Breast MRI at 3.0 T in a high-risk familial breast cancer screening cohort: comparison with 1.5 T screening studies

M D PICKLES, PhD and L W TURNBULL, MD, FRCR

Centre for Magnetic Resonance Investigations, Division of Cancer, Postgraduate Medical Institute at Hull York Medical School, University of Hull, Hull Royal Infirmary, Hull, UK

Objectives: The sensitivity of X-ray mammography for the detection of breast malignancy in younger females is lower than that of breast MRI; consequently, guidelines recommend annual MRI for patients with a significantly elevated lifetime risk. The improved signal-to-noise ratio obtainable at 3.0 T should result in data superior to those obtainable at 1.5 T. However, breast imaging on higher field strength systems poses specific problems. As a result, caution has been urged in the implementation of breast MRI at 3.0 T. The aim of this study was to determine if it is appropriate to use 3.0 T MRI in the screening of patients by comparing the summary statistics achieved by this 3.0 T MRI programme against the published results of 1.5 T screening studies.

Methods: Over a 20-month period, 291 patients referred with an elevated familial risk of breast cancer were examined at 3.0 T. Resulting images were scored based on the Royal College of Radiologists Breast Group imaging classification. The reference standard was a combination of histology and follow-up imaging.

Results: Follow-up data were available in 267 patients. Analysis revealed positive and negative post-test probabilities of 28% [95% confidence intervals (CI); range, 10–60%] and 1% (95% CI; range, 0–2%), respectively. These results compared favourably against those of a recent meta-analysis [25.3% (95% CI; range, 18.4–33.8%) and 0.4% (95% CI; range, 0.2–0.9%), respectively].

Conclusion: Given the similar summary statistics between this work and the 1.5 T results, it would appear that screening of high-risk patients at 3.0 T has potential. Further studies should be undertaken to verify this result.

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It is believed that between 5% and 15% of all breast cancers can be attributed to hereditary risk due to genetic mutations [1]. A number of mutations have been identified, including BRCA1, BRCA2, TP53, PTEN, STK11 and CDH1 [2]. These mutations can result in a cumulative lifetime risk as high as 80% [1], compared with a risk of only 10% in the general female population [3]. Additionally, evidence suggests that in the breast malignancies that result from these genetic mutations a more aggressive phenotype is prevalent with higher grade, proliferation rates and negative hormone receptors [3].

Management of patients deemed to have an increased hereditary risk of breast cancer usually follows one of two pathways: either a risk-reducing strategy such as prophylactic mastectomy, or active breast cancer surveillance. Regarding the latter, several prospective trials have reported that the sensitivity of X-ray mammography for the detection of breast malignancy in younger females is lower than that of MRI mammography [4–9]. Consequently, recent guidelines from the National Institute for Health and Clinical Excellence in the UK

and the American Cancer Society have recommended annual MRI mammography for patients with a significantly elevated lifetime risk [10, 11].

While breast MRI has been demonstrated to have a higher sensitivity than X-ray mammography for this cohort of females, there is little if any consensus on the acquisition of breast MRI data. This lack of consensus is derived in part from the rapid pace of technical developments in MRI. Typically, technical advances in either software or hardware are rapidly adopted by those practitioners with appropriate access. A classic example has been the move from two-dimensional multislice non-contiguous dynamic acquisitions to three-dimensional (3D) total breast coverage dynamic acquisitions, which are now almost universally adopted. In recent years, 3.0 T scanners capable of breast imaging have become available. Theoretically, the improved signal-to-noise ratio (SNR) obtainable at 3.0 T should result in data superior to those obtainable at 1.5 T. The improved SNR level allows imaging protocols with greater spatial and/or temporal resolution than those achievable with 1.5 T systems. However, breast imaging on higher field strength systems also poses specific problems such as larger chemical shift, greater susceptibility artefacts, B1 inhomogeneities and increased T_1 relaxation times. Consequently, caution has been urged in the implementation of breast MRI at 3.0 T [12, 13].

Address correspondence to: Dr Martin Pickles, Centre for Magnetic Resonance Investigations, Division of Cancer, Postgraduate Medical Institute at Hull York Medical School, University of Hull, Hull Royal Infirmary, Anlaby Road, Hull HU3 2JZ, UK. E-mail: m.pickles@hull.ac.uk

The aim of this study was to determine whether it is appropriate to use 3.0 T breast MRI in the screening of patients at high familial risk of breast cancer by comparing the likelihood ratios and post-test probabilities achieved by this 3.0 T MRI breast screening programme against the published results of screening studies at 1.5 T.

Methods and materials

Between May 2007 and December 2008, all patients referred with an elevated familial risk of breast cancer underwent MRI (3.0 T HDx; GE Healthcare, Milwaukee, WI) in combination with an eight-channel dedicated breast coil. A patient's individual risk was determined in a dedicated high familial risk of breast cancer clinic with support from the regional genetic service. Patients aged between 25 and 52 years (20–52 years including those with TP53 mutations), with a >8% 10-year risk were referred for MRI screening in addition to X-ray mammography where appropriate. Additionally, those patients who had a raised risk (3–8% 10-year risk) and non-diagnostic dense breasts on X-ray mammography were also offered MRI screening. Patients with a history of breast cancer were not followed up in this cohort.

Patients were invited to attend their MRI examination between days 6 and 16 of their menstrual cycle to minimise hormonally mediated breast parenchyma enhancement. Initially (May–December 2007), studies used our standard breast MRI protocol: axial T_1 weighted 3D fast spoiled gradient echo (FSPGR) [30° flip; repetition time (TR), 6.4; echo delay time (TE), 2.1 fractional echo (Fr); 62.5 kHz; 34 × 34-cm field of view (FOV); 512 × 512 matrix; 3.4/–1.7 mm slice/gap], sagittal 3D T_1 weighted fat-suppressed volume imaging for breast assessment (VIBRANT™; GE Healthcare) dynamic [10° flip; TR, 4.1; TE, 1.6 Fr; 41.7 kHz; 22 × 22-cm FOV; 220 × 160 matrix; 4/–2 mm slice/gap; parallel imaging × 2] and delayed high spatial resolution fat-suppressed post-contrast axial 3D FSPGR T_1 weighted imaging [30° flip; TR, 12.1; TE, 2.1 Fr; 62.5 kHz; 34 × 34-cm FOV; 512 × 512 matrix; 3.4/–1.7 mm slice/gap). However, in January 2008, the original imaging technique was superseded by a new protocol with certain spatial resolution advantages. This was achieved by switching from the axial to the sagittal plane. Additionally, a fat-saturated T_2 weighted sequence was added to aid in the identification of benign pathology in this cohort. The current protocol now includes axial 3D T_1 weighted FSPGR (30° flip; TR, 6.4; TE, 2.1 Fr; 62.5 kHz; 34 × 34-cm FOV; 512 × 512 matrix; 3.4/–1.7 mm slice/gap), sagittal 3D T_1 weighted fat-suppressed VIBRANT dynamic [10° flip; TR, 4.1; TE, 1.6 Fr; inversion time (TI), 6.0; 41.7 kHz; 22 × 22-cm FOV; 220 × 160 matrix; 4/–2 mm slice/gap; parallel imaging × 2], delayed high spatial resolution fat-suppressed post-contrast sagittal 3D T_1 weighted VIBRANT (10° flip; TR, 7.5; TE, 2.9 Fr; TI, 5.0; 41.7 kHz; 20 × 20-cm FOV; 512 × 512 matrix; 3.6/–1.8 mm slice/gap) and sagittal T_2 weighted fat-saturated fast spin echo (TR, 2500; TE, 63.3; Ef; 41.7 kHz; 20 × 20-cm FOV; 384 × 288 matrix; 3.6/0 mm slice/gap).

Regardless of imaging protocol, the dynamic sequence included 2 phases of pre-contrast administration and 10

phases of post-contrast administration, which throughout the study were collected with a temporal resolution of approximately 35 s. Minor alterations in temporal resolution due to the number of locations within the 3D sequence required to image both breasts in their entirety were noted. Contrast medium was delivered by power injector (Spectris Solaris; Medrad, Warrendale, PA). At the start of the third phase, a bolus injection of gadolinium contrast agent (0.075 mmol kg⁻¹) was immediately followed by a 20-ml saline flush. The total injection time for all patients was 10 s.

Although the use of the sagittal plane combined with a small FOV was preferred, a pre-contrast axial T_1 weighted sequence was also acquired in the current protocol. The axial plane allowed assessment of the axillary lymph nodes, which was not afforded by the sagittal plane. Additionally, a pre-contrast T_1 weighted sequence allowed the breasts to be assessed for haemorrhagic products and duct ectasia.

Images were reviewed by a radiologist with 16 years' experience of breast MRI reporting. The radiologist was not aware of the results of any other imaging modality at the time of reporting. Patients were divided between benign and malignant groups. The imaging features of those lesions characterised as benign corresponded to the Royal College of Radiologists (RCR) Breast Group imaging classifications MRI 1–3 [14], while the imaging features of those lesions classified as malignant corresponded with the RCR Breast Group imaging classifications MRI 4–5. Those lesions classified as RCR MRI 3 and MRI 4–5 were discussed by the breast multidisciplinary team (MDT) and further investigations (imaging and/or biopsy) were undertaken if necessary. Table 1 presents the RCR Breast Group classification system.

Patients were followed up annually via the high familial risk of breast cancer clinic. In addition to clinical palpation, X-ray mammography and ultrasound (where necessary), patients were offered follow-up MRI surveillance at either 12 or 24 months depending on their relative risk. Consequently, a combination of histology and follow-up imaging validated the results of the MRI examinations. A review of the patient's electronic notes was undertaken for each individual to ensure that all available follow-up information had been assessed. For the purposes of this retrospective analysis, if a malignant lesion, was detected at or before the next MRI examination, the original surveillance scan was treated as a false-negative case. False-positive cases were defined as any lesion identified as malignant by MRI that was subsequently shown by histopathology or serial imaging assessment to be normal/benign.

The following summary statistics were used to describe the diagnostic accuracy of this study: sensitivity, specificity, likelihood ratios and post-test probabilities. Sensitivity was calculated as true positive/(true positive + false negative); specificity as true negative/(true negative + false positive); pre-test odds as prevalence/(1 – prevalence); positive likelihood ratio as sensitivity/(1 – specificity); negative likelihood ratio as (1 – sensitivity)/specificity; positive post-test odds as pre-test odds × positive likelihood ratio; negative post-test odds as pre-test odds × negative likelihood ratio; positive post-test probability as positive post-test odds/(positive post-test

Table 1 Royal College of Radiologists Breast Group scoring system [14]

Score	Level of suspicion
1	Normal; there is no significant imaging abnormality
2	Benign findings; the imaging findings are benign, and further investigation purely on the basis of the imaging findings is not indicated
3	Indeterminate/probably benign findings; there is a small risk of malignancy and further investigation is indicated
4	Findings suspicious of malignancy; there is a moderate risk of malignancy and further investigation is indicated
5	Findings highly suspicious of malignancy; there is a high risk of malignancy and further investigation is indicated

odds+1) and negative post-test probability as negative post-test odds/(negative post-test odds+1).

Because sensitivity, specificity and positive and negative predictive results are all dependent on the prevalence of disease within the study population, these results cannot be generalised beyond that study from which they originate [15]. Consequently, to allow a meaningful comparison with previous results, likelihood ratios and post-test probabilities were used. Likelihood ratios contain information regarding both the sensitivity and the specificity of the test. Likelihood ratios compare the probability of a positive test result in those patients with the condition against the probability of having that result if the patient was healthy. In this study, the positive likelihood ratio is the ratio of the probability of a positive result (MRI score 4–5) in patients who did have breast cancer to the probability for individuals with a positive test result (MRI score 4–5) but who did not have breast cancer. Positive likelihood ratios >1 indicate that the test result is associated with the disease; similarly, negative likelihood ratios <1 indicate that a negative test result is unlikely in a disease-positive individual [14]. Before a patient undergoes a test, the chance of them having the disease is known as the “pre-test odds” (~prevalence). The chance of them having the disease after the test result is known is termed the “post-test odds.” This is either increased or decreased based on the result of the test and the likelihood ratio of that test. Once the post-test odds are known, the probability of the patient having the disease in question can be expressed as a percentage via the post-test probability. The positive post-test probability represents the chance of a patient with a positive result (MRI score 4–5) having breast cancer, while the negative post-test probability is the chance of a patient with a negative result (MRI score 1–3) having breast cancer. A Fagan’s nomogram is a tool that can be used to demonstrate the interplay between pre- and post-test probabilities with likelihood ratios.

Results

Between May 2007 and December 2008, 291 patients were referred for breast MR surveillance. Of the original 291 patients, follow-up data were unavailable in 24 cases; consequently, 267 patients were entered into this retrospective analysis. The median age of the patients studied was 41 years (range, 22–56 years); 2 patients were older than the age criterion (52 years). One patient was only 1 year over the limit; she turned 53 years old in the interval between request of scan and acquisition of data. The other patient was scanned at the age of 56 years. Owing to this

patient’s particular family history, it was felt necessary to extend her MR surveillance beyond the age of 52 years.

The results from the first MR screening round and follow-up results are presented in Table 2. In the initial MR screening round, 8 lesions were identified as having malignant RCR MRI scores (4–5), while 259 were scored as benign. Further investigations (X-ray mammography, ultrasound, histology and imaging follow-up) revealed two out of eight lesions with RCR MRI scores 4–5 to be malignant. One was a node-negative small (3-mm) focus of high-grade ductal carcinoma *in situ* (DCIS) at the margin of a 14-mm radial scar/complex sclerosing lesion, while the other was a node-positive 17-mm grade III invasive ductal carcinoma bordered by a 6-mm field of high-grade DCIS. Five of the eight RCR MRI score 4–5 lesions were determined to be benign and represented false-positive findings. In the remaining patient with an RCR MRI score 4–5 lesion, a routine surveillance X-ray mammography performed in August 2007 revealed a new density in the right breast. Subsequent ultrasound revealed only simple cysts. The screening MR scan performed in September 2007 reported moderately dense breasts and fibrocystic disease bilaterally in addition to a lesion with spiculated margins and a reduction in signal intensity centrally (rim enhancement) in the right breast. Given the results of the breast MRI, a biopsy was undertaken, the results of which were normal. When the patient was recalled to clinic for further follow-up in February 2008, she mentioned a new palpable mass in her left breast. Further investigation revealed a node-negative grade III invasive carcinoma of no specific type. Consequently, this patient simultaneously represents a false-positive and a false-negative finding. For the purposes of this analysis, this result will be treated as a false negative; this is reflected in Table 2.

An additional false-negative case was revealed when a malignant lesion was discovered during a patient’s annual screening clinic appointment. The patient was initially scored as benign in her first surveillance round. She originally underwent X-ray mammography in March 2008, which revealed a new density. A subsequent ultrasound scan revealed only simple cysts. The patient’s

Table 2 MRI surveillance results and validated follow-up results

MRI surveillance	Follow-up		
	Benign	Malignant	Total
Benign	258	2	260
Malignant	5	2	7
Total	263	4	267

screening breast MRI in May 2008 reported fibroadenomas and simple cysts; therefore, she was given an RCR MRI score of 2. However, when the patient was next in the high-risk familial clinic in March 2009, she complained of skin tethering over the lower outer quadrant of her left breast. Further ultrasound and MR examinations revealed a suspicious lesion measuring 5 and 6 mm, respectively. Following surgery, the lesion was confirmed as a node-negative 9-mm grade II invasive ductal carcinoma with a small field of intermediate DCIS. Consequently, the initially MRI result from 2008 was treated as a false-negative finding.

Breast MR surveillance in this cohort resulted in the following summary statistics: sensitivity, 50.0% [95% confidence intervals (CI); range, 9.2–90.8%]; specificity, 98.1% (95% CI; range, 95.4–99.3%); positive likelihood ratio, 26.3 (95% CI; range, 7.1–97.4); negative likelihood ratio, 0.51 (95% CI; range, 0.19–1.36); positive post-test probability, 28% (95% CI; range, 10–60%) and negative post-test probability, 1% (95% CI; range, 0–2%). To facilitate a comparison between studies, Table 3 presents the results of this work and those of previous 1.5 T studies, while Figure 1 presents a Fagan's nomogram illustrating the interplay between pre-test probability, likelihood ratios and post-test probability for this study.

In the five false-positive results, the initial MRI characteristics of the lesions appeared to justify the malignant diagnoses. Patient 123 demonstrated three small areas of abnormality in close proximity extending over 20 mm, with the largest focus measuring 6 mm in diameter. These lesions demonstrated mixed Type II/III kinetic curves, heterogeneous enhancement and irregular margins. To aid further characterisation, X-ray mammography and ultrasound were undertaken, both of which identified only benign lesions. Nevertheless, in

light of the MRI result, a biopsy was taken, which failed to reveal any malignant tissue. In patient 131, prominent ductal enhancement in a branching pattern was noted. This enhancement had a mixed Type I/II kinetic curve. Several small areas (<1 mm) of low signal intensity suspicious of calcification were also noted. Given the distribution of the enhancement, this lesion was believed to represent an area of DCIS. Calcification was also noted in a follow-up ultrasound examination, prompting an ultrasound-guided biopsy. Analysis of the biopsy revealed mild fibrosis. Patient 168 demonstrated a 24-mm diameter area of increased contrast uptake with a Type II kinetic curve. Morphologically, the mass demonstrated a fine honeycomb appearance that was quite distinct from the surrounding breast parenchyma. An ultrasound-guided biopsy failed to reveal any malignant tissue. Images from patient 209 revealed a 25-mm area of architectural distortion with a morphologically coarse honeycomb appearance. A mixed Type II/III kinetic curve was noted for the inferior component of the lesion. A follow-up ultrasound demonstrated a vague architectural distortion with posterior shadowing over a 20-mm length in the same area noted by MRI, which necessitated ultrasound-guided biopsy of the lesion. Histological analysis of these biopsy samples revealed only fibrocystic disease and epithelial hyperplasia of the usual type in addition to normal breast tissue. Finally, in patient 247, an ill-defined area of contrast uptake was noted, which was believed to represent hormonally mediated enhancement and the patient was recalled for an additional study. The ill-defined area of contrast uptake was unchanged in the recall study and therefore treated as malignant. The patient elected to undergo MRI-guided biopsy, which failed to reveal any malignant tissue.

Table 3 Summary statistics of diagnostic accuracy for this study with representative literature results and a meta-analysis of 1.5 T studies^a

Report	Patients (n)	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV (95% CI)	PLR (95% CI)	Positive test post-test probability % (95% CI)	NLR (95% CI)	Negative test post-test probability % (95% CI)
Current study	267	50.0 (9.2–90.8)	98.1 (95.4–99.3)	28.6 (5.1–69.7)	26.3 (7.1–97.4)	28 (10–60)	0.51 (0.19–1.36)	1 (0–2)
MARIBS [4]	649	51 ^b	96 ^b	21 ^b				
Kriege et al [5]	1909	64 ^b	96 ^b	16 ^b				
Warner et al [6]	236	77	95	46				
Kuhl et al [7]	529	91	97	50				
Lehman et al [8]	367	100	93 ^b	13 ^b				
Sardanelli et al [9]	278	94 (82–99)	98 ^b	63				
Warner et al meta-analysis [16]	4125	75 (62–88) ^b	96.1 (94.8–97.4) ^b		16.6 (11.1–25.0) ^b	25.3 (18.4–33.8) ^b	0.22 (0.12–0.43) ^b	0.4 (0.2–0.9) ^b

CI, confidence intervals; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value.

Data are given as percentage or percentage (range) unless otherwise indicated.

^aRepresentative 1.5 T literature results are those studies utilised by the National Institute for Health and Clinical Excellence [10] and the American Cancer Society [11] high familial risk of breast cancer guidelines.

^bFrom reference [16].

Figure 1 Fagan's nomogram illustrating the pre-test probabilities, negative likelihood ratio and post-test probabilities in red (with 95% CI), and positive likelihood ratio and post-test probabilities in blue (with 95% CI). CI, confidence interval.

During the initial MRI screening round, 10 patients were recalled owing to suspected hormonally mediated enhancement. Additionally, seven patients were scored as RCR MRI 3: "indeterminate/probably benign findings; there is a small risk of malignancy, and further investigations are indicated" [14]. In four of these seven patients, a combination of X-ray mammography and/or ultrasound failed to reveal any malignant imaging features. The MDT did not request any further investigation in one case. Additional imaging demonstrated lesions with imaging features that warranted biopsy in the remaining two patients. In one case, fibrocystic disease and columnar cell change with mild atypia was noted, while in the other patient only mild duct ectasia was reported.

In total, further imaging and/or biopsy was undertaken in 24 patients (10 recalled for hormonally mediated parenchyma enhancement, 8 who had an RCR MRI score of 4–5 and 6 who had an RCR MRI score of 3), resulting in a recall rate for further assessment (imaging and/or biopsy) of 9.0% (24/267), which is below the RCR minimum standard of <10% [14].

Discussion

We believe that this is the first study to present summary statistics for breast MRI screening of females at high familial risk of breast cancer using a 3.0 T scanner. In a cohort of 267 patients, 2 cancers were correctly identified; additionally, 2 false-negative and 5 false-positive cases were noted. 10 patients were recalled owing to hormonally mediated enhancement and 7 cases were classified as RCR MRI score 3, necessitating further investigation in 6 of these patients.

While the sensitivity and specificity results fell within the ranges noted in other studies undertaken at 1.5 T (Table 3), as discussed earlier, it is perhaps more informative to compare likelihood ratios and post-test probabilities. For this study, the summary positive likelihood ratio of an RCR MRI score 4–5 lesion was 26.3 (95% CI; range, 7.1–97.4) while the negative likelihood ratio for an RCR MRI score 1–3 lesion was 0.51 (95% CI; range, 0.19–1.36). While the negative likelihood ratios from this study compare well with the negative likelihood ratios quoted in a meta-analysis undertaken by Warner et al [16], the positive likelihood ratios were somewhat elevated in comparison. In the meta-analysis, the results of 4125 patients from 8 studies were combined to provide, amongst other summary statistics, the positive and negative likelihood ratios of 16.6 (95% CI; range, 11.1–25.0) and 0.22 (95% CI; range, 0.12–0.43), respectively. In this study, breast imaging reporting and data system (BI-RADS) 4–5 lesions were classified as malignant. Since BI-RADS 4–5 classifications are commensurate with RCR MRI scores 4–5 [14], a comparison between the likelihood ratios was valid. Perhaps the more clinically relevant summary statistic is the post-test probability. When undertaking any diagnostic test, it is important to understand how the test result predicts the probability of the abnormality in question being present [15]. In this study, the pre-test probability of a malignant breast lesion was 1.5%; however, the post-test probability was 28% (95% CI; range, 10–60%) in those patients with an RCR MRI score 4–5 lesion, while the post-test probability was only 1% (95% CI; range, 0–2%) for those lesions that scored RCR MRI 1–3. Again, these post-test probability results are in line with the meta-analysis of Warner et al [16] (Table 3). This result demonstrates that a benign RCR MRI score is associated with a very low probability of malignancy. However, even though the probability of malignancy is much higher for an RCR MRI score of 4–5 (at 28%), it cannot be viewed as conclusive and can in part be attributed to the number of false-positive and -negative results noted in this and other studies.

Obviously, when comparing the results of this report with other studies undertaken at 1.5 T, it is important to realise that field strength was not the only difference. Many differences exist not only between this 3.0 T study and the previously mentioned 1.5 T studies but also within the 1.5 T cohort. These differences include the risk status of patients, with some studies only accepting known BRCA mutation carriers, while others had a broader risk assessment based on family history gleaned from questionnaires. The subject's age also added to interstudy heterogeneity, with some studies skewed towards a younger or older population. Both age and

risk status can have an effect on incidence rates. The MRI techniques used and the experience of physicians are other obvious areas where wide differences are noted in the literature and which could account for differences in diagnostic accuracy. However, on the whole, as Warner et al [16] highlighted, the level of agreement between the studies is encouraging.

In relation to this work, a number of limitations should be outlined. First, given the number of patients involved and the single-site nature of this study, the results may not be applicable to all other 3.0T scanners. Although 267 patients were included in this report—more than in 5 of the 11 reports examined by Warner et al [16]—the numbers are still relatively small for a report on screening accuracy. This small sample size did impact negatively on the precision of the reported summary statistics, as evidenced by the large CIs; consequently, caution is urged in the interpretation of these results. While a single-site study has some advantages (chiefly, the adherence to protocol), its main disadvantage is the applicability of results. Several manufacturers offer 3.0T scanners capable of breast imaging; however, only one manufacturer was involved in this study. Consequently, translation of these results to other scanners may be flawed. Second, the number of malignant cases was relatively small at 1.5% (4/267). This, in part, reflects the population under investigation, in which rather wide risk criteria were employed. Additionally, prior to the initiation of an MRI screening programme, some members of the study population had been screened via X-ray mammography. While the causes of the low incidence rate are understood, the consequences should be underscored. Low incidence rates result in imprecise estimates of sensitivity and positive predictive values, as observed in the relative 95% CIs (Table 3), emphasising the need to use likelihood ratios and post-test probabilities. Third, the retrospective nature of the study may have introduced bias into the work; for example, 8% (24/291) of the total cohort was lost to follow-up—a figure that may have been smaller in a controlled prospective study.

In conclusion, this study has demonstrated that the likelihood ratios and post-test probabilities noted for a 3.0T screening programme of females with an elevated familial risk of breast cancer are comparable to similar studies undertaken at 1.5T, as is evident from the meta-analysis of Warner et al [16]. Additionally, given the similar summary statistics between this work and the 1.5T results, it would appear that screening high-risk patients at 3.0T is not adversely affected by high-field-strength artefacts and has potential. Further studies should be undertaken to verify this result.

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