Introduction
Dynamic contrast enhanced (DCE)-MRI of the breast is currently the most accurate technique available for diagnosing and delineating the extent of in situ and invasive breast cancer, with studies consistently reporting sensitivities above 95%. It can identify disease which cannot be seen on mammography and ultrasound, is not affected by breast density and gives the best correlation with pathological size. Following publication of prospective randomised trials showing high levels of effectiveness in high risk populations, DCE-MRI of the breast is now the preferred screening method in women at very high risk of developing breast cancer.

Over the last decade, an increasing number of breast MRs have been performed at institutions throughout the UK and improving technologies such as high field scanning, functional sequences and superior contrast agents will mean a further increase in the use of breast MR. This is likely to lead to greater reporting of indeterminate and false-positive findings which can delay the patient pathway and cause unnecessary psychological anxiety. Because of this, caution should remain in case selection for breast MR as, despite the perceived benefit, there is no published evidence to suggest that it can reduce the re-operation rate, tumour recurrence rate or overall mortality and has paradoxically been associated with an increase in the re-excision rate in patients with non-palpable breast cancer.

Clinical indications for breast MRI
DCE-MRI allows a combined assessment of morphological features and functional dynamic enhancement characteristics which give the greatest sensitivity for cancer detection. The main limitation with breast MR is its variable specificity, with pooled estimates from recent meta-analyses reporting specificities of 72-75%, indicating that while DCE-MRI is excellent for detecting abnormalities in the breast it cannot always confidently determine whether the tissue is malignant, sometimes necessitating second-look ultrasound and further tissue sampling. This, coupled with the high cost of performing breast MR, means that cases should be selected carefully and indications are best limited to the following clinical scenarios:

1. Any woman presenting with core-biopsy proven invasive lobular carcinoma (ILC). ILC tends to produce masses that are of relatively low radiographic opacity, similar to normal fibro glandular breast tissue, making mammographic detection challenging. It may also be multifocal (more than one area of disease in one quadrant of the breast) or multicentric (more than one area of disease in more than one quadrant of the breast). The detection of additional sites of disease can change management.

2. As a problem-solving tool and in discordant imaging findings. MRI is particularly useful in women with very dense breast tissue and in detecting occult disease that is not seen on mammography and ultrasound.

3. Assessing response to neoadjuvant chemotherapy. Pre- and post-treatment scans are the most informative with volumetric assessment of large, locally invasive tumours giving the most accurate assessment of tumour response.

4. Screening women at high risk of developing breast cancer. BRCA1/2 mutation carriers and those who have previously received supradiaphragmatic mantle radiotherapy are offered annual breast MR from the age of 30 and annual MR and mammography from the age of 40.

5. To assess the integrity of breast implants. Non-confluent and silicone specific sequences mean that this can be performed quickly to evaluate breast implants.

Performing and reporting breast MRI
High quality examinations are essential for optimal radiological assessment and evaluation. Patient positioning and comfort are vital to limit movement which can lead to misregistration artefact and hamper interpretation of subtracted dynamic images. Breast MRI should ideally be performed between days 6-16 of the menstrual cycle to minimise parenchymal enhancement that is worse in the later phase of the cycle due to elevated levels of progesterone. This is not always practical though and interpretation of scans performed outside of this window should be made with this in mind.

Standard sequences recommended for breast MRI include pre-contrast T1W and T2W for lesion characterisation and a post-contrast high resolution T1W sequence with integral fat suppression. Dynamic sequences should be obtained before and after a rapid bolus of intravenous contrast for up to seven minutes, ideally with a temporal resolution of <60 seconds with integral fat suppression or subtraction to improve lesion conspicuity. Post-processing of dynamic sequences to obtain multiplanar reformats (MPR) and maximum intensity projection (MIP) images provide the multidisciplinary team with a three-dimensional appreciation of abnormalities which aids in planning surgery.

Temporal enhancement characteristics differ between malignant and normal or benign tissues, as malignant lesions exhibit much faster contrast enhancement and stronger signal intensity than benign or normal tissues due to an increase in functional permeability of blood vessels in malignant neoangiogenic vasculature. Enhancement can either show rapid wash-in and wash-out (type III) or a plateau (type II) curve, with these two curves seen in 91% of malignant cases (57% for type III and 34% for type II). A gradually enhancing (type I) curve is seen in benign lesions in 83% of cases (Figure 1). Interpretation of breast MR enhancing lesions should be made using a modified BI-RADS lexicon incorporating lesion morphology, position within the breast and dynamic enhancement kinetics (Figure 2). Reported lesions are either enhancing masses >5mm (enhancing foci <5mm should generally be ignored as they are unlikely to amount to any-
thing) or non mass-like enhancement which does not have a correlating morphological abnormality. An MR score and suggested management plan is advised. Double reporting can increase the cancer detection rate by 6-10\%\cite{10} and screening MR units should perform at least 100 examinations per year.\cite{11}

**Advances in breast MRI**

Advanced MR techniques are available, including functional sequences such as diffusion-weighted imaging (DWI) and spectroscopy as well as high field scanning. These can improve the specificity of breast MRI and there is a lot of interest in developing these techniques further for improved clinical evaluation. Increasing availability of 3.0T scanners which offer better resolution and faster scanning times suggest improved overall image quality and confidence in reporting smaller lesions.\cite{12}

DWI is a functional MRI technique that can improve the specificity of breast MRI up to 85\%.\cite{13} It provides different and complementary information to DCE-MRI, being sensitive to factors that affect the microscopic movement of water molecules over very small distances (<30μm) such as changes in cellularity. Breast cancers demonstrate restricted diffusion because of a high cell density which results in a high signal intensity lesion on DWI and a corresponding low signal focus on the derived apparent diffusion coefficient (ADC) map (figure 3). Differentiation between malignant and benign breast lesions on DWI is well reported, with malignant lesions having low ADC values (0.9-1.61x10^{-3} mm^2/s), benign lesions a slightly higher ADC (1.41-2.01x10^{-3} mm^2/s),\cite{14,15} and normal fibroglandular tissue an even higher ADC (1.51-2.37x10^{-3} mm^2/s).\cite{16} Proton magnetic resonance spectroscopy (H-MRS) provides in vivo information on the molecular composition of tissues. High levels of choline can be found in breast cancers from proliferating cell membranes, detection of which can also further improve the specificity of DCE-MRI.\cite{17}

**Conclusion**

DCE-MRI of the breast provides invaluable information on the extent of disease within the breast and is increasingly being used by the multidisciplinary team in suitable cases to plan the most appropriate therapy. Exciting technical developments will further enhance our diagnostic confidence and reporting of breast MRI.

**References**

Figure 2A, 2B and 2C
Dynamic contrast-enhanced breast MRI. (A) Fat supressed subtraction images taken one minute 50 seconds post intravenous contrast show a large tumour mass in the left breast with colour mapping to demonstrate relative enhancement. (B) The time-signal intensity curve from the tumour shows initial rapid uptake of contrast followed by >10% washout over the next few minutes. This is a type III curve that is typical of primary invasive breast cancer. (C) Maximum intensity projection reconstruction allows 3D appreciation of the extent of disease in the left breast. Two enhancing foci in the medial aspect of the right breast were found to be incidental foci of invasive carcinoma following tissue sampling.

Figure 3A and 3B
Diffusion-weighted imaging of the breast. (A) Diffusion-weighted images at b=0, 350, 700, 1150 and (B) apparent diffusion coefficient (ADC) map from a woman with a large locally invasive breast cancer.