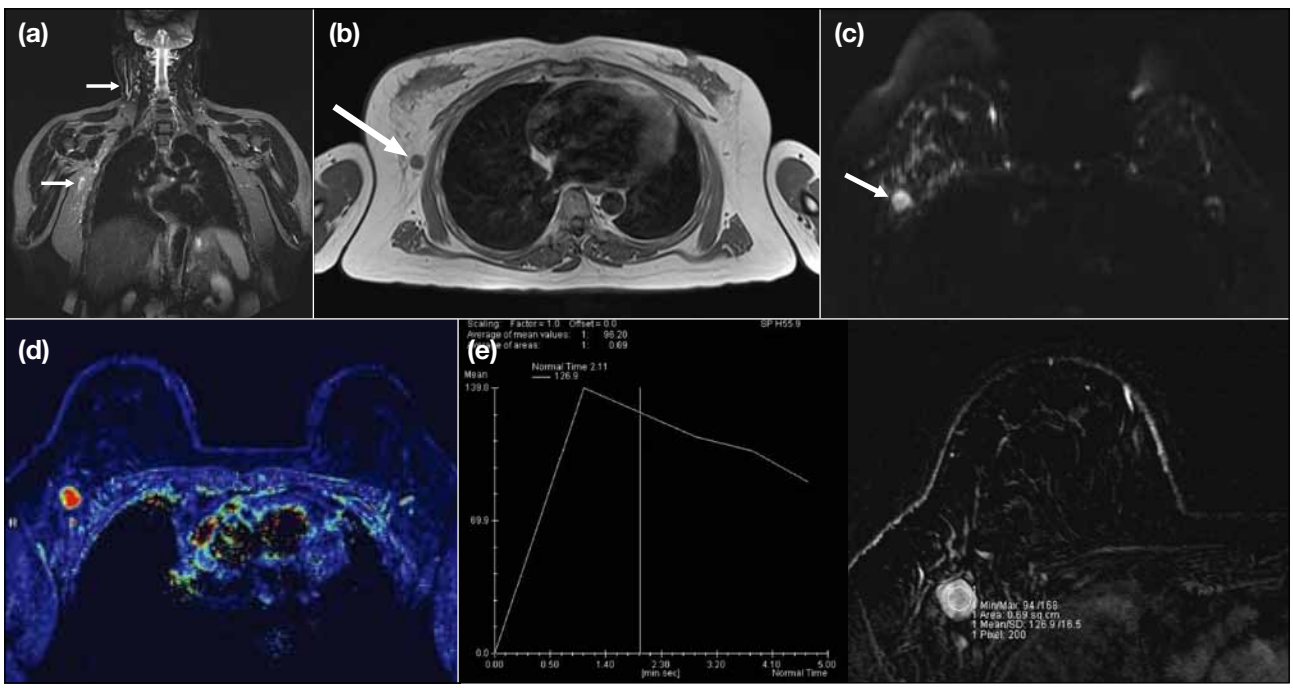

Figure 5. Lymph node staging and characterisation in carcinoma of breast. (a) Coronal T2 turbo inversion recovery magnitude imaging using a body coil demonstrates an enlarged right axillary level I lymph node and prominent right cervical lymph nodes (arrows). (b) An axial T1 turbo spin echo image shows the same enlarged right axillary level I lymph node (arrow). (c) An axial diffusion image detects restricted diffusion (arrow). (d) Colour overlaying image documents the rapid enhancement in red. (e) Enhancement kinetic curve reveals rapid contrast wash-in and wash-out pattern.

Al dedicated breast coil is used to obtain different sequences including diffusion-weighted images with the patient in a prone position. Post-processing with colour overlay perfusion images allows surgeons or oncologists easy appreciation of the overall disease extent and progress after neoadjuvant chemotherapy (Figure 6).

POTENTIAL PITFALLS AND ARTEFACTS

As with other types of MRI, there are a number of technical artefacts and pitfalls that can potentially limit interpretation of the images by masking or simulating disease. Because of the coils and computer-aided

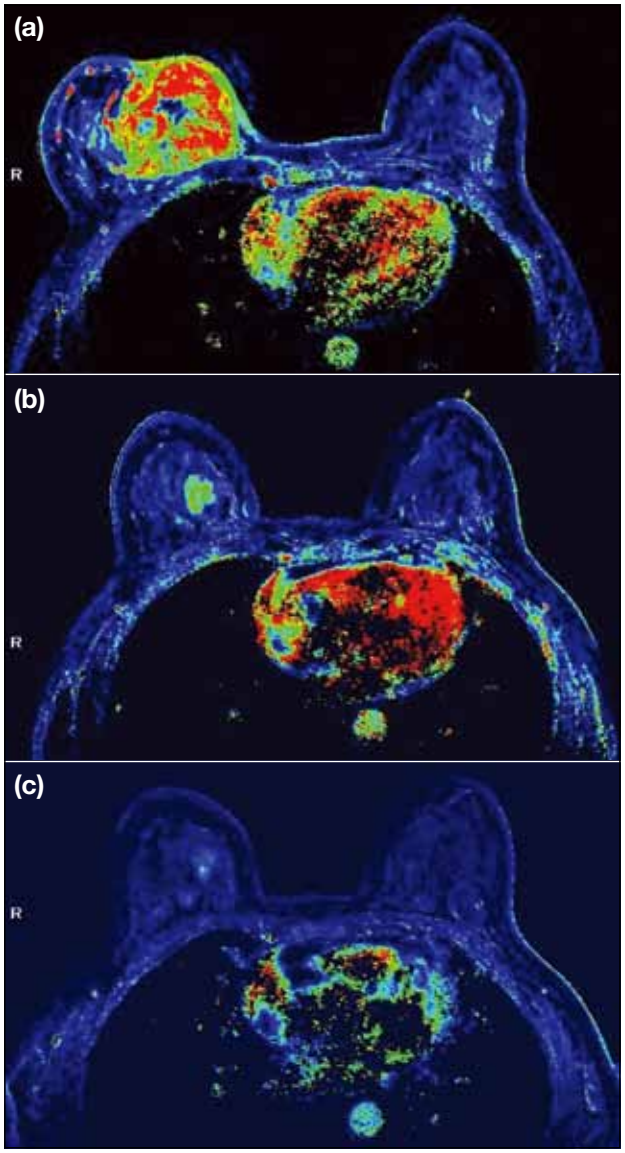

Figure 6. Response to neoadjuvant chemotherapy in advanced stage carcinoma of breast, using colour overlay perfusion images. (a) Disease extent pre-chemotherapy; (b) interval assessment during treatment; and (c) image after whole course of chemotherapy and preoperative assessment. An overall decrease in tumour size and red colour assignment is evident; comparisons use the same window settings.

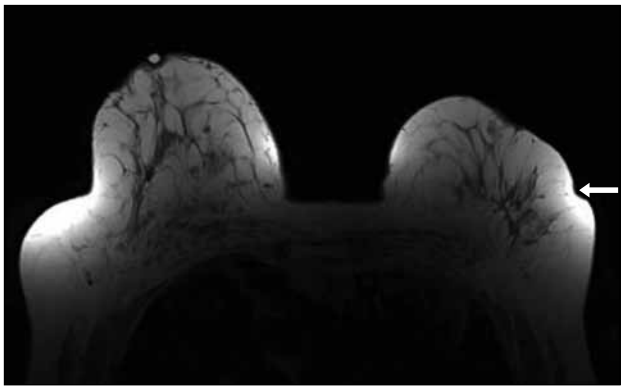

Figure 7. Lack of fat saturation in a patient with breasts having a high percentage of fat. Positioning in the breast coil can also be difficult for women with large breasts, which tend to overfill the coil. Deformities are seen where the coil support touches the left breast (arrow) and signal intensity changes are seen where breast tissue is in proximity to coil elements.

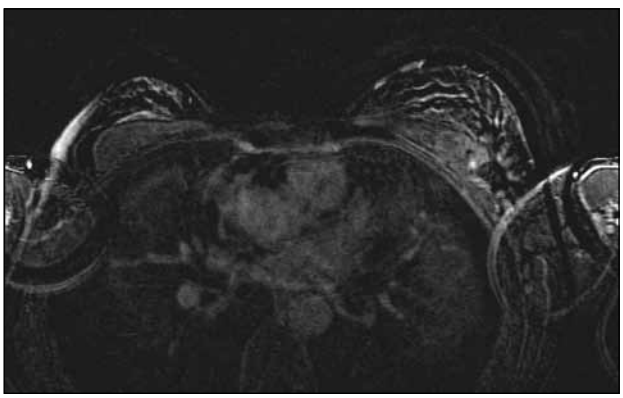

Figure 8. Wraparound artefacts due to parallel-positioned upper limbs in a breast dedicated coil. This is solved by changing the position of the patient's upper limbs to above-head position.

detection software specific to breast MRI, there are additional technical considerations unique to this type of MRI.

Correct positioning is the first essential and important step in breast imaging.[17] The breast should be centred superior to inferior, within the dedicated breast coil. The breasts should then be pulled away from chest wall and dive down into the holes in the bilateral breast coil (Figure 7). Female staff should be present during positioning. Lead glass between the control panel and MRI suite should be blocked with blinds to ensure the patient privacy. Failure of contrast injection may lead to misinterpretation of breast MR images as negative.

The contrast-enhanced appearance of thoracic aorta and heart should be noted.[16] A kinetic curve with the region of interest on the thoracic aorta or cardiac ventricles can help further verification. Fat suppression is essential for detection of breast cancer as the high signal of fat decreases sensitivity in detecting enhancing lesions.[18] Difficulties with lack of fat saturation are more common in breasts with a high percentage of fat (Figure 7). If fat saturation is difficult in such patients, the patient should be instructed to remain extra still during the whole

examination in order to make the subtraction images accurate and interpretable.

Wraparound artefact is also known as aliasing or phrase wrap, as it occurs in a phase-encoding direction (Figure 8), when there are signals from unwanted tissue or structure superimposed onto the field of view. This can be reduced by increasing the number or sampling points in the phase encoding direction or by enlarging the field of view.[19]

CONCLUSION

Contrast-enhanced MRI is a powerful imaging modality in the evaluation of breast diseases. An awareness of proper imaging technique, potential pitfalls, and artefacts is critical to accurate image interpretation. When breast MRI is performed with the required technical finesse and in the appropriate clinical setting, it is highly sensitive (up to 95-100%[3,4]) and reasonably specific method (85-100%, depending on the imaging protocol[4,20-22]) for the detection of breast cancer.

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