Comparison of supplemental breast cancer imaging techniques—interim results from the BRAID randomised controlled trial

Fiona J Gilbert, Nicholas R Payne, Iris Allajbeu, Lim Yit, Sarah Vinnicombe, Iain Lyburn, Nisha Sharma, Will Teh, Jonathan James, Archana Seth, Tamara Suaris, Reena Aggarwal, Miaad Al-Attar, Sarah Savaridas, Antonis Antoniou, Paul Pharoah, Stephen Duffy

Summary

Background It is not known which supplemental imaging technique is most beneficial for women with dense breasts attending breast screening. This study compares abbreviated MRI, automated whole breast ultrasound (ABUS), and contrast-enhanced mammography versus standard of care in women with dense breasts and a negative mammogram. We report on interim results from the first round of supplemental imaging.

Methods In this UK randomised controlled trial, at ten breast screening sites, women (aged 50–70 years) were independently allocated by batches (day/mobile screening van) to either abbreviated MRI, ABUS, or contrast-enhanced mammography or standard of care (full-field digital mammography) varied by modality availability at each centre. Women were invited if their mammogram was negative and they had dense breasts. Primary outcome was detection rate, defined as the percentage of women with a positive result on supplemental imaging that resulted in histologically confirmed breast cancer. Analysis was by imaging received (intention to treat) using network meta-analysis, treating each site as a study in the meta-analysis, with two analyses carried out: one using only the three active intervention arms (primary analysis) that compared the three supplemental imaging techniques with respect to cancer detection, recall, and biopsy rates in addition to those resulting from full-field digital mammography alone; and one with the addition of the observational data from Cambridge on full-field digital mammography alone. This trial is closed for recruitment and is registered with ClinicalTrials.gov, NCT04097366.

Findings From October 18, 2019, to March 30, 2024, 9361 eligible women were recruited and randomly assigned (2318 to abbreviated MRI, 2240 to ABUS, 2235 to contrast-enhanced mammography, and 2568 to standard of care). Of those, 6305 completed supplementary imaging (2130 in the abbreviated MRI, 2141 in the ABUS, and 2035 in the contrast-enhanced mammography) and were included in the outcome analysis. The cancer detection rate was 17·4 (95% CI 12·2–23·9, n=37) per 1000 examinations for abbreviated MRI, 4·2 (1·9–8·0, n=9) per 1000 examinations for ABUS, and 19·2 (13·7–26·1, n=39) per 1000 examinations for contrast-enhanced mammography, of which 15·0 (10·3–21·1, n=32) per 1000 women for abbreviated MRI, 4·2 (1·9–8·0, n=9) per 1000 examinations for ABUS, and 15·7 (10·8–22·1, n=32) per 1000 examinations for contrast-enhanced mammography were invasive cancers. The detection rates for abbreviated MRI were significantly higher than for ABUS (p=0·047) and non-significantly higher than for contrast-enhanced mammography (p=0·62). There was one case of extravasation in the abbreviated MRI arm (0·5 events per 1000 examinations), no adverse events in the ABUS arm, and 24 iodinated contrast reactions (17 minor [8·4 events per 1000 examinations], six moderate [2·9 events per 1000 examinations], and one severe [0·5 events per 1000 examinations]) and three extravasations (1·5 extravasations per 1000 examinations) in the contrast-enhanced mammography arm.

Interpretation Abbreviated MRI and contrast-enhanced mammography detected three times as many invasive cancers compared with ABUS, with cancers being half the size. This study shows that supplemental imaging could lead to earlier detection of cancer in women with dense breasts but does not estimate the level of overdiagnosis.

Funding Cancer Research UK, GE Healthcare, and Bayer Healthcare.

Introduction

Underdiagnosis of breast cancer with screening mammography is a problem in women with dense breast tissue.[1] Breast density, a measure of the amount of fibroglandular tissue, is a known risk factor for breast cancer—in women with the densest breasts there is a 4-fold increased risk compared with women with fatty breasts.[2,3] In the UK, almost 10% of women in the 50–70-year age group have extremely dense breasts with sensitivity of mammography just over 50% in the 3-yearly screening programme.[4] Women with dense breasts have an increased probability of their cancer being detected at a later stage at screening,[5] or as an interval cancer (cancer detected between screening rounds),[4] with resulting worse

Published Online May 21, 2025 https://doi.org/10.1016/S0140-6736(25)00582-3

See Online/Comment https://doi.org/10.1016/S0140-6736(25)00803-7

Department of Radiology, School of Clinical Medicine (Prof F J Gilbert MBChB FRCR, N R Payne PhD, I Allajbeu MD) **and Department of Public Health** (Prof A Antoniou MBChB PhD), **University of Cambridge, Cambridge, UK; Nightingale Centre, Manchester University NHS Foundation Trust, Manchester, UK** (L Yit MBChB); **Department of Radiology, Cheltenham and Gloucestershire Hospital NHS Foundation Trust, Cheltenham, UK** (S Vinnicombe MBChB FRCR, I Lyburn MBChB); **Department of Radiology, Leeds Teaching Hospitals NHS Trust, Leeds, UK** (N Sharma MBChB); **Department of Radiology, Royal Free London NHS Foundation Trust, London, UK** (W Teh MBChB); **Nottingham Breast Institute, Nottingham University Hospitals NHS Trust, Nottingham, UK** (J James MBChB); **Department of Radiology, West of Scotland Breast Screening Services and Gartnavel General Hospital, Glasgow, UK** (A Seth MBChB); **Department of Radiology, St Bartholomew's NHS Hospital Trust, Lonodn, UK** (T Suaris MBChB); **Department of Radiology, University Hospitals of Leicester NHS Trust, Leicester, UK** (R Aggarwal MBChB, M Al-Attar MBChB); **Department of Radiology, University of Dundee, Ninewells Hospital NHS Tayside, Dundee, UK** (S Savaridas MBChB); **Cedars-Sinai Hospital, Los Angeles, CA, USA** (Prof P Pharoah MBChB PhD); **Department of Epidemiology,**

Queen Mary University of London, London, UK
(Prof S Duffy MSc)
Correspondence to:
Prof Fiona J Gilbert, Department of Radiology, School of Clinical Medicine, University of Cambridge, Cambridge CB2 0QQ, UK
fjg28@cam.ac.uk

prognosis. In the USA, reporting of breast density for women is mandated by the Food and Drug Administration since September 2024.[6] However, there is no consensus on the management of women with dense breasts with the benefits of supplemental imaging unclear.[7]

In a systematic review and meta-analysis of 22 trials in women with dense breasts at average or intermediate risk for breast cancer, MRI was shown to be superior to ultrasound and digital breast tomosynthesis for the detection of additional cancers.[8] Abbreviated MRI has been shown to have almost equal performance to full-protocol MRI with reduced cost of the examination.[9,10] However, contrast techniques such as contrast-enhanced mammography offer alternative viable strategies with several studies suggesting that higher cancer detection rates compared with mammography or digital breast tomosynthesis can be achieved in women with dense breasts.[11] A systematic review challenged the belief that contrast-enhanced mammography was inferior to MRI for detecting cancer,[12] and the authors questioned the interpretation of some of the papers concluding that the question of which of the contrast techniques is better is still open to debate.[13] Automated whole breast ultrasound (ABUS) has proven to be a viable supplemental screening tool for dense breasts, offering wide accessibility, no contrast or radiation, and better tolerability for women.[14] Previous studies have shown the ability of ABUS to increase cancer detection rates (two to four per 1000 women),[15–18] with most detected cancers being small, invasive, and node-negative. Research[19] highlights comparable performance of ABUS with handheld ultrasound, along with lower recall rates and improved efficiency. As a three-dimensional imaging technique performed by trained radiographers, ABUS provides improved reproducibility and is therefore more suitable for screening purposes.[14]

The Breast screening—Risk Adapted Imaging for Density (BRAID) study is a randomised controlled trial which aims to compare supplemental imaging of abbreviated MRI, ABUS, and contrast-enhanced mammography with standard mammography (standard of care) in women with dense breasts and a negative screening mammogram.

Research in context

Evidence before this study

Mammography screening in women with dense breast tissue has low sensitivity and detected cancers can be large. Supplemental imaging with MRI or ultrasound have both been shown to be effective in early cancer detection. A detailed search of the literature and clinical trials website was conducted to determine whether or not a direct comparison had been made between abbreviated MRI, contrast-enhanced mammography, and whole breast ultrasound as supplemental imaging tools in women with dense breasts. No prospective trials were found.

Added value of this study

This study is the first large scale randomised trial comparing these supplemental imaging techniques in women with normal mammograms and dense breast tissue. In this protocol-defined analysis the objective was to determine which modality detected more early breast cancers and the recall rate of each technique. This study shows that contrast techniques detect an additional 17 cancers per 1000 examinations compared with four cancers per 1000 examinations with ultrasound. The majority of the cancers were less than 2 cm in size and lymph-node-negative.

Implications of all the available evidence

These results demonstrate that supplemental imaging can be delivered in a screening programme to women with dense breast tissue. The small size of the additional cancers found shows that the tools are effective in early detection. Contrast techniques find almost three times as many cancers with twice the recall rate compared to ultrasound. However, the health benefit of the additional cancer detection is not established.

Methods

Study design and participants

From Oct 18, 2019, to March 30, 2024, women aged 50–70 years who attended the 3-yearly UK National Health Service (NHS) Breast Screening Programme and had a normal mammogram with a Breast Imaging Reporting and Data System (BI-RADS)-graded breast density C (the breasts are heterogeneously dense, which can obscure small masses) or D (the breasts are extremely dense, which lowers the sensitivity of mammography) were invited to participate.[20] Readers were encouraged to include women with C density where they felt a cancer could be masked. Following informed consent an appointment was made for supplemental imaging with the arm pre-allocated from the screening mammogram clinic batches. There were three supplemental imaging arms: abbreviated MRI, ABUS, and contrast-enhanced mammography. A fourth arm was offered standard of care, full-field digital mammography only. Different supplemental imaging techniques were offered by different centres due to availability and capacity of equipment. Randomisation was carried out with varying ratios at the different centres in order that overall, there would be an approximate 1:1:1:1 ratio in the four arms.

Ethical approval was given by the London–Surrey Research Ethics Committee (19/LO/0350; IRAS ID 251317) and the study is registered with ClinicalTrials.gov, NCT04097366.

Procedures

Supplementary imaging offered varied by site and was performed within 6 months of the screening

mammogram. Sites could choose which of the imaging modalities were being offered. Screen readers assessed the mammograms as either C or D density and a visual assessment score was given.

Abbreviated breast MRI protocol, which has been published,[21] was carried at nine sites (majority 1·5 T scanners with one 3 T scanner) with a 10 min imaging protocol comprising of a pre-contrast and two post-contrast dynamic contrast-enhanced T1W sequences with a T2W examination. Single dose contrast was given at 0·2 mL/kg by pump injector (Bayer, Leverkusen, Germany). Maximum intensity projection and image subtraction were used in analysis. Images were double read by experienced breast radiologists.

Contrast-enhanced mammography was offered at nine sites on both GE Healthcare (Chicago, IL, USA) and Hologic machines. Following eligibility checks 100 mL (or dose by bodyweight) of iodinated contrast was given by pump injector and images were taken (left mediolateral oblique view, right mediolateral oblique view, left craniocaudal view, and right craniocaudal view) starting 2–3 min after the injection. Recombined images together with low-energy images were double read by breast radiologists.

ABUS (GE Healthcare) was offered at three sites. Two or three views of each breast were taken depending on breast coverage. Standard protocol consisted of three views per breast; additional views were performed for larger breasts, for optimum breast coverage, whilst two views were usually sufficient in small breasts. Images were double read on a dedicated viewer by breast radiologists following modality-specific training.

For all modalities consensus reading or arbitration was undertaken if the readers disagreed on whether or not to recall the case for further investigation. Normal cases were offered a second round of imaging at 18 months, if consented to before March 31, 2023. Second round results are not reported in this manuscript. All recalled cases were further assessed with additional imaging, including further mammographic views, targeted ultrasound, and stereotactic or ultrasound-guided biopsy if a lesion was confirmed. For the abbreviated MRI arm, a full protocol MRI was conducted when no lesion could be found on assessment. For all cases, if there was doubt about whether or not a lesion was present then a repeat contrast-enhanced mammography or MRI were conducted or short-term follow-up was offered.

Evaluation of the technical challenges associated with introducing these new imaging techniques in the UK NHS setting was conducted at the Cambridge site for both the abbreviated MRI and ABUS imaging arms.[21,22]

The validated BOADICEA model-based CanRisk tool was used to estimate a woman's risk of developing breast cancer.[23–26] An online questionnaire was created to collect all risk factor information directly from participants. The breast density, using BI-RADS, was added centrally when calculating the likelihood of developing cancer, using the CanRisk Web-service.[23] Participants were classified into four categories based on their lifetime risk at baseline: general population at 17% or less, moderate risk at 18–29%, high risk at 30–40%, and very high risk at more than 40%.[27] This result was not given to women or readers and did not influence the type of imaging offered or subsequent management.

Outcomes

The primary outcome was the difference in the cancer detection rate between arms. The cancer detection rate was defined as the percentage of women with a positive result on supplemental imaging that resulted in histologically confirmed breast cancer among all the women who had undergone supplemental imaging. Data were collected on the size and type and grade of cancer from histopathology records.

Secondary outcomes were the difference in the recall rates and tumour characteristics between arms. The recall rate was defined as the percentage of women who had a positive result on any modality (BI-RADS 3, 4, or 5) who went to assessment or who had a repeat examination.

Although rates are reported explicitly for those imaged, formal inference used intention to treat—that is, the comparisons were made among the total participants randomly assigned rather than the total participants imaged. The 95% CIs on the rates were calculated in logarithmic scale, based on the appropriate transformed binomial variance, then retransformed to linear scale. Hence they are not symmetric around the point estimates.

Serious adverse events related to the trial were recorded centrally using the online trial data collection database. Minor adverse events were reported by each site.

Statistical analysis

The study was powered for the comparison of screening sensitivity. The sampling strategy is based on the expectation of cancer risk exceeding 2·5% over 5 years, although this is likely to be higher than this boundary value. In terms of statistical power, we expect in this mammographically dense arm a difference of 2% versus 1% detection rates for any intervention imaging compared with standard of care; 2276 screening episodes in each arm would confer 80% power to detect a significant difference. The trial was originally designed with 3000 participants per arm to give more than 90% power, but due to the necessary hiatus during the COVID-19 pandemic, we were forced to revise the study size, but have ensured that there is still 80% power. Screening sensitivities were compared among arms using logistic regression, as were recall rates and incidence rates of cancer by stage and biological type. We used network meta-analysis methods to take account of the multiple treatments, and different treatment allocations by centre.[28]

Randomisation was site specific, since the supplemental imaging offered varied from site to site, and was carried out using the computer random number generator

For the **CanRisk tool** see www.canrisk.org

provided by the statistical package STATA. The trial has four arms, including a control arm, full-field digital mammography only, and our original intention had been to record total cancer detection rate and recall rates within all four arms (ie, including cancers detected only by full-field digital mammography). Unfortunately, this proved logistically impossible for the participating centres, so our outcomes had to be recalls and cancers in those with no cancers detected by full-field digital mammography. Subsequent analysis of interval cancer rates will be possible, so there will be some outcomes from all four randomised arms in the future. Thus, we randomly assigned women in the eligible breast density category who had not had cancer diagnosed with mammography alone. As a consequence, we had data on additional cancers detected as a result of the augmented imaging in each of the three intervention arms, but not on the cancers detected by mammography alone in these or in the control arm. Therefore, our primary analysis compared the three supplemental imaging techniques with respect to cancer detection, recall, and biopsy rates in addition to those resulting from full-field digital mammography alone. However, we were aware that there would be considerable interest in comparison of the supplementary regimens with usual care with respect to cancer detection rate and recall rates. In order to make these comparisons with usual care, we used contemporaneous data on detection of cancers by mammography alone in this dense

For **MyPeBS** see https://www.mypebs.eu/

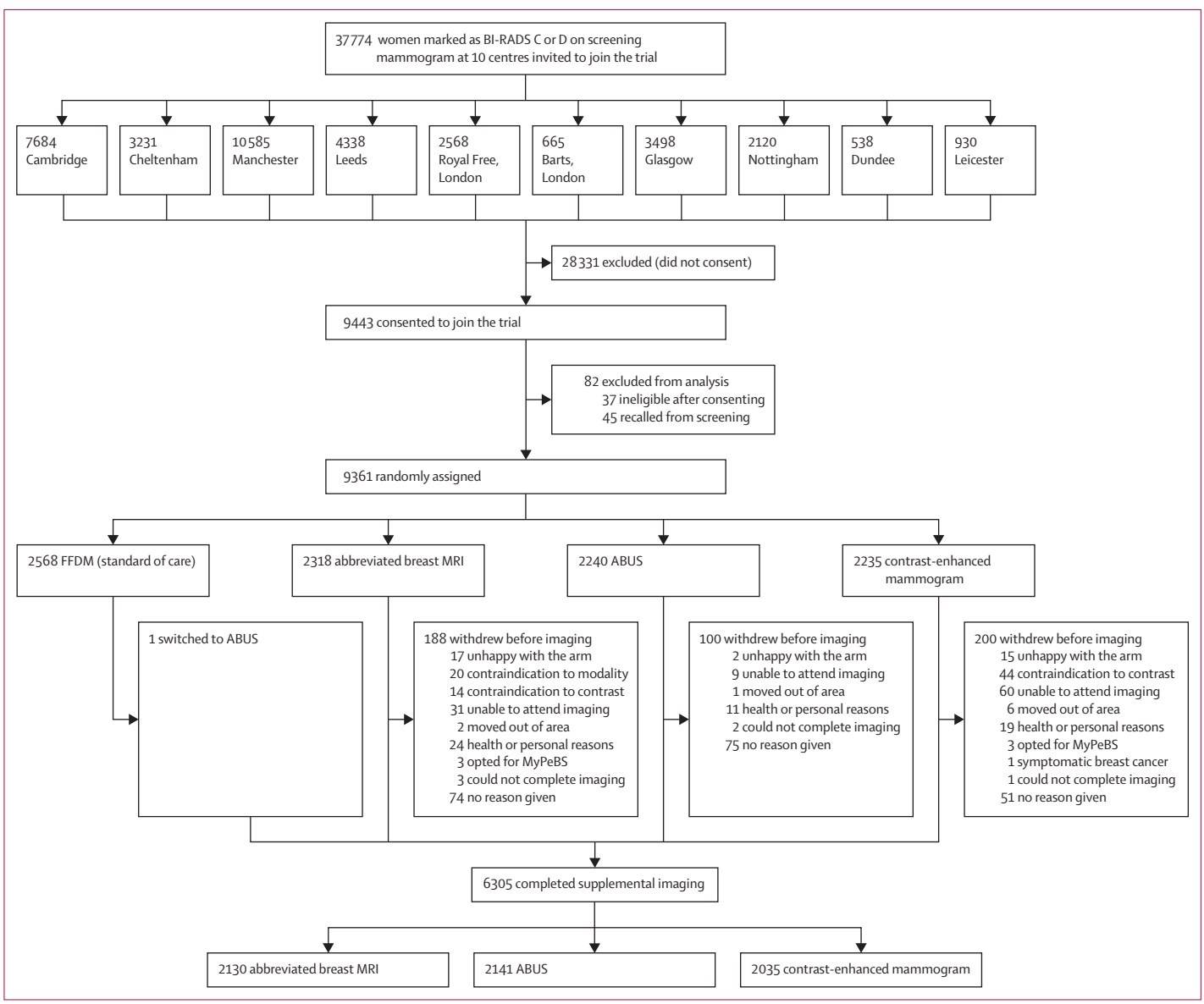

Figure: **Trial profile**
ABUS=automated whole breast ultrasound. BI-RADS=Breast Imaging Reporting and Data System. FFDM=full-field digital mammography. MyPeBS=My Personal Breast Screening.

breast tissue population from one of the centres, Cambridge.[4] This gave the recall and cancer detection rates but not biopsy rates for full-field digital mammography alone in the C and D density arms. The total recall and detection rates for any given supplemental imaging were calculated as those expected from full-field digital mammography alone plus those observed in the relevant supplemental imaging arm. The total rates were then compared between the four arms.

Because of the varying imaging interventions offered by the different sites, we analysed the results using network meta-analysis techniques, treating each site as a study in the meta-analysis.[29] Two analyses were carried out, one using only the three active intervention arms, and one with the addition of the observational data from Cambridge on full-field digital mammography alone. The network meta-analysis was based on total numbers randomised—that is, on intention to treat.

The statistical package STATA version 18 was used for all analyses.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

	Supplemental imaging			Standard of care (n=2568)
	Abbreviated breast MRI (n=2318)	ABUS (n=2240)	Contrast-enhanced mammogram (n=2235)	
Median age at screening mammogram, years (IQR)	56 (52–61)	56 (52–62)	56 (52–61)	56 (52–61)
Mammographic breast density				
C	1936 (83·5%)	1943 (86·7%)	1769 (79·1%)	2151 (83·8%)
D	382 (16·5%)	297 (13·3%)	466 (20·9%)	417 (16·2%)
Trial centre				
Cambridge	548	874	502	357
Cheltenham	445	0	387	521
Manchester	419	818	0	416
Leeds	186	548	202	282
Royal Free, London	233	0	258	209
Barts, London	76	0	169	191
Glasgow	243	0	208	21
Nottingham	0	0	366	242
Dundee	52	0	55	41
Leicester	116	0	88	96

Data are n (%) unless otherwise stated. Standard of care was full-field digital mammography. ABUS=automated whole breast ultrasound.

Table 1: **Characteristics of cohort at baseline**

Results

Of the 9361 women (median age 56 years) who were recruited into this study from ten UK centres, 2318 were assigned to the abbreviated MRI, 2240 to ABUS, 2235 to contrast-enhanced mammography, and 2568 to standard of care. Of those assigned, 2130 in the abbreviated MRI, 2140 in the ABUS, and 2035 in the contrast-enhanced mammography underwent supplemental imaging in their respective arms; one participant from the standard of care arm underwent the ABUS (figure). The four arms were well balanced with respect to baseline characteristics (table 1). Supplemental imaging by site data is given in table 2. The distribution of participants based on their predicted lifetime multifactorial risk across the four arms is shown in the appendix (pp 1–2). The distributions were similar across the arms, with the overall distribution of 88·8% (7779 of 8757) of participants classified as general population risk, 10·4% (913 of 8757) as moderate risk, 0·6% (51 of 8757) as high risk, and 0·2% (14 of 8757) as very high risk. 604 participants were of unknown risk; 431 participants did not complete a questionnaire, 52 participants could not be scored due to a previously diagnosed cancer, and 121 were not scored by the tool for unknown reasons.

Overall, 85 cancers were found following the negative screening mammogram. Of these, 73 were invasive cancers and 12 were pure ductal carcinoma in situs (DCIS; table 3). When analysed by arm the cancer detection rates were 17·4 (95% CI 12·2–23·9) per 1000 examinations (37 of 2130), 4·2 (1·9–8·0) per 1000 examinations (nine of 2141), and 19·2 (13·7–26·1) per 1000 examinations (39 of 2035) for abbreviated MRI, ABUS, and contrast-enhanced mammography, respectively, of which 15·0 (10·3–21·1) per 1000 examinations (32 of 2130), 4·2 (1·9–8·0) per 1000 examinations (nine of 2141), and 15·7 (10·8–22·1) per 1000 examinations (32 of 2035) were invasive cancers. The median invasive tumour size was 10 mm (IQR 8–15), 22 mm (14–35), and 11 mm (7–15) in the respective arms. The DCIS size was 10 mm (3–55), and 27 mm (13–40) in the abbreviated MRI and contrast-enhanced mammography arms. A total of six cases were lymph node positive—three in the abbreviated MRI arm, two in the contrast-enhanced mammography arm, and one in the ABUS arm—with the remainder of the invasive cases lymph-node-negative. In 12 participants, axillary sampling was not performed.

See Online for appendix

The cancer detection rate for mammography in the contemporaneous Cambridge cohort of 18 107 women with C and D density as measured by Volpara was 8·4 per 1000 examinations (95% CI 7·2–9·9).[4]

The odds ratios (ORs) from the network meta-analysis comparing the three supplemental imaging arms with respect to recall, biopsy, and cancer detection rates are shown in the appendix (p 1). The global test for a difference in cancer detection rates among the three modalities was not significant (p=0·14), but the detection rates for abbreviated MRI were significantly higher than for ABUS (p=0·047) and non-significantly higher than for contrast-enhanced mammography (p=0·62).

	Abbreviated breast MRI (n=2318)	ABUS (n=2240)	Contrast-enhanced mammogram (n=2235)
Withdrew before imaging	188	100	200
Examinations by centre			
Cambridge	532	853	477
Cheltenham	417	0	360
Manchester	344	765	0
Leeds	173	523	169
Royal Free, London	220	0	229
Barts, London	66	0	152
Glasgow	218	0	185
Nottingham	0	0	334
Dundee	49	0	47
Leicester	111	0	82
Total	2130	2141	2035
Median time in days between screening mammogram and supplemental imaging (IQR)	143 (98–183)	111 (77–150)	134 (91–173)
Received supplemental imaging 0–89 days after screening mammogram	434/2130 (20·4%)	721/2141 (33·7%)	478/2035 (23·5%)
Received supplemental imaging 90–179 days after screening mammogram	1113/2130 (52·3%)	1173/2141 (54·8%)	1111/2035 (54·6%)
Received supplemental imaging 180–269 days after screening mammogram	515/2130 (24·2%)	230/2141 (10·7%)	395/2035 (19·4%)
Received supplemental imaging 270–365 days after screening mammogram	57/2130 (2·7%)	13/2141 (0·6%)	42/2035 (2·1%)
Received supplemental imaging over 365 days after screening mammogram	6/2130 (0·3%)	1/2141 (<0·1%)	4/2035 (0·2%)

ABUS=automated whole breast ultrasound.

Table 2: **Supplemental imaging**

The ORs from the network meta-analysis, comparing the supplemental imaging arms to the standard of care arm, are shown in the appendix (p 1). The global test for a difference among the four arms was highly significant (p=0·0003). All three supplemental imaging arms showed a significantly higher cancer detection rate than the standard of care, with the greatest difference being shown for abbreviated MRI (p<0·0001).

The recall rate in each arm was 9·7% (95% CI 8·4–11·0) for abbreviated MRI (206 of 2130), 4·0% (3·2–4·9) for ABUS (85 of 2141), and 9·7% (8·4–11·0) for contrast-enhanced mammography (297 of 2035). The recall rate for mammography in the C density and D density within the contemporaneous Cambridge cohort was 5·4% (95% CI 5·1–5·8).[4]

There was some variation in recall rate between sites for each arm, with abbreviated MRI recall ranging from 5·2% (18 of 344) to 14·7% (78 of 532), ABUS ranging from 1·0% (eight of 765) to 6·3% (33 of 523), and contrast-enhanced mammography ranging from 4·3% (eight of 185) to 18·2% (87 of 477; appendix p 2). Overall, there were three grade 3 cancers, all in the abbreviated MRI arm, 45 grade 2 cancers (18 in abbreviated MRI arm, six in the ABUS arm, and 21 in the contrast-enhanced mammography arm), and 24 grade 1 cancers (ten in abbreviated MRI arm, three in the ABUS arm, and 11 in the contrast-enhanced mammography arms; table 4). When comparing the recall rates among the three supplemental imaging modalities using network meta-analysis (appendix p 1), there was a significant difference among the three arms (p<0·0001), and a significant difference in biopsy rates (p=0·0028), with similar rates for abbreviated MRI and contrast-enhanced mammography, and lower rates for ABUS.

The corresponding comparison of recall rates with standard of care showed a highly significant difference (p<0·0001) with ABUS, abbreviated MRI, and contrast-enhanced mammography all showing an approximate doubling of the odds of recall (appendix p 1.)

The pathological attributes of the additional cancers diagnosed are shown in table 4. Five (13·5%) of 37 cancers in the abbreviated MRI arm and seven (17·9%) of 39 in the contrast-enhanced mammography arm were pure DCIS. No DCIS were detected by ABUS. The average sizes of the invasive cancers detected by abbreviated MRI and contrast-enhanced mammography were respectively 10 mm and 11 mm. The average size of the cancers detected by ABUS was 22 mm. Only three of the invasive cancers were grade 3, all in the abbreviated MRI arm. Oestrogen-receptor status and progesterone-receptor status were similar among the three arms. However, there were eight HER2-enriched cancers in the abbreviated MRI arm (23·5% of those with known status), none in the ABUS arm, and three in the contrast-enhanced mammography arm (9·1%).

There was one case of extravasation in the abbreviated MRI arm (0·5 events per 1000 examinations) with no other adverse events. There were no adverse events in the ABUS arm. In the contrast-enhanced mammography arm, there were a total of 24 iodinated contrast events (11·8 events per 1000 examinations), with 17 minor events (8·4 events per 1000 examinations), six moderate events (2·9 events per 1000 examinations), and one severe event (0·5 events per 1000 examinations) and three mammography contrast extravasations (1·5 extravasations per 1000 examinations; appendix p 3).

Discussion

This is the first randomised controlled trial to compare supplemental imaging techniques in women of average population risk with dense breasts. Abbreviated breast MRI and contrast-enhanced mammography detected three times as many invasive cancers than whole breast ultrasound. The invasive tumour size found by abbreviated MRI and contrast-enhanced mammography was half the size of those found with ABUS. The

two contrast-enhanced imaging techniques detected DCIS not seen on the screening mammograms with twice as many women with DCIS being found by contrast-enhanced mammography than by abbreviated MRI. No DCIS was found by ABUS.

The large number of cancers found by abbreviated MRI is similar to the Dutch DENSE trial where 16·5 cancers per 1000 examinations were found with full protocol MRI in women of population risk with dense breasts.[30] In earlier studies where MRI was offered in addition to mammography to women at increased risk an additional 18·0 cancers per 1000 examinations were found by MRI.[31] In a subsequent German study of women aged 40–70 years with negative mammography and ultrasound, MRI found 22·6 cancers per 1000 examinations.[32] Using abbreviated MRI and comparing this to digital breast tomosynthesis in a cross sectional study in women with dense breasts, MRI found significantly more invasive cancers (11·8 cases per 1000 examinations *vs* 4·8 cases per 1000 examinations).[33]

The number of cancers found by ABUS with a cancer detection rate of 4·2 cases per 1000 examinations is similar to the previously published literature.[16,17,34–37] In an early study of 4419 women with dense breasts Kelly and colleagues reported that an additional 3·6 cancers per 1000 examinations were found with whole breast ultrasound.[15] The prospective J-START,[38] in which supplemental ultrasound with mammography was offered to women aged between 40–49 years with heterogeneously or dense breasts, showed a cancer detection rate of 5·0 cases per 1000 examinations. Similarly, in a recent study conducted in China by Dang and colleagues,[18] involving 5978 asymptomatic women aged 35–69 years, ABUS as the sole screening modality achieved a cancer detection rate of 4·0 cases per 1000 examinations, with 95·8% of cancers being invasive and 73·9% node-negative. In another study published in 2024 by Paul and colleagues,[39] reviewing a 5-year ABUS programme at a US academic medical centre, 9865 women with dense breasts underwent supplemental ABUS screening, detecting 2·4 additional cancers per 1000 examinations, primarily early-stage and node-negative.

The contrast-enhanced mammography cancer detection rate of 19·2 cases per 1000 examinations was not significantly different to that found with abbreviated MRI. In a systematic review of seven studies MRI had higher sensitivity for breast cancer than contrast-enhanced mammography (97%, 95% CI 86–99 *vs* 91%, 77–97; p<0·001) but lower specificity (69%, 46–85 *vs* 74%, 52–89; p=0·09),[12] with similar results found in a meta-analysis by Xiang and colleagues.[40] Sorin and colleagues reported an incremental cancer detection rate of 13·1 cases per 1000 examinations with contrast-enhanced mammography in a study of women at increased risk and dense breasts.[11] The CMIST study (NCT05625659) seeks to determine if contrast-enhanced mammography is more accurate than digital breast tomosynthesis in women with dense breasts. The aim is to recruit over 2032 women across 15 sites.

Recall rates were more than twice as high in the two contrast arms compared with ABUS (9·7% *vs* 4·0%). The high recall rate with abbreviated MRI is similar to the DENSE trial (9·5%) and similar to the German trial of

	Abbreviated breast MRI (n=2130)	ABUS (n=2141)	Contrast-enhanced mammogram (n=2035)
Recalled	206	85	197
Recall rate	9·7% (8·4–11·0)	4·0% (3·2–4·9)	9·7% (8·4–11·0)
Biopsied	105	32	89
Biopsy rate	4·9% (4·0–5·9)	1·5% (1·0–2·1)	4·4% (3·5–5·4)
Cancer detected	37	9	39
Cancer detection rate (arm) per 1000	16·0 (11·3–21·9)	4·0 (1·8–7·6)	17·4 (12·4–23·8)
Cancer detection rate (imaged) per 1000	17·4 (12·2–23·9)	4·2 (1·9–8·0)	19·2 (13·7–26·1)
PPV1	18·0% (13·0–23·9)	10·6% (5·0–19·2)	19·8% (14·5–26·1)
PPV3	35·2% (26·2–45·2)	28·1% (13·7–46·7)	43·8% (33·3–54·7)
Cancer type			
DCIS only	5/37 (13·5%)	0/9	7/39 (17·9%)
Invasive cancer	32/37 (86·5%)	9/9 (100·0%)	32/39 (82·1%)

Data are n or % (95% CI). ABUS=automated whole breast ultrasound. DCIS=ductal carcinoma in situ. PPV=positive predictive value.

Table 3: **Supplemental imaging performance metrics**

	Abbreviated breast MRI	ABUS	Contrast-enhanced mammogram
Invasive grade			
1	10	3	11
2	18	6	21
3	3	0	0
Unknown	1	0	0
DCIS grade			
Low	2	0	0
Intermediate	0	0	1
High	3	0	6
Tumour size, mm			
Invasive (IQR)	10 (8–15)	22 (14–35)	11 (7–15)
DCIS (IQR)	10 (3–55)	NA	27 (13–40)
Invasive cancer receptor status (positive/total tested)			
Oestrogen receptor	29/35 (82·9%)	7/9 (77·8%)	31/36 (86·1%)
HER2	8/34 (23·5%)	0/9	3/33 (9·1%)
Progesterone receptor	13/19 (68·4%)	7/9 (77·8%)	19/22 (86·4%)
Confirmed triple-negative breast cancer	3	2	2
Lymph node status (positive/total tested)	3/32 (9·4%)	1/9 (11·1%)	2/32 (6·3%)

ABUS=automated whole breast ultrasound. DCIS=ductal carcinoma in situ. NA=not applicable.

Table 4: **Characteristics of cancer detected by supplemental imaging**

For the **UK Breast Screening MRI guidelines** see https://www.gov.uk/government/publications/breast-screening-consolidated-programme-standards/nhs-breast-screening-programme-screening-standards-valid-for-data-collected-from-1-april-2021

MRI with a recall of 9·7%.[30,32] The UK Breast Screening MRI guidelines (2021 NHS Breast Screening Programme guidelines) have set a maximum recall rate of 10% with an achievable rate of less than 7%. In our trial not all sites met this standard. In an audit by Healy and O'Keeffe, in Ireland, a recall rate of 14·2% (86 of 607) in the prevalent round of MRI screening and 8·5% (71 of 838) in the incident round of screening was reported for high-risk women.[41] High recall rates are distressing for women, costly, and labour intensive when large scale screening is being undertaken. However, with further screening rounds recalls fall to acceptable rates. In round 2 of the DENSE trial the false positive rate fell from 79·8 results per 1000 screening examinations (95% CI 72·4–87·9) in the first round to 26·3 results per 1000 screening examinations (21·5–32·3) in the second round which coincided with a drop in the cancer detection rate.[42] Our ABUS 4·0% recall rate is lower than most published studies,[15,16] including recent ones,[18,19] which reported recall rates of 11·9% and 9·0% for ABUS. It is comparable with that reported by Wilczek and colleagues,[17] with a first-round recall rate of 3·5%, that was further reduced to 0·9% in the second round, highlighting the importance of the learning curve in improving ABUS performance.

The median invasive tumour size of 10 mm (IQR 8–15) is similar on the contrast-enhanced techniques and is half that of those found by ABUS. The median size of abbreviated MRI and contrast-enhanced mammography tumours is similar to the DENSE trial where median size of screen detected cancers was 9·5 mm (IQR 6·8–12·0). Data from the English NHS screening programme from 2009–16 of over 11 million examinations showed that the mean size of screen-detected tumours was 13·7 mm, 19·0 mm, and 21·4 mm at prevalent screens and for incident rounds the sizes were 11·6 mm, 16·7 mm, and 19·0 mm for grades 1, 2, and 3 invasive cancers, respectively ($p<0·001$).[43] These data were not analysed by breast density but our study shows that the contrast-enhanced supplemental techniques are superior to mammography. The median invasive tumour size detected with ABUS in our study was 22 mm (IQR 14–35), larger than the 10–15 mm reported in previous studies.[15–18] Although all ABUS detected cancers in our study were invasive and node-negative, similar to previous studies discussed here, the larger tumour size might reflect differences in population characteristics and screening intervals. The learning curve associated with ABUS implementation, as emphasized by Winkelman and colleagues,[19] could also have contributed to detecting more advanced-stage cancers in earlier phases of its adoption.

All but six of the cancers were lymph-node-negative, confirming early-stage disease. While smaller cancer size should lead to improved prognosis, grade of cancer is important. Our study does not have sufficient power to differentiate detection of high grade and intermediate grade compared with low grade cancers by modality. Overall, we found only three grade 3 cancers, which were all in the abbreviated MRI arm, and 44 grade 2 cancers and 22 grade 1 cancers with the same proportions in each arm.

The strength of this randomised trial is the sequential recruitment of women with increased breast density from ten UK screening sites. Pragmatically the sites offered the imaging techniques available to them. Three supplemental techniques were randomly offered and the results provide a direct comparison of these. The abbreviated MRI protocol used in this study has found as many cancers as studies reported with standard MRI but is more easily delivered and less costly.

The main limitation of this study is that screening benefit, notably breast cancer specific mortality reduction, and longer-term harm, such as overdiagnosis, cannot be measured in this trial. Our study was not designed to address these outcomes; instead it focused on comparing initial detection measures as the first step in providing evidence on screening outcomes. It should be acknowledged that improved detection does not necessarily translate to a further reduction in breast cancer mortality. Intermediate outcomes, for example impact on interval cancer and advanced cancer rates, can be assessed as surrogates for potential benefit but these require longer follow-up and a larger study sample size. However, with reporting of the tumour sizes and stage the results can be used to inform downstream sophisticated modelling. The high recall rates in both contrast arms, although similar to other reported studies and within the NHS Breast Screening Programme guidelines, means that care will need to be taken to minimise these when supplemental techniques are introduced for population screening. It is difficult to estimate the overdiagnosis rate in this study. However, the cohort will be followed up to measure interval and next round cancers over the next 3 years. A major protocol deviation was that women who had a mammography screen detected cancer were difficult to recruit as invariably a biopsy was performed at assessment before supplemental imaging could be undertaken. A decision was taken not to attempt to recruit women with screen detected cancers and focus on mammography-negative women as would happen in practice. This meant that we only had cancer detection rate data from full-field digital mammography alone in only one centre of the study and these data were observational. Additional protocol deviations included a participant randomly assigned to the standard of care arm receiving an ABUS examination and 1263 participants receiving supplemental imaging more than 6 months after the screening mammogram from which they were recruited (578, 224, and 441 in the abbreviated MRI, ABUS, and contrast-enhanced mammography arms, respectively).

This study shows that contrast-enhanced techniques such as abbreviated MRI and contrast-enhanced

mammography have a superior performance compared with whole breast ultrasound. This is in line with systematic reviews of performance,[44] although no other study has directly compared these techniques in the same cohort of average-risk women. The information in this trial will allow sophisticated modelling to estimate the cost benefit of implementing a supplemental imaging strategy.

Contributors

Conceptualisation: FJG, NS, JJ, SV, PP, and AA. Funding acquisition: FJG and PP. Study design: FJG, SD, NS, JJ, PP, IL, and SV. Data collection: FJG, NRP, IA, LY, SV, IL, NS, WT, JJ, AS, TS, RA, MA-A, and SS. Data analysis: NRP, FJG, IA, and SD. Data interpretation: FJG, NP, IA, SD, NS, and AA. Writing group: FJG, NP, and SD. Reviewing and editing of the manuscript: FJG, NP, SD, IA, AA, LY, SV, IL, NS, WT, JJ, AS, TS, RA, MA-A, SS, and PP. All authors had access to the underlying data, reviewed and approved the final version of the manuscript, and had final responsibility for the decision to submit for publication

Declaration of interests

We declare no competing interests.

Data sharing

De-identified individual participant data that underlie the results reported in this Article will be made available for non-commercial use following the conclusion of the BRAID study. Accounting for the variable round length in breast screening, data are anticipated to be complete and available from July, 2027, for a duration of 12 months. The MR images are being made available to the EU funded ODELIA study for the public challenge to demonstrate federated learning of artificial intelligence. The anonymised images were originally held in the Cancer Research UK funded NCITA repository but this is no longer available. The images will be held in a repository in Cambridge University, Cambridge, UK. Access requests can be made by email to the corresponding author (fjg28@cam.ac.uk).

Acknowledgments

We thank all the women who participated in this trial. The trial was supported by an early detection programme grant from Cancer Research UK (C543/A26884), NIHR Cambridge Biomedical Research Centre (NIHR203312), GE Healthcare loaned equipment and gave financial support, and Bayer Pharmaceuticals gave free contrast for the MRI examinations. FJG and AA are supported by a Cancer Research UK grant (PPRPGM-Nov20\100002 to FG and C543/A26884 to AA). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care. We thank the following staff for their enormous contribution: Cambridge: Johanna Field-Rayner, Kate Charnley, Kirsten Morris, Fleur Kilburn-Toppin, Kathryn Taylor, Elisabetta Giannotti, Nuala Healy, Penelope Moyle, Muzna Nanaa, Yuyin Yang, Jaimie Taylor, Esme Radin, Ilse Patterson, and Amy Fox. Manchester: Soujanya Gadde, Caroline Parkin, Trupti Kaulkarni, Emma Hall, Natasha Jones, Caroline Fosbury, and Karen Rhodes. Cheltenham and Gloucester: Minna Pugh, Tasneem Rahman, Ellie Pollock, Rekha Plackal, Holly Brown, Helen Farmer, Olivia Parr, Sophie Smith, Helen Taylor, Victoria Andriessen, and Zoe Wray. Leeds: Maggie Fletcher, Julie Simpson, Isobel Haigh, Michelle McMahon, Dilani Manual, Sabrina Rajan, Ferdows Eskandari, Aneesha Qadeer, and Jodie Marr. Royal Free, London: Mia Morgan, Bharti Shah, Sonia Narula, Triet Hoang, Julia Scarth, Toral Patel, Sheela Kulaveerasingam, Daisy Canlas, Hannah Powell, and Molly Kiley. Glasgow: Sophia Sakellariou, Allison McCall, Kathryn Sinclair, Alison Gavin, Gillian Reece, Jacqueline Keenan, Ainslie McAdam, Katharine Sharp, Helen Bannister, and Linda Wilson. Nottingham: Lisa Brock, Lauren Clarke, Sarah Tennant, Adam Hughes, Amanjot Karrupiah, and Lisa Hamilton. Barts, London: Taniascarlet Pachecososa, Caterina Vieira, Shefali Dani, Vasiliki Papalouka, Philip Dilks, Nithya Vidyaprakash, Sasha Usiskin, Charlotte Longman, and Linda Metaxa. Leicester: Kaitlin Walker, Heath Hopewell, Tracyann Crawshaw, Lisa Grosvenor, Nicola Hartley, Kristin Henning, Moin Hoosein, Nadin Jallad, Sandra Jordan, Gayle McDonald, Lubna Phillips, Michelle Siu, Lakshmi Sundaram, Zoey Wane, Karim Ziada, Sandra Jordan, Joanne Wormleighton, Deborah Cotterill, UHL Breast Care Centre admin team, and UHL Research and Innovation team. Dundee: Maira Tosh, Benedict Gandakusuma, Sau Lee Chang, Malavika Rajeev, and Frances McGregor.

References

1 Mann RM, Athanasiou A, Baltzer PAT, et al. Breast cancer screening in women with extremely dense breasts recommendations of the European Society of Breast Imaging (EUSOBI). *Eur Radiol* 2022; **32:** 4036–45.

2 Bodewes FTH, van Asselt AA, Dorrius MD, Greuter MJW, de Bock GH. Mammographic breast density and the risk of breast cancer: a systematic review and meta-analysis. *Breast Edinb Scotl* 2022; **66:** 62–68.

3 Lynge E, Vejborg I, Lillholm M, Nielsen M, Napolitano G, von Euler-Chelpin M. Breast density and risk of breast cancer. *Int J Cancer* 2023; **152:** 1150–58.

4 Payne NR, Hickman SE, Black R, Priest AN, Hudson S, Gilbert FJ. Breast density effect on the sensitivity of digital screening mammography in a UK cohort. *Eur Radiol* 2025; **35:** 177–87.

5 Duffy SW, Morrish OWE, Allgood PC, et al. Mammographic density and breast cancer risk in breast screening assessment cases and women with a family history of breast cancer. *Eur J Cancer* 2018; **88:** 48–56.

6 US Food and Drug Administration. FDA updates mammography regulations to require reporting of breast density information and enhance facility oversight. 2024. https://www.fda.gov/news-events/press-announcements/fda-updates-mammography-regulations-require-reporting-breast-density-information-and-enhance (accessed Dec 17, 2024).

7 US Preventive Services Task Force, Nicholson WK, Silverstein M, et al. Screening for breast cancer: US Preventive Services Task Force recommendation statement. *JAMA* 2024; **331:** 1918–30.

8 Hussein H, Abbas E, Keshavarzi S, et al. Supplemental breast cancer screening in women with dense breasts and negative mammography: a systematic review and meta-analysis. *Radiology* 2023; **306:** e221785.

9 Seely JM, Domonkos V, Verma R. Auditing abbreviated breast MR imaging: clinical considerations and implications. *Radiol Clin North Am* 2024; **62:** 687–701.

10 Baxter GC, Selamoglu A, Mackay JW, Bond S, Gray E, Gilbert FJ. A meta-analysis comparing the diagnostic performance of abbreviated MRI and a full diagnostic protocol in breast cancer. *Clin Radiol* 2021; **76:** 154.e23–e32.

11 Sorin V, Yagil Y, Yosepovich A, et al. Contrast-enhanced spectral mammography in women with intermediate breast cancer risk and dense breasts. *AJR Am J Roentgenol* 2018; **211:** W267–74.

12 Pötsch N, Vatteroni G, Clauser P, Helbich TH, Baltzer PAT. Contrast-enhanced mammography versus contrast-enhanced breast MRI: a systematic review and meta-analysis. *Radiology* 2022; **305:** 94–103.

13 Lobbes MBI, Jochelson MS, Neeter LMFH, Nelemans PJ. Contrast-enhanced mammography and breast MRI: friends or foes? *Radiology* 2023; **307:** e221558.

14 Allajbeu I, Hickman SE, Payne N, et al. Automated breast ultrasound: technical aspects, impact on breast screening, and future perspectives. *Curr Breast Cancer Rep* 2021; **13:** 141–50.

15 Kelly KM, Dean J, Comulada WS, Lee S-J. Breast cancer detection using automated whole breast ultrasound and mammography in radiographically dense breasts. *Eur Radiol* 2010; **20:** 734–42.

16 Brem RF, Tabár L, Duffy SW, et al. Assessing improvement in detection of breast cancer with three-dimensional automated breast US in women with dense breast tissue: the SomoInsight Study. *Radiology* 2015; **274:** 663–73.

17 Wilczek B, Wilczek HE, Rasouliyan L, Leifland K. Adding 3D automated breast ultrasound to mammography screening in women with heterogeneously and extremely dense breasts: report from a hospital-based, high-volume, single-center breast cancer screening program. *Eur J Radiol* 2016; **85:** 1554–63.

18 Dang X, Gao Y, Ju Y, et al. Automated breast ultrasound with remote reading for primary breast cancer screening: a prospective study involving 46 community health centers in China. *AJR Am J Roentgenol* 2025; **224:** e2431830.

19 Winkelman AJ, Tulenko K, Epstein SH, Nguyen JV, Ford C, Miller MM. Breast cancer screening with automated breast US and mammography *vs* handheld US and mammography in women with dense breasts in a real-world clinical setting. *J Breast Imaging* 2024; **6:** 493–501.

20 Sickles E, D'Orsi C, Bassett L. ACR BI-RADS mammography. Reston, VA: American College of Radiology, 2013.

21 Vinnicombe S, Harvey H, Healy NA, et al. Introduction of an abbreviated breast MRI service in the UK as part of the BRAID trial: practicalities, challenges, and future directions. *Clin Radiol* 2021; **76:** 427–33.

22 Allajbeu I, Morris K, Nanaa M, et al. Introduction of automated breast ultrasound as an additional screening tool for dense breasts in the UK: a practical approach from the BRAID trial. *Clin Radiol* 2024; **79:** e641–50.

23 Carver T, Hartley S, Lee A, et al. CanRisk tool—a web interface for the prediction of breast and ovarian cancer risk and the likelihood of carrying genetic pathogenic variants. *Cancer Epidemiol Biomarker Prev* 2021; **30:** 469–73.

24 Lee A, Mavaddat N, Wilcox AN, et al. BOADICEA: a comprehensive breast cancer risk prediction model incorporating genetic and nongenetic risk factors. *Genet Med Off J Am Coll Med Genet* 2019; **21:** 1708–18.

25 Yang X, Eriksson M, Czene K, et al. Prospective validation of the BOADICEA multifactorial breast cancer risk prediction model in a large prospective cohort study. *J Med Genet* 2022; **59:** 1196–205.

26 Lee A, Mavaddat N, Cunningham A, et al. Enhancing the BOADICEA cancer risk prediction model to incorporate new data on RAD51C, RAD51D, BARD1 updates to tumour pathology and cancer incidence. *J Med Genet* 2022; **59**: 1206–18.

27 Rouge-Bugat M-E, Balleyguier C, Laurent N, et al. MyPeBS International randomized study comparing personalised, risk-stratified to standard breast cancer screening in women aged 40–70: focus on recruitment strategy in France. *Presse Médicale Open* 2022; **3:** 100022.

28 Dias S, Caldwell DM. Network meta-analysis explained. *Arch Dis Child Fetal Neonatal Ed* 2019; **104:** F8–12.

29 White IR. Network meta-analysis. *Stata J* 2015; **15:** 951–85.

30 Bakker MF, Lange SV de, Pijnappel RM, et al. Supplemental MRI screening for women with extremely dense breast tissue. *N Engl J Med* 2019; **381:** 2091–102.

31 Berg WA, Zhang Z, Lehrer D, et al. Detection of breast cancer with addition of annual screening ultrasound or a single screening MRI to mammography in women with elevated breast cancer risk. *JAMA* 2012; **307:** 1394–404.

32 Kuhl CK, Strobel K, Bieling H, Leutner C, Schild HH, Schrading S. Supplemental breast MR imaging screening of women with average risk of breast cancer. *Radiology* 2017; **283:** 361–70.

33 Comstock CE, Gatsonis C, Newstead GM, et al. Comparison of abbreviated breast MRI vs digital breast tomosynthesis for breast cancer detection among women with dense breasts undergoing screening. *JAMA* 2020; **323:** 746–56.

34 Buchberger W, Geiger-Gritsch S, Knapp R, Gautsch K, Oberaigner W. Combined screening with mammography and ultrasound in a population-based screening program. *Eur J Radiol* 2018; **101:** 24–29.

35 Chang JM, Cha JH, Park JS, Kim SJ, Moon WK. Automated breast ultrasound system (ABUS): reproducibility of mass localization, size measurement, and characterization on serial examinations. *Acta Radiol* 2015; **56:** 1163–70.

36 Tagliafico AS, Mariscotti G, Valdora F, et al. A prospective comparative trial of adjunct screening with tomosynthesis or ultrasound in women with mammography-negative dense breasts (ASTOUND-2). *Eur J Cancer* 2018; **104:** 39–46.

37 Gatta G, Cappabianca S, La Forgia D, et al. Second-generation 3D automated breast ultrasonography (Prone ABUS) for dense breast cancer screening integrated to mammography: effectiveness, performance and detection rates. *J Pers Med* 2021; **11:** 875.

38 Ohuchi N, Suzuki A, Sobue T, et al. Sensitivity and specificity of mammography and adjunctive ultrasonography to screen for breast cancer in the Japan strategic anti-cancer randomized trial (J-START): a randomised controlled trial. *Lancet* 2016; **387:** 341–48.

39 Paul S, McPeek C, Lieberenz J, et al. Supplemental automated breast US screening in patients with dense breasts: 5-year experience from an academic medical center. *J Breast Imaging* 2025; **7:** 35–44.

40 Xiang W, Rao H, Zhou L. A meta-analysis of contrast-enhanced spectral mammography versus MRI in the diagnosis of breast cancer. *Thorac Cancer* 2020; **11:** 1423–32.

41 Healy NA, O'Keeffe SA. Determination of recall rates for assessment in high-risk women undergoing annual surveillance breast MRI. *Clin Radiol* 2016; **71:** 1143–47.

42 Veenhuizen SGA, de Lange SV, Bakker MF, et al. Supplemental breast MRI for women with extremely dense breasts: results of the second screening round of the DENSE trial. *Radiology* 2021; **299:** 278–86.

43 Blanks RG, Wallis MG, Alison RJ, Given-Wilson RM. An analysis of screen-detected invasive cancers by grade in the English breast cancer screening programme: are we failing to detect sufficient small grade 3 cancers? *Eur Radiol* 2021; **31:** 2548–58.

44 Lobig F, Caleyachetty A, Forrester L, et al. Performance of supplemental imaging modalities for breast cancer in women with dense breasts: findings from an umbrella review and primary studies analysis. *Clin Breast Cancer* 2023; **23:** 478–90.