Radiography and Clinical Technology

Self-study CPD activity

Activity Reference Number:
A13(26) 2028

Topic
Double-Reading Mammograms

Article(s)
Performance of Radiologists and Radiographers in Double-Reading Mammograms: The UK National Health Service Breast Screening Program

Speciality
Mammography

Profession(s)
Radiographer
Radiologist
Medical Practitioner

This activity is approved for **THREE (3)** ***Clinical*** Continuing Education Units (CEU's)

Radiology

Performance of Radiologists and Radiographers in Double Reading Mammograms: The UK National Health Service Breast Screening Program

Yan Chen, PhD • *Jonathan J. James, FRCR* • *Eleni Michalopoulou, MSc* • *Iain T. Darker, PhD* • *Jacquie Jenkins, MSc*

From the University of Nottingham, School of Medicine, Division of Cancer and Stem Cells, City Hospital Campus, Hucknall Road, Nottingham, NG5 1PB, United Kingdom (Y.C., E.M., I.T.D.); Nottingham University Hospitals NHS Trust, Nottingham Breast Institute, City Hospital Campus, Nottingham, United Kingdom (J.J.J.); and Public Health Commissioning and Operations, Directorate of the Chief Operating Officer, NHS England and NHS Improvement, Redditch, United Kingdom (J.J.). Received November 22, 2021; revision requested January 5, 2022; revision received June 30; accepted July 13. **Address correspondence to** Y.C. (email: *Yan.Chen@nottingham.ac.uk*).

Personal Performance in Mammographic Screening (PERFORMS) test scheme funded by National Health Service England.

Conflicts of interest are listed at the end of this article.

See also the editorial by Hooley and Durand in this issue.

Radiology 2023; 306:102–109 • https://doi.org/10.1148/radiol.212951 • Content codes: BR HP

Background: Double reading can be used in screening mammography, but it is labor intensive. There is limited evidence on whether trained radiographers (ie, technologists) may be used to provide double reading.

Purpose: To compare the performance of radiologists and radiographers double reading screening mammograms, considering reader experience level.

Materials and Methods: In this retrospective study, performance and experience data were obtained for radiologists and radiographer readers of all screening mammograms in England from April 2015 to March 2016. Cancer detection rate (CDR), recall rate (RR), and positive predictive value (PPV) of recall based on biopsy-proven findings were calculated for first readers. Performance metrics were analyzed according to reader professional group and years of reading experience using the analysis of variance test. *P* values less than .05 were considered to indicate statistically significant difference.

Results: During the study period, 401 readers (224 radiologists and 177 radiographers) double read 1 404 395 screening digital mammograms. There was no difference in CDR between radiologist and radiographer readers (mean, 7.84 vs 7.53 per 1000 examinations, respectively; $P = .08$) and no difference for readers with more than 10 years of experience compared with 5 years or fewer years of experience, regardless of professional group (mean, 7.75 vs 7.71 per 1000 examinations respectively, $P = .87$). No difference in the mean RR was observed between radiologists and radiographer readers (5.0% vs 5.2%, respectively, $P = .63$). A lower RR was seen for readers with more than 10 years of experience compared with 5 years or fewer, regardless of professional group (mean, 4.8% vs 5.8%, respectively; $P = .001$). No variation in PPV was observed between them ($P = .42$), with PPV values of 17.1% for radiologists versus 16.1% for radiographers. A higher PPV was seen for readers with more than 10 years of experience compared with 5 years or less, regardless of professional group (mean, 17.5% and 14.9%, respectively; $P = .02$).

Conclusion: No difference in performance was observed between radiographers and radiologists reading screening mammograms in a program that used double reading.

Online supplemental material is available for this article.

Double reading of screening mammograms is the standard of care in the National Health Service Breast Screening Program (NHSBSP) in the United Kingdom. It has been shown to improve cancer detection rates (CDRs) by 6%–15% while keeping recall rates (RRs) low but is labor intensive (1–3). The NHSBSP screens 2.23 million women annually in England (4). Radiologist shortages have been mitigated by using nonradiologist readers since the mid-1990s (5). Nonradiologist readers are from one of two professional groups: They are either radiographers (ie, technologists) or breast clinicians (ie, medically qualified practitioners trained specifically in the diagnosis and management of breast disease) (Appendix E1 [online]). In the NHSBSP, radiographers are 83% of the nonradiologist readers (6). A national workforce survey (6) found that 78% of breast screening units in England employed at least one radiographer in an advanced practice (physician extender) role, with an average of between three and four radiographers.

Previous studies have shown that double reading by a radiologist and radiographer is an alternative to double reading by two radiologists, but it has been suggested that radiographers exhibit lower reader specificity with higher RRs and rates of false-positive interpretations (7–9). However, these studies are historical, were performed in the predigital era, and did not consider the experience of readers within each professional group (7–9). The use of nonradiologist readers is now firmly embedded in the NHSBSP, and double reading by a radiologist and radiographer is the most encountered reading regimen; however, some centers also use only radiographers for double reading (10). Breast radiology in the UK NHSBSP has always had its performance heavily audited as part of the quality assurance process but this would typically be for the screening center as

Abbreviations

CDR = cancer detection rate, NHSBSP = National Health Service Breast Screening Program, PERFORMS = Personal Performance in Mammographic Screening, PPV = positive predictive value, RR = recall rate

Summary

No difference in diagnostic performance was observed for breast cancer screening when comparing radiologist and radiographer (ie, technologist) readers in the National Health Service Breast Screening Program.

Key Results

- When performing the double reading of screening digital mammograms as the first reader, radiologists and trained radiographers (ie, technologists) demonstrated no difference as readers in cancer detection rates (7.84 and 7.53 per 1000 examinations, respectively; $P = .08$) in the National Health Service Breast Screening Program.
- Recall rates (RRs) for radiologists and radiographers were similar (5% and 5.2%, respectively; $P = .63$).
- Positive predictive values of RRs were also similar for radiologists and radiographers (17.1% and 16.1%, respectively, $P = .42$).

a whole rather than for each individual reader. The recent introduction of a Breast Screening Information System in England, which provides national and local performance statistics, produces individual real-life performance data during rolling 3-year periods (11). The aim of our study is to compare the real-life performance of radiologists and radiographer readers in double reading mammograms in the UK screening program, considering differing levels of reading experience.

Materials and Methods

Study Sample

The retrospective study was carried out in accordance with local security and data protection policies. The requirement for ethical approval was waived after discussion with the University of Nottingham research and development team because this retrospective study was deemed to represent an audit of current practice.

All readers in the NHSBSP in England who also took part in an individual performance assessment scheme, Personal Performance in Mammographic Screening (PERFORMS), were eligible to take part and asked to give consent for their individual breast screening performance data to be accessed from the Breast Screening Information System for the 3-year period of 2013–2016 as part of an evaluation of the PERFORMS scheme. Details of the PERFORMS scheme and its evaluation are described elsewhere (12). For our study, the individual NHSBSP reader CDR, RR, and positive predictive value (PPV) available from the Breast Screening Information System for the most recent 12 months in the 3-year time frame were used, covering the period from the beginning of April 2015 to the end of March 2016.

Double Reading in the NHSBSP

The NHSBSP has 80 screening centers in England and routinely invites all women between age 50 and 70 years to undergo two-view two-dimensional digital mammography in each breast. Digital breast tomosynthesis was not used as a screening tool during the study period. Women over age 70 years can self-refer. The NHSBSP has a 3-year screening interval. All mammograms were routinely read by two readers (double reading). Readers in the NHSBSP belong to one of three professional groups: board certified radiologists, radiographers (technologists), and breast clinicians. Radiologists and radiographers are 94% of readers (6). Radiographers involved in the interpretation of screening mammograms undergo additional postgraduate specialist training, typically to a master's degree level, and are employed at the grade of an advanced practitioner or consultant radiographer. Breast clinicians, although not radiologists, are medically qualified practitioners who are trained specifically in the diagnosis and treatment of breast disease. Further information on the NHSBSP and readers including qualifications and training can be found in Appendix E1 (online).

Double reading is the standard of care in the NHSBSP. Double reading of an individual woman's mammograms may be performed by two radiologists; two nonradiologists (either a radiographer or breast clinician); or, most commonly, one radiologist and one nonradiologist, depending on screening center staffing. Qualified readers from any professional group can act as either a first or second reader on any examination. Discrepancies between readers were resolved either by arbitration, with an independent third reader, or consensus depending on local screening center protocols (3,13).

Exclusions

The NHSBSP requires that all readers interpret a minimum of 5000 screening or diagnostic mammograms per year, with a minimum of 1500 screening mammograms as the first reader. The Breast Screening Information System performance data primarily focus on performance as a first reader. The second reader in the double reading workflow is often not completely blinded to the opinion of the first reader, so it is only the first read that is the unbiased read and the most reliable performance indicator. Readers who did not reach this minimum reading standard were excluded from the study. Readers with missing data were also excluded from the study. Data regarding professional groups (radiologist, radiographer, or breast clinician) were extracted from the PERFORMS database. Only the performance of the two largest professional groups reading in the NHSBSP in England were compared; breast clinicians were excluded from the analysis because of small numbers. Participants in the PERFORMS scheme were asked to give their reading experience, so readers were assigned to three groups based on their number of years of breast screening mammogram reading experience for April 2015 to March 2016 (≤5 years, between 5 and 10 years, and >10 years of reading experience). The flowchart (Fig 1) outlines the recruitment process and exclusion criteria.

Statistical Analysis

The CDR, RR, and PPV of recall on the basis of biopsy-proven pathologic findings were calculated for each individual acting as a first reader. CDR was calculated as the number of examina-

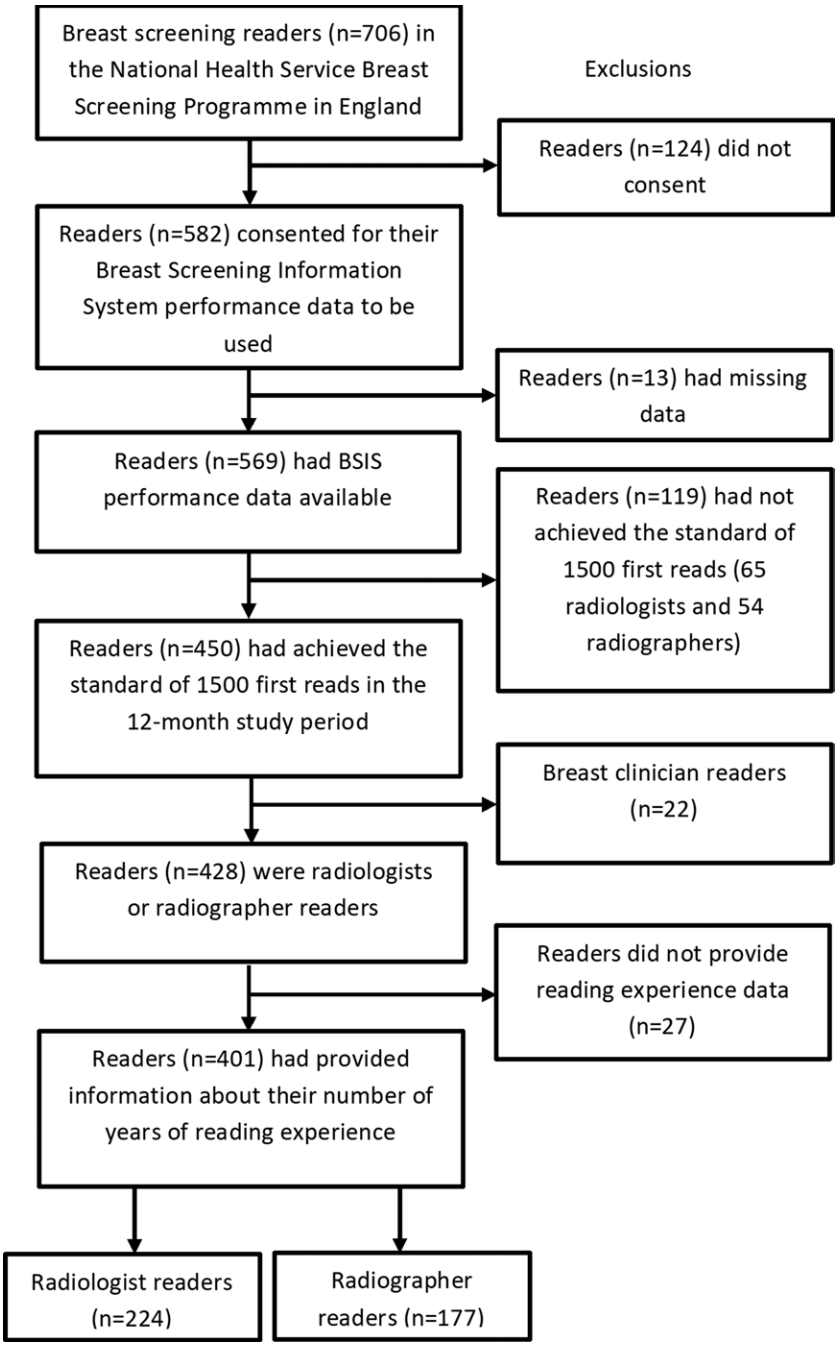

Figure 1: Flowchart of recruitment process, eligible readers, and exclusions. BSIS = Breast Screening Information System.

tions at which a biopsy-proven cancer was detected by the reader per 1000 examinations. RR was calculated as the total number of recalled examinations as a proportion of the total number of examinations read. PPV was calculated as the total number of biopsy-proven cancers detected as a proportion of the total number of examinations recalled. Interval cancer data were collected using information from the cancer registry and published for each screening center, but individual real-life performance data are not updated on the Breast Screening Information System to reflect this. Therefore, CDR and PPV are based on biopsy-proven pathologic findings at the time of the original screening episode. The NHSBSP uses CDR, PPV, and RR as the key individual performance metrics as without the inclusion of interval cancer data in the Breast Screening Information System, it is not possible to calculate a truly accurate sensitivity and specificity for each reader.

Each breast screening metric was analyzed according to reader profession (radiographer or radiologist), years of experience in breast screening (≤5 years, >5 years to 10 years, >10 years), and any interaction between them using analysis of variance. More detail regarding the statistical analysis and analysis of variance results can be found in Appendix E1 (online). The α level for statistical significance was set at *P* value less than .05 for all analyses. Statistical calculations were performed using statistical software (SPSS Statistics version 27.0; IBM).

Results

Characteristics of Study Sample

There were 706 readers in the NHSBSP in England. A total of 401 readers consented and were eligible to take part in the study (Fig 1) and double read the mammograms in 1 404 395 women in the 12-month period from the beginning of April 2015 to the end of March 2016. There were 224 radiologists who read 763 958 mammograms as the first reader and 177 radiographers who read 640 437 mammograms as the first reader. The Table shows the years of experience of readers from each professional group. Radiologists were overrepresented in the highest experienced band, with radiologists making up 63% (131 of 209) of readers with more than 10 years of experience. Radiologists accounted for 48% (93 of 192) of readers with less than 10 years of experience.

CDR in Readers

The Table and Figure 2 show the CDR per 1000 examinations for each professional group and the years of experience of the readers. Overall, the mean CDR was 7.70 per 1000 examinations, with a mean CDR for radiologists and radiographers of 7.84 and 7.53 per 1000 examinations, respectively (Figs 3, 4). No variation in CDR was observed based on professional group: radiologist and radiographer readers (mean, 7.84 vs 7.53 per 1000 examinations, respectively; $P = .08$). The mean CDR values for readers with less than 5 years of experience and those with more than 10 years of experience were 7.71 and 7.75 per 1000 examinations, respectively. No variation in CDR was observed based on years of experience for either professional group ($P = .87$). No interaction between the readers' professional group and years of experience was observed ($P = .37$).

Key Performance Metrics for Readers from Each Professional Group by Years of Experience Reading Mammography Screenings

Performance Metric and Reading Experience	Radiographer		Radiologist		All Readers		*P* Value
	Mean	No. of Readers	Mean	No. of Readers	Mean	No. of Readers	
CDR per 1000 examinations							
≤5 y or less	7.37 ± 1.76	34 (19.2)	8.15 ± 1.85	26 (11.6)	7.71 ± 1.83	60 (15.0)	…
>5 y and ≤10 y	7.62 ± 1.55	65 (36.7)	7.61 ± 1.78	67 (29.9)	7.62 ± 1.66	132 (32.9)	…
>10 y	7.51 ± 1.73	78 (44.1)	7.89 ± 2.14	131 (58.5)	7.75 ± 2.00	209 (52.1)	…
Total	7.53 ± 1.67	177	7.84 ± 2.01	224	7.70 ± 1.87	401	…
Interaction of profession and experience	…	…	…	…	…	…	.37
Effect of experience	…	…	…	…	…	…	.87
Effect of professional group	…	…	…	…	…	…	.08
RR (%)							
≤5 y or less	5.8 ± 2.2	34	5.7 ± 1.9	26	5.8 ± 2.0	60	…
>5 y and ≤10 y	5.0 ± 1.5	65	5.1 ± 1.4	67	5.0 ± 1.4	132	…
>10 y	5.0 ± 1.6	78	4.7 ± 1.6	131	4.8 ± 1.6	209	…
Total	5.2 ± 1.7	177	5.0 ± 1.6	224	5.0 ± 1.7	401	…
Interaction of profession and experience	…	…	…	…	…	…	.71
Effect of experience	…	…	…	…	…	…	.001
Effect of professional group	…	…	…	…	…	…	.63
PPV of recall (%)							
≤5 y or less	14.7 ± 7.8	34	15.2 ± 4.4	26	14.9 ± 6.5	60	…
>5 y and ≤10 y	16.3 ± 4.9	65	15.9 ± 5.3	67	16.1 ± 5.1	132	…
>10 y	16.5 ± 6.6	78	18.2 ± 6.6	131	17.5 ± 6.6	209	…
Total	16.1 ± 6.3	177	17.1 ± 6.1	224	16.7 ± 6.2	401	…
Interaction of profession and experience	…	…	…	…	…	…	.32
Effect of experience	…	…	…	…	…	…	.02
Effect of professional group	…	…	…	…	…	…	.42
Cases read as first reader in 2015–2016							
≤5 y or less	3974 ± 2018	34	2858 ± 960	26	3490 ± 1726	60	…
>5 y and ≤10 y	3532 ± 1433	65	3143 ± 1411	67	3335 ± 1430	132	…
>10 y	3535 ± 1276	78	3657 ± 1781	131	3611 ± 1609	209	…
Total	3618 ± 1501	177	3411 ± 1623	224	3502 ± 1572	401	…
Effect of professional group	…	…	…	…	…	…	.01

Note.—Mean data are ± SD; data in parentheses are percentages. CDR = cancer detection rate, PPV = positive predictive value, RR = recall rate.

RR in Readers

Overall, the mean RR was 5.0%. The RR based on professional group and years of experience is shown in the Table and Figure 5. The mean RR for radiologists was 5.0% and 5.2% for radiographers. No variation in RR was observed based on professional group (P = .63), and no interaction between the professional group of an individual and years of experience was observed (P = .71). All readers, regardless of professional group, demonstrated a lower RR with more years of experience (P = .001). RR was highest among radiologists and radiographers with less than 5 years of experience (mean RR values, 5.7% and 5.8%, respectively), and mean RRs were lower for radiologists and radiographers with more than 10 years of experience (4.7% and 5.0%, respectively). In pairwise post hoc comparisons, RR was higher among readers with less than 5 years of experience (mean, 5.8% ± 2.0) than for readers with between 5 and 10 years of experience (mean, 5.0% ± 1.4; Bonferroni P = .011) and readers with more than 10 years of experience (mean, 4.8% ± 1.6; Bonferroni P = .001).

PPV in Readers

Overall, the mean PPV was 16.7%. Radiologists had a mean PPV of 17.1% compared with radiographers who had a mean PPV of 16.1% (Table, Fig 6). No variation in PPV was observed between the two professional groups (P = .42) and no interaction was found between the readers' professional group and years of experience (P = .32). PPV varied based on years of experience for all readers regardless of professional group (P = .02), with improved PPV values from a low of 15.2% and 14.7% for radiologists and radiographers with less than 5 years of reading experience, respectively, to a high of 18.2% and 16.5% for radiologists and radiographers with more than 10 years of experience, respectively. In pairwise post hoc comparisons, PPV was lower among readers with less than 5 years of experience (mean, 14.9% ± 6.5) than among readers with more than 10 years of experience (mean, 17.5% ± 6.6; Bonferroni P = .031).

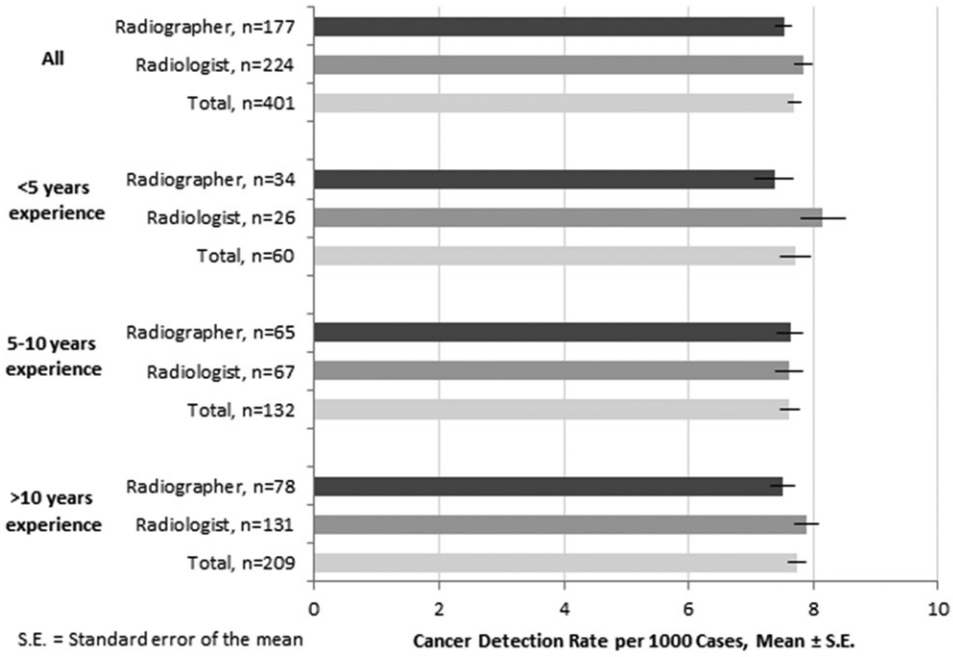

Figure 2: Cancer detection rate (CDR) per 1000 cases read for radiologists and radiographers of different experience levels. There was no difference in CDR and no variation with years of experience.

Discussion

Our study found no difference in the performance of radiologist and radiographer readers in the UK breast screening program who were using double reading as the standard of care. There was no evidence of a difference in cancer detection rate (CDR) for readers who were radiologists versus radiographers (mean, 7.84 vs 7.53 per 1000 examinations, respectively; P = .08). No variation in CDR was observed with years of reading experience for either professional group (readers with ≤5 years of experience: mean, 7.71 per 1000 examinations; readers with >5 to 10 years of experience: mean, 7.62 per 1000 examinations; and readers with >10 years of experience: mean, 7.75 per 1000 examinations; P = .87). No variation in recall rate (RR) was seen based on the professional group of readers (mean, radiologists vs radiographer readers: 5.0% and 5.2%, respectively; P = .63), but a lower RR was observed with more reader experience for all readers regardless of professional group (readers with ≤5 years of experience: mean, 5.8%; readers with >10 years of experience: mean, 4.8%; P = .001). The third key performance metric measured was positive predictive value (PPV), representing the trade-off between detecting cancers and recalling women for further investigation. Again, no variation for this metric between radiologists and radiographers was observed (mean, 17.1% and 16.1%, respectively; P = .42). All readers showed a higher PPV with more experience regardless of their professional group (readers with ≤5 years of experience vs >10 years: mean, 14.9% vs 17.5%; P = .02).

Previous studies have assessed the performance of radiographers interpreting mammography screening using both test sets and real-life performance data. The study by Torres-Mejía et al (14) showed that 15 radiographers had comparable sensitivity to radiologists in North America. This is similar to the findings of our study, in which the CDR can be used as a proxy for sensitivity. The study by Torres-Mejia et al found that radiographer readers had higher false-positive rates. Historical data from the PERFORMS test-set–based scheme used by the NHSBSP to assess performance in the United Kingdom have suggested that radiographers read as well as radiologists, after accounting for years of experience (15). This is what we observed in our current real-life data study. However, concern has been raised that experimental conditions using test sets can influence the behavior of readers and therefore may not be a true reflection of real life, which is the so-called laboratory effect (16). The Dutch screening program uses radiographers to flag observed mammographic abnormalities to the radiologist prior to reading. Geertse et al (17) found that this was not effective, with lower RRs and higher PPV observed when the warning system was switched off, and no effect on cancer detection. The approach in the United Kingdom is different; radiographers undergo extensive reader training and are subjected to the same quality assurance standards as radiologists (Appendix E1 [online]).

In a pilot study from the NHSBSP using real-life performance data from the clinical setting, Pauli et al found that double reading by a radiographer and radiologist led to an increase in sensitivity of 6.4% compared with single reading, but with a decrease in specificity of 0.6% (8). This was similar to sensitivity increases achieved in contemporary studies of double reading by two radiologists when increases of 4%–15% were observed (18–20). Another pilot study of double reading by two

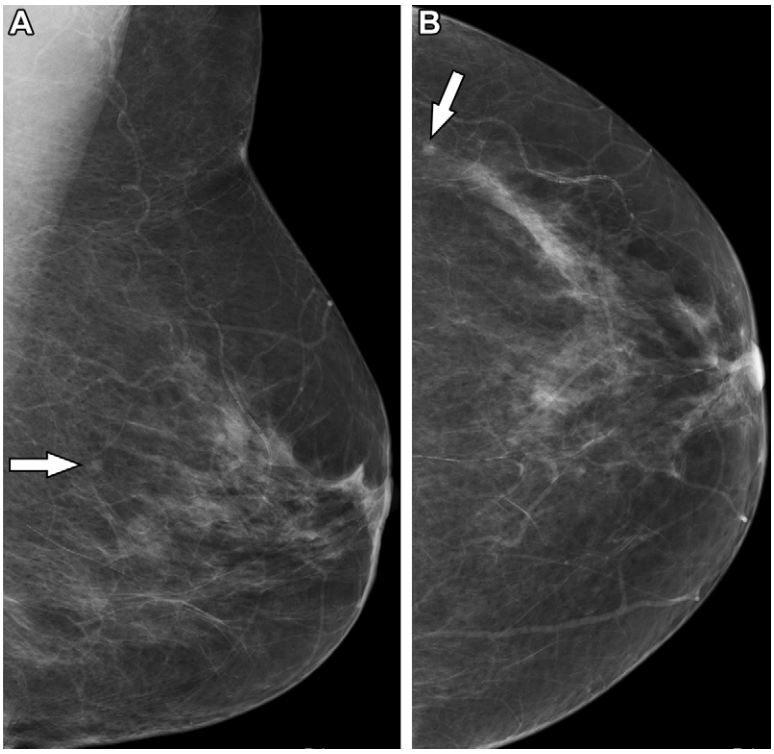

Figure 3: Mammograms in a 50-year-old woman undergoing her first screening mammographic examination. A 3-mm mass (arrow) is demonstrated in the left breast on the **(A)** mediolateral oblique and the **(B)** craniocaudal view. It was not recalled by the radiologist who read the mammogram first but was recalled by the radiographer who read the image second. Because the opinions were discordant, the case was recalled for further assessment after arbitration by a third reader. US-guided biopsy demonstrated a 3-mm histologic grade 1 ductal carcinoma.

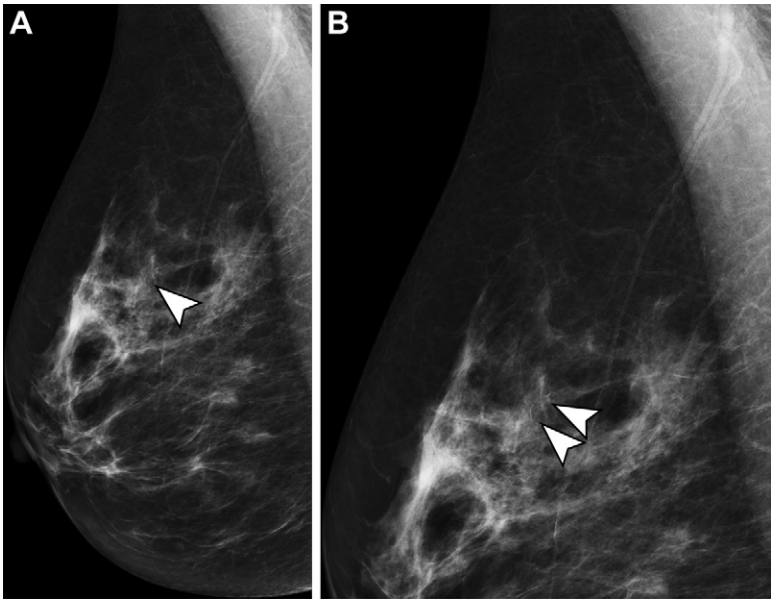

Figure 4: Mammograms in a 54-year-old woman undergoing her second screening mammographic examination. **(A)** There are 15 mm of pleomorphic microcalcifications (arrowhead) in the superior right breast on the mediolateral oblique view. **(B)** The microcalcifications (arrowheads) are best observed on this magnified view. It was not recalled by the radiographer who read the mammogram first and was recalled by the radiologist who read the image second. Stereotactic-guided biopsy showed high-grade ductal carcinoma in situ.

radiographers found an increase in RRs for the first and subsequent screening rounds of 8% and 7%, respectively, but no difference in CDRs (10). Following the completion of these pilot studies, the use of radiographer reporting became more popular, and over the last 20 years, radiographer reading has become an established part of double reading in the United Kingdom, with at least one read performed by a radiographer in many centers.

In a more recent analysis from the NHSBSP, the study by Cornford et al (21) found no difference in CDRs between radiographers and radiologists (odds ratio, 0.98; $P = .24$) but identified higher RRs (odds ratio, 1.11; $P = .01$) and consequently a lower PPV (odds ratio, 0.87; $P = .002$) for consultant radiographers than for consultant radiologists. As with these previous studies, we also found no differences in cancer detection between the two professional groups, however, we did not identify any difference in RR or PPV between radiologists and radiographer readers. Lower RR and higher PPV values were observed for readers with more experience, but this was independent of professional grouping. The differences in real-life performance metrics such as specificity, RR, and PPV between radiologists and radiographers observed in previous studies are probably explained by different reader experience levels rather than by a fundamental difference in performance between professional groups. In our study, radiographers were numerically overrepresented in the two lower experience bands, confirming the importance of taking years of reading experience into account when comparing reading performance between the different professional groups.

Other solutions to radiologist shortages have been assessed in the NHSBSP. Single reading with computer-aided detection has been proposed as an alternative to double reading. In 2008, the study by Gilbert et al (22) found that the CDR for a single reader by using a computer-aided detection system was similar to double reading (7.02 per 1000 examinations and 7.06 per 1000, respectively), but it led to a 15% higher RR of 3.9%, up from 3.4%. Consequently, the use of a single reader with computer-aided detection as an alternative to the double reading was not cost-effective and was not adopted in the NHSBSP (23). There is much interest in the current generation of artificial intelligence products based on deep learning, which could potentially be used as a replacement for one of the human readers in the double reading workflow. Early results suggest that artificial intelligence can perform at the level of a human reader when used for mammographic interpretation, but this evidence is from a small number of retrospective studies, with none of these products yet ready for real-world implementation (24).

Our study had limitations. First, 124 readers declined consent to have their real-life performance data accessed and analyzed, so this may have been a source of bias. Second, we only assessed first reader performance metrics because in many centers this is the only truly unbiased interpretation. Therefore, we assumed that first reader performance was representative of overall performance. The NHSBSP requires all readers to undertake a minimum of 1500 first reader interpretations per annum. Third, we only analyzed the performance of readers who achieved this minimum first reader standard to avoid statistical uncertainty at lower reading volumes, but this potentially excluded some lower-volume readers and again may have been a source of bias. In addition, the findings of our study were only likely to be generalizable to screening programs that use two-dimensional digital mammography rather than digital breast tomosynthesis and have 3-year screening intervals. Our study only provided evidence to support the participation of nonradiologists as readers in programs that use double reading. Our findings did not support the use of nonradiologist readers in other settings.

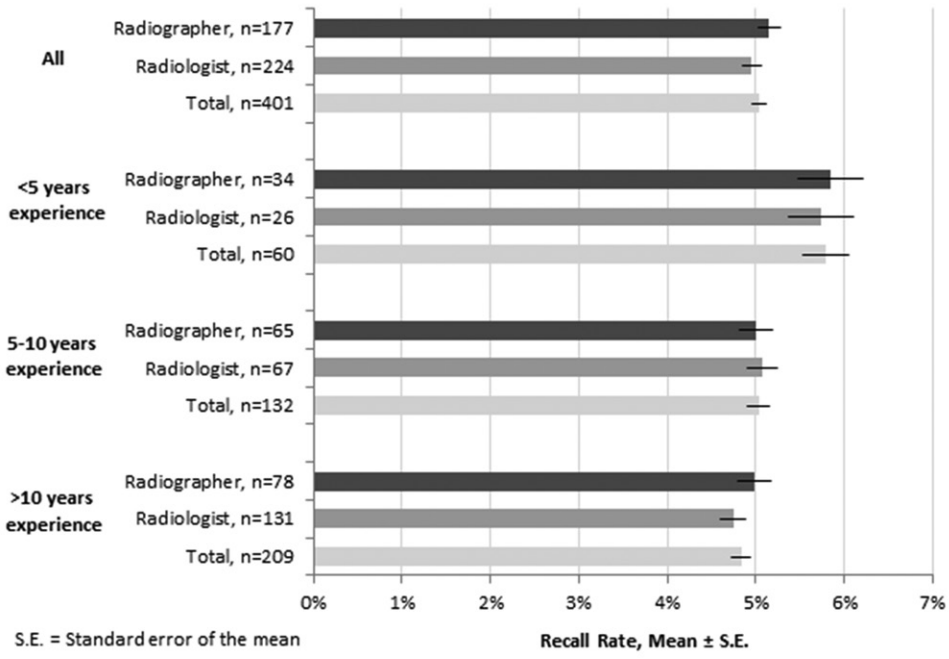

Figure 5: Recall rate (RR) for radiologists and radiographers of different experience levels. There was no difference in RRs between radiologists and radiographers, but lower RRs were seen with greater reading experience regardless of professional group.

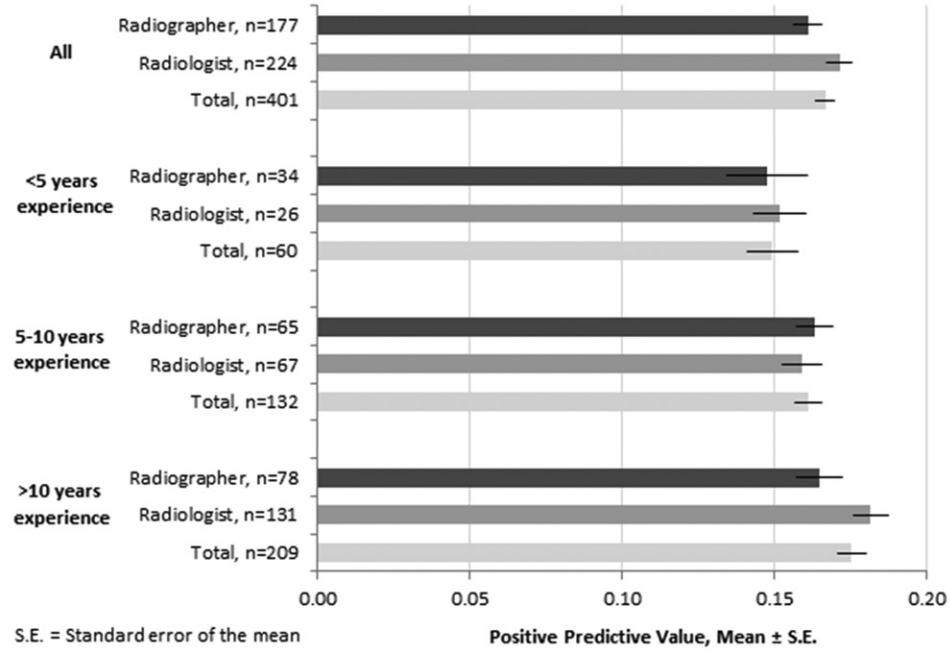

Figure 6: Positive predictive value (PPV) of recall for radiologists and radiographers of different experience levels. There was no difference in PPV between radiologist and radiographers, but a higher PPV was observed with greater reading experience regardless of professional group.

In conclusion, no differences were observed in the performance of radiographers and radiologists as readers in the National Health Service Breast Screening Program, where double reading of two-dimensional screening digital mammograms is the standard of care. Readers from each professional group showed no statistically significant difference in the key screening performance metrics of cancer detection rate, recall rate (RR), and positive predictive value (PPV) and demonstrated lower RR and higher PPV with more reader experience. In our study setting, trained nonradiologists performed equally well, suggesting that reading performance is dependent on experience rather than the broad and advanced medical education undertaken by radiologists. The use of trained radiographer readers in the double-reading workflow may offer a potential solution to the shortage of radiologists experienced by some breast screening programs, but more studies are needed to determine whether such physician extender roles can and should be used to read screening mammograms independent of the radiologist.

Author contributions: Guarantor of integrity of entire study, **Y.C.**; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, **Y.C., J.J.J.**; clinical studies, **J.J.J.**; experimental studies, **Y.C., I.T.D.**; statistical analysis, **Y.C., I.T.D.**; and manuscript editing, all authors

Disclosures of conflicts of interest: Y.C. No relevant relationships. **J.J.J.** Payments to author from GE Healthcare for lectures. **E.M.** No relevant relationships. **I.T.D.** No relevant relationships. **J.J.** No relevant relationships.

References

1. Harvey SC, Geller B, Oppenheimer RG, Pinet M, Riddell L, Garra B. Increase in cancer detection and recall rates with independent double interpretation of screening mammography. AJR Am J Roentgenol 2003;180(5):1461–1467.
2. Ciatto S, Ambrogetti D, Bonardi R, et al. Second reading of screening mammograms increases cancer detection and recall rates. Results in the Florence screening programme. J Med Screen 2005;12(2):103–106.
3. Blanks RG, Wallis MG, Moss SM. A comparison of cancer detection rates achieved by breast cancer screening programmes by number of readers, for one and two view mammography: results from the UK National Health Service breast screening programme. J Med Screen 1998;5(4):195–201.
4. Screening & Immunisations Team. Breast Screening Programme, England 2018-2019: Report. NHS Digital Website. https://files.digital.nhs.uk/6A/9EB938/breast-screening-programme-eng-2018-19-report.pdf. Published January 30, 2020. Accessed September 12, 2021.
5. Culpan A. Radiographer involvement in mammography image interpretation: A survey of United Kingdom practice. Radiography 2016;22(4):306–312.
6. The breast imaging and diagnostic workforce in the United Kingdom: Results of a survey of breast screening programme units and radiology departments. The Royal College of Radiologists Website. https://www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr162_bsbr_survey.pdf. Published April 17, 2016. Accessed September 12, 2021.
7. Duijm LEM, Louwman MWJ, Groenewoud JH, van de Poll-Franse LV, Fracheboud J, Coebergh JW. Inter-observer variability in mammography screening and effect of type and number of readers on screening outcome. Br J Cancer 2009;100(6):901–907.
8. Pauli R, Hammond S, Cooke J, Ansell J. Comparison of radiographer/radiologist double film reading with single reading in breast cancer screening. J Med Screen 1996;3(1):18–22.
9. Tonita JM, Hillis JP, Lim CH. Medical radiologic technologist review: effects on a population-based breast cancer screening program. Radiology 1999;211(2):529–533.
10. Bennett RL, Sellars SJ, Blanks RG, Moss SM. An observational study to evaluate the performance of units using two radiographers to read screening mammograms. Clin Radiol 2012;67(2):114–121.
11. Cohen SL, Blanks RG, Jenkins J, Kearins O. Role of performance metrics in breast screening imaging - where are we and where should we be? Clin Radiol 2018;73(4):381–388.
12. Chen Y, James JJ, Cornford EJ, Jenkins J. The relationship between Mammography Readers' real-life performance and performance in a test set-based assessment scheme in a national breast screening program. Radiol Imaging Cancer 2020;2(5):e200016.
13. Healy NA, O'Brien A, Knox M, et al. Consensus Review of Discordant Imaging Findings after the Introduction of Digital Screening Mammography: Irish National Breast Cancer Screening Program Experience. Radiology 2020;295(1):35–41.
14. Torres-Mejía G, Smith RA, Carranza-Flores ML, et al. Radiographers supporting radiologists in the interpretation of screening mammography: a viable strategy to meet the shortage in the number of radiologists. BMC Cancer 2015;15(1):410.
15. Scott HJ, Gale AG, Woodman C. Breast screening technologists: does real-life case volume affect performance? In: Chakraborty DP, Eckstein MP, eds. Medical Imaging 2004: Image Perception, Observer Performance, and Technology Assessment. Bellingham, Wash: SPIE Press, 2004; 399–406.
16. Gur D, Bandos AI, Cohen CS, et al. The "laboratory" effect: comparing radiologists' performance and variability during prospective clinical and laboratory mammography interpretations. Radiology 2008;249(1):47–53.
17. Geertse TD, Setz-Pels W, van der Waal D, et al. Added Value of Prereading Screening Mammograms for Breast Cancer by Radiologic Technologists on Early Screening Outcomes. Radiology 2022;302(2):276–283.
18. Denton ERE, Field S. Just how valuable is double reporting in screening mammography? Clin Radiol 1997;52(6):466–468.
19. Anderson EDC, Muir BB, Walsh JS, Kirkpatrick AE. The efficacy of double reading mammograms in breast screening. Clin Radiol 1994;49(4):248–251.
20. Thurfjell EL, Lernevall KA, Taube AAS. Benefit of independent double reading in a population-based mammography screening program. Radiology 1994;191(1):241–244.
21. Cornford E, Cheung S, Press M, Kearins O, Taylor-Phillips S. Optimum screening mammography reading volumes: evidence from the NHS Breast Screening Programme. Eur Radiol 2021;31(9):6909–6915.
22. Gilbert FJ, Astley SM, Gillan MGC, et al. Single reading with computer-aided detection for screening mammography. N Engl J Med 2008;359(16):1675–1684.
23. Guerriero C, Gillan MGC, Cairns J, Wallis MG, Gilbert FJ. Is computer aided detection (CAD) cost effective in screening mammography? A model based on the CADET II study. BMC Health Serv Res 2011;11(1):11.
24. Hickman SE, Woitek R, Le EPV, et al. Machine Learning for Workflow Applications in Screening Mammography: Systematic Review and Meta-Analysis. Radiology 2022;302(1):88–104.

QUESTIONNAIRE
A13(26)
Performance of Radiologists and Radiographers in Double-Reading Mammograms: The UK National Health Service Breast Screening Program

INSTRUCTIONS

- Read through the article and answer the multiple-choice questions provided below.
- All questions have only **ONE** correct answer

Introduction and Background

Question 1: What is the standard of care in the UK NHS Breast Screening Program (NHSBSP)?

A: Single reading by radiologists
B: Double reading of mammograms
C: AI-assisted reading only
D: Radiographer-only reading

Question 2: Radiographers have been used as non-radiologist readers in the NHSBSP since the mid-1990s.

A: TRUE
B: FALSE

Question 3: Is the following statement TRUE or FALSE regarding double reading of mammograms?

"It has been shown to improve cancer detection rates (CDRs) by 6%–15% while keeping recall rates (RRs) low but is labour intensive".

A: TRUE
B: FALSE

Study Design and Methods

Question 4: What type of study was conducted?
A: Prospective randomized trial
B: Cross-sectional
C: Case-control study
D: Retrospective audit of practice

Question 5: How many readers participated in the study?

A: 200
B: 300
C: 401
D: 500

Question 6: What was the minimum number of first reads required annually by NHSBSP standards?

A: 1500
B: 1000
C: 500
D: 2000

Cancer Detection Rate (CDR)

Question 7: What was the mean CDR for radiologists?

A: 6.5 per 1000
B: 7.53 per 1000
C: 7.84 per 1000
D: 8.5 per 1000

Question 8: What was the mean CDR for radiographers?

A: 6.5 per 1000
B: 7.53 per 1000
C: 7.84 per 1000
D: 8.5 per 1000

Question 9: Which **ONE** of the following statement is **TRUE**?

A: Variation in CDR was observed based on professional group
B: No variation in CDR was observed based on years of experience for either professional group
C: Significant interaction was found between readers' professional group and years of experience
D: All the above

Recall Rate (RR)

Question 10: What was the mean recall rate (RR) for radiologists?

- **A:** 4.5%
- **B:** 5.0%
- **C:** 5.2%
- **D:** 6.0%

Question 11: What was the mean recall rate (RR) for radiographers?

- **A:** 4.5%
- **B:** 5.0%
- **C:** 5.2%
- **D:** 6.0%

Question 12: Reader experience influenced recall rates, with lower RR observed among those with >10 years of experience.

- **A:** TRUE
- **B:** FALSE

Results: Positive Predictive Value (PPV)

Question 13: What was the mean PPV for radiologists?

- **A:** 14.9%
- **B:** 16.1%
- **C:** 17.1%
- **D:** 18.5%

Question 14: What was the mean PPV for radiographers?

- **A:** 14.9%
- **B:** 16.1%
- **C:** 17.1%
- **D:** 18.5%

Question 15: PPV improved with reader experience, regardless of professional group.

- **A:** TRUE
- **B:** FALSE

Conclusion and Implications

Question 16: Select the **FALSE** statement.

- **A:** The so-called laboratory effect can influence the behaviour of readers
- **B:** The Dutch screening program uses radiographers to flag observed mammographic abnormalities to the radiologist prior to reading
- **C:** In the UK radiographers undergo extensive reader training, but are not subject to the same quality assurance standards as radiologists

Question 17: What was the overall conclusion of the study?

- **A:** Radiologists outperform radiographers significantly
- **B:** Radiographers are unsuitable for double reading
- **C:** No difference in performance between radiologists and radiographers in double reading
- **D:** AI should replace human readers

THE END

FOCUS ON HEALTH
www.foh-cpd.co.za
Cell: 074 230 3874
Tel: 012 653 0133 / 2373 / 2394
Mon-Fri: 08:00-16:00

400 Theuns van Niekerk Street
Wierda Park
0157

PO Box 71
Wierda Park
0149

MEMBER INFO

(Complete sections marked with an asterisk *)

*FOH number	*HPCSA number

ID number

Personal detail changes

I hereby declare that the completion of this document is my own effort without any assistance.

SIGNED: DATE:

This activity is accredited for **THREE (3) CLINICAL** CEU'S. You have to achieve 70% to pass this activity.

ANSWER SHEET

A13(26)

Performance of Radiologists and Radiographers in Double-Reading Mammograms: The UK National Health Service Breast Screening Program

*Time spent on activity			hour					min			
	A	B	C	D	E		A	B	C	D	E
1						10					
2						11					
3						12					
4						13					
5						14					
6						15					
7						16					
8						17					
9											

How relevant was the content of this activity to your scope of practice?			
Not at all	Somewhat	Mostly	Extremely

RETURN ANSWER SHEET TO

Online members, complete your answer sheet online

CPD PORTAL: http://foh-cpd.co.za/cpd-online/cpd-user (Username: FOH number & Password: ID)

(Results are available immediately)

Email or **hard copy members**, complete your answer sheet online or return it to:

WHATSAPP: 074 230 3874 **EMAIL:** info@foh-cpd.co.za

(Results will be sent via email)

You will receive a confirmation of receipt either by Whatspp or email within 12-24hours, if not received please send again.

Have a suggestion or comment?

Send it to us on **EMAIL or WHATSAPP**