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An initial exploration of factors that may impact radiographer performance in reporting mammograms

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ABSTRACT

Objectives: In the United Kingdom, radiographers with a qualification in image interpretation have interpreted mammograms since 1995. These radiographers work under the title of radiography advanced practitioners (RAP) or Consultant Radiographer. This study extends upon what has been very recently published by exploring further clinical, non-clinical and experiential factors that may impact the reporting performance of RAPs.

Methods: Fifteen RAPs interpreted an image test set of 60 2D mammograms of known truth using the Detected-X software platform. Unknown to the reader, twenty cases contained a malignancy. Sensitivity, specificity, lesion sensitivity, receiver operating characteristic (ROC) and jack-knife free response operating characteristic (AFROC) values were established for each RAP. Specific features that had significant impact on accuracy were identified using Student's-T and Mann Whitney tests.

Results: RAPs with more than 10 years' experience in image interpretation, compared to those with less than 10 years' experience, demonstrated lower specificity (51.3% vs 84.8%, $p = 0.0264$), ROC (0.83 vs 0.91, $p = 0.0264$) and AFROC (0.75 vs 0.87, $p = 0.0037$) values. Further, higher sensitivity values of 90.7% were seen in those RAPs who had an eye test in the last year compared to those who had not, 82% ($p = 0.021$). Other changes are presented in the paper.

Conclusion: These data reveal previously unidentified factors that impact the diagnostic efficacy of RAPs when interpreting mammographic images. Highlighting such findings will empower screening authorities to better examine ways of standardising performance and offer a baseline for performance benchmarks.

Implications for practice: This study for the first time performs an initial exploration of the factors that may be associated with RAP performance when interpreting screening mammograms.

Introduction

Breast cancer is the most prevalent form of cancer in the United Kingdom (UK) with approximately 41,000 cases reported annually.[1,2] Nine out of ten women will survive for a minimum of five years if diagnosed early. Organised screening programmes such as the UK National Health Service Breast Screening Programme (NHSBSP) improves breast cancer outcomes by early detection when the presence of the disease is impalpable.[3] Interpretation of mammograms remains the gold standard and offers a non-invasive inexpensive solution to detecting cancers of less than 1 cm[4] and efficient interpretation is the foundation of breast screening programmes. Health care professionals who review mammograms, require the knowledge to identify areas for further investigation, and differentiate between malignant, normal and benign appearances.[5,6] This requires specialised training and experience.

UK Radiographers have been trained to interpret mammograms since 1995. This resulted from a paucity of radiologists and an increasing need for mammography interpretation.[7] A plethora of data is available on radiologist interpretation[8,9] as well as evidence in support of radiographers performing to the same level as a breast radiologist,[10,11] however, factors that specifically promote radiographic interpretation, unlike radiologic interpretation have not been explored. It may be naïve to presume that factors pertinent to radiologists are relevant to radiographers when demographic characteristics, clinical experience and educational background are quite different between the two groups.[12,13]

Criteria that impact upon image interpretation have been identified through platforms such as Personal Performance in

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Mammographic Screening (PERFORMS) in the UK and Breast Screen Reader Assessment Strategy (BREAST) in Australia. The focus of both programmes has been based primarily on radiologist data, with statistical analysis demonstrating an array of factors which determine high diagnostic efficacy, including reading volume,[14,15] type of training,[16,13] sleeping patterns,[17] time of day when reporting,[18] lesion type,[12] gender[12] and social networking.[19] Such data are rarely available for Radiography Advanced Practitioners (RAPs) or Consultant Radiographers, and currently we do not fully understand if these factors affect radiographers and radiologists in the same way.

This work extends on that by Clerkin et al. (2023) which looked at a number of *clinical* factors and their impact on RAP performance, for example annual reading volume, years of experience and the availability of prior images.[20] The current paper reports on further examination of clinical and experiential factors, years' experience and work pattern and performs an initial exploration of the factors that may be associated with RAP performance when interpreting screening mammograms. It also investigates *non-clinical* considerations for example extracurricular activities, personal eye health as well as work experience outside of the clinical setting. This is to further ascertain potential reasons for varying RAP and Consultant Radiographer mammographic screening performance and identify areas to facilitate reporting optimisation.

Methods

The study comprised of a two part quantitative approach to investigate factors that may impact RAP image interpretation. An image test set was used to allow radiographers to interpret a set of mammograms followed by a questionnaire to document demographic and detailed parameters documented below. The image test set and questionnaire were accessed through the DetectedX online platform. Advanced Radiographers who report for the National Health Service (NHS) breast symptomatic and breast screening service were recruited for the project. A qualification in breast image interpretation was part of the inclusion criteria as well as only those RAPs who could complete the image test set under clinical conditions using a 5 MP imaging workstation. Specific reader location was not limited, as all UK readers, both radiologists and radiographers, must meet the same national performance targets outlined by the NHSBSP, regardless of where in the country they read.

15 radiographers holding a qualification in breast image interpretation were involved in the work and these were located Norfolk, West Suffolk, Derbyshire, Essex, Yorkshire, Cumbria, Hampshire, Somerset, Cornwall, Antrim, Armagh and Derry. Recruitment occurred via the Society and College of Radiographers (SCoR) Consultant Radiography Synapse Group, recruitment material, a national conference and the NHS breast service. Prior to commencing the study, a participation information document was provided to all participants. Once informed consent was obtained, detailed instructions was provided through an instruction leaflet. This leaflet contained researcher contact information, allowing all participants to avail of an in-person meeting or digital video call if required. An instruction video on how to utilise the platform was also available to all readers. University of Suffolk (RETH(P)21/006) granted ethical approval for the work.

All candidates completed a questionnaire, from which details used in the statistical analysis section below were acquired.

Once registered, a 60-mammogram test set was presented to each participant representative of a typical reading session. Each case was collated from the Australian Breast Screening Programme and an independent radiologist expert in breast screening verified that all cases included were of acceptable quality and varied density, comparable to the UK population. Each case included two standard cranial-caudal (CC) and two medial-lateral oblique (MLO) projections. 20 of these cases contained a biopsy-detected malignancy; the remaining 40 received a return to normal screening result, the reader was not informed of this. The 20 detected cancers included both invasive and in-situ disease: 12 of the invasive cases included 2 asymmetric densities and 10 spiculated masses, whilst the remaining 8 cases demonstrated indeterminate micro calcification positive for ductal carcinoma in situ. The 40 normal cases included benign findings such as duct ectasia, fibroadenomas, oil cysts and intra-mammary lymph nodes. All results were established by two independent reporting radiologists alongside a two-year follow up mammography result. Comparable to a reader's clinical environment, readers were able to re-enter the study and amend their selections as often as they wished, until the point where they finally submitted their findings for analysis. Information on the number of cases with an abnormality was not made available to the participant.

Using the Detected-X platform, participants were invited to analyse each case and mark any suspicious areas for concern. Once an area was identified, the reader could rate the region of interest. The rating used represents the scoring system used in the Australian Screening service, which aligns with the UK's one to five scale,[7] one demonstrating no concern and five highlighting a definitive malignancy. Markings selected by the participant within a specific pre-set radius were accepted as correct, with radii set by expert radiologists supported by associated pathology reports. Post-processing tools available were also available, these included contrast, windowing, panning and magnification. When an area was identified as suspicious by the participant, the reader could then use a drop-down selection to describe their findings. These included: mass, asymmetric density, architectural distortion, micro-calcification and other. Subsections within this list included descriptions of the identified mass (global/focal) and micro-calcification (amorphous/course heterogenous/pleomorphic/linear branching). Benign options were also available for selection. These included: low-lying inframammary nodes, a superimposed nipple, or a subcutaneous lesion. If no findings were selected, the mammogram was presumed as normal. The scoring system and post processing options was explained to each reader prior to commencing the study.

In order to simulate a clinical reporting environment all 15 participants acting as first reader, undertook the study in their clinical workplace, using a 5 MP imaging workstation under optimum lighting conditions. As recommended by the NHSBSP, optimum viewing conditions are stated as a maximum luminance of no lower than 450cd/m2 with all rooms darkened with no direct sunlight with a typical lux value of 10–20.[21] Viewer functionality on the Detected-X platform ensured full native resolution was available to all participants.

Of the 15 participants, 14 currently read for the NHS breast screening programme and the symptomatic service and one for the symptomatic service only. 93% of readers are required to read a minimum of 5000 mammograms per year with 86% of readers with more than five years of experience in mammography image interpretation.

Statistical analysis

Sensitivity, lesion sensitivity, specificity, response operating character curve (ROC) and Jack-knife alternative free-response operating characteristic curve (AFROC) curves were analysed using built-in algorithms available on the Detected-X platform.

The performance metrics are defined below:

- Sensitivity: the percentage of accurately identified breast cancer cases divided by total number of breast cancer cases[22];
- Lesion sensitivity: the percentage of correctly located malignant findings versus the total number of malignancies[23];
- Specificity: the number of negative mammograms read by the participant divided by the number of actual negative cases;
- ROC curve is a graph of the true positive fraction (y axis) against the false positive fraction (x axis)[24] and the area under the curve is calculated;
- AFROC curve is a graph of the lesion localization fraction (LLF) (y co-ordinate) versus the non-lesion localisation fraction (NLF) (x-coordinate). The denominators for the fractions are defined as the total number of lesions and images respectively[25] and the area under the curve is calculated.

Depending on the distribution of data and whether it was non-skewed or not (as tested by the D'Agostino-Pearson omnibus normality test), either an unpaired Student's T-tests (parametric) or an unpaired Mann-Whitney tests (non-parametric) was used to analyse the effect of the following on performance values: participants age; gender; subjects studied at school; number of years qualified; qualification type; method of working; years of experience; any additional third level qualifications; extra-curricular activities; optician visits; sleep patterns; volume of reads per year; image Interpretation time; intervals taken in during reporting; readers' service type; involvement in shared learning activities; and multi-disciplinary attendance. Finally, RAPs' opinions were achieved through the questionnaire on whether noise levels within their reading environment, interruptions whilst reporting and their emotional mindset effected their reading performance as well as the importance of previous imaging and opinions on most challenging pathologies.

Results

The results of the statistical analyses are presented in Tables 1 and 2 with all significant findings highlighted in the tables and described below.

It was Identified that RAPs with more than 10 years' experience in image interpretation, compared to those with less than 10 years' experience, had lower specificity (51.3% vs 84.8%, $p = 0.0264$), lower ROC (0.83 vs 0.91, $p = 0.0264$) and lower AFROC (0.75 vs 0.87, $p = 0.0037$) scores. Lower specificity values (88.0 vs 75.0, $p = 0.0275$) were also seen in readers who did not undertook sporting activities compared to those who did.

Higher sensitivity (90.7 vs 82.0, $p = 0.021$) and lesion sensitivity values (90.4 vs 81.0, $p = 0.021$) were seen in RAPs who had an eye test in the last year compared to those who had not had their eyes tested.

Higher lesion sensitivity values were also identified ($p = 0.0067$) were demonstrated in Radiographers who held a radiography

Table 1
History: Sensitivity, Specificity and Lesion Sensitivity is shown in the table with standard deviation or *interquartile values* in brackets.
(Asterisks indicates where a significant difference is shown, with a * = p < 0.05; **p < 0.01; ***p=<0.001).

Parameter	Sensitivity	Specificity	Lesion Sensitivity
39 years or younger (n = 4)	88.7 (7.9)	89.0 (78.5–93)	90 (7.6)
40 years or older (n = 11)	88.0 (7.5)	82.5 (67–88.5)	86 (8.4)
<20 Years Radiography experience (n = 6)	86.8 (7.8)	85.9 (8.7)	88.6 (9.5)
>20 Years Radiography experience (n = 9)	90.7 (6.7)	68.9 (28.8)	86.4 (5.6)
FT Work Pattern (n = 9)	89.6 (6.2)	76.1 (24.0)	87.5 (6.9)
PT Work Pattern (n = 6)	85.8 (9.7)	85.5 (7.5)	82.5 (9.7)
≤10 Years Image Interpretation Experience (n = 10)	85 (80–95)	84.8 (8.1)**	85 (85–95)
>10 Years Image Interpretation Experience (n = 5)	90 (90–95)	51.3 (40.4)	90 (80–90)
Analog Reading Experience (n = 11)	90 (85–95)	88 (75–93)	85.0 (6.7)
No Analog Reading Experience (n = 4)	85 (80–100)	80 (70–90)	92.1 (8.6)
Interventional Breast Technique Experience (n = 10)	95 (82.5–100)	80 (41.5–91.5)	85.0 (3.2)
Other Breast Speciality (n = 5)	85 (82.5–90)	85 (76.5–93)	89.2 (9.5)
Other Work Experience (n = 3)	85 (77.5–83.7)	80 (23.5–93.8)	86.2 (12.5)
Only Rad Experience (n = 12)	90 (83.7–96.2)	85 (77.3–93)	88.2 (7.0)
Corrective Lenses (n = 9)	90.0 (6.6)	82.5 (73.8–90.8)	89.0 (7.4)
No Lenses required (n = 6)	86.2 (8.3)	86.5 (78.5–95)	86.2 (9.2)
Most Recent Eyes Test <1 Year (n = 11)	90.7 (6.7)*	80 (72.5–93)	90.4 (7.2)*
Most Recent Eyes Test >1 Year (n = 4)	82.0 (5.7)	88 (81.5–94)	81.0 (6.5)
Hours slept≥8 Hours (n = 8)	88.8 (7.9)	86.1 (6.3)	88.1 (7.9)
Hours slept <8 Hours (n = 7)	88.0 (7.5)	73.8 (25.9)	87.5 (8.6)
Degree Qualification (n = 11)	89.3 (7.03)	86.5 (75–93)	90.4 (6.6)**
Diploma or Other Qualification (n = 4)	85.0 (9.1)	82.5 (63.5–92.5)	78.8 (6.3)
Interventional Experience (n = 6)	89.2 (4.9)	69.5 (32.7)	85 (3.2)
No Interventional Experience (n = 9)	97.9 (8.6)	84.1 (8.5)	89.1 (9.5)
Ultrasound Experience (n = 13)	90 (80–95)	85 (75–93)	85 (80–90)
No Ultrasound Experience (n = 2)	85 (85–95)	80 (70–90)	100 (85–100)
CT Experience (n = 3)	85 (85–92.5)	88 (75–93)	93 (7.58)
No CT Experience (n = 12)	90 (80–95)	85 (75–91.5)	85.7 (7.59)
Sport Activities (n = 7)	86.8 (8.2)	88 (80–93)	87.3 (9.0)
Other Activities (n = 8)	90.7 (6.1)	75 (58–90)	88.6 (6.9)
Gardening Activities (n = 4)	92.0 (6.7)	80 (41.5–91.5)	89 (6.5)
Other Activities (n = 9)	86.9 (7.5)	85 (91.5–93)	87.3 (8.8)
Puzzles Activities (n = 4)	95 (90–95)	48.7 (36.9)***	85.0[5]
Other Activities (n = 11)	85 (80–90)	85.4 (8.0)	88.3 (8.6)
Board games Activities (n = 3)	85.0 (80–90)	89 (85–93)	82.5 (82.5–85)
Other Games (n = 12)	87.5 (85–95)	82.5 (82.5–95)	87.5 (85–95)

Table 2
History: ROC values are shown in the table with standard deviation or interquartile values in brackets (Asterisks indicates where a significant difference shown, with a. * = p < 0.05; **p < 0.01; p=<0.001).
AFROC values are shown with the upper and lower limits of the confidence intervals shown in brackets.
Numbers of participants used for each analysis are shown by (n = XXX).

Parameter	ROC	AFROC
39 years or younger (n = 4)	0.91 (0.03)	0.86 (0.76, 0.99)
40 years or older (n = 11)	0.89 (0.07)	0.83 (0.57, 0.99)
<20 Years Radiography experience (n = 6)	0.90 (0.04)	0.86 (0.77, 0.99)
>20 Years Radiography experience (n = 9)	0.98 (0.09)	0.82 (0.57, 0.98)
Full Time Work Pattern (n = 9)	0.89 (0.07)	0.84 (0.57, 0.99)
Part Time Work Pattern (n = 6)	0.92 (0.04)	0.86 (0.77, 0.99)
≤10 Years Image Interpretation Experience (n = 10)	0.91 (0.04)	0.87 (0.77, 0.99)
>10 Years Image Interpretation Experience (n = 5)	0.83 (0.19)	0.75 (0.57, 0.98)
Analog Reading Experience (n = 11)	0.93 (0.88–0.96)	0.87 (0.81, 0.88)
No Analog Reading Experience (n = 4)	0.88 (0.85–0.95)	0.86 (0.82, 0.90)
Interventional Breast Technique Experience (n = 10)	0.95 (0.82–0.96)	0.80 (0.57, 0.99)
Other Breast Speciality (n = 5)	0.91 (0.86–0.95)	0.87 (0.76, 0.99)
Other Work Experience (n = 3)	0.87 (0.75–0.95)	0.81 (0.57, 0.99)
Only Rad Experience (n = 12)	0.93 (0.87–0.95)	0.86 (0.67, 0.99)
Corrective Lenses (n = 9)	0.91 (0.05)	0.85 (0.63, 0.98)
No Lenses required (n = 6)	0.88 (0.08)	0.83 (0.57, 0.99)
Most Recent Eyes Test <1 Year (n = 11)	0.92 (0.86–0.95)	0.84 (0.57, 0.99)
Most Recent Eyes Test >1 Year (n = 4)	0.91 (0.86–0.96)	0.86 (0.77, 0.98)
Hours slept≥8 Hours (n = 8)	0.91 (0.03)	0.86 (0.63, 0.99)
Hours slept <8 Hours (n = 7)	0.88 (0.07)	0.83 (0.57, 0.98)
Degree Qualification (n = 11)	0.92 (0.86–0.94)	0.87 (0.82–0.90)
Diploma Qualification (n = 4)	0.91 (0.82–0.95)	0.85 (0.73–0.87)
Interventional Experience (n = 6)	0.91 (0.78–0.93)	0.79 (0.57, 0.99)
No Interventional Experience (n = 9)	0.93 (0.87–0.96)	0.87 (0.76, 0.99)
Ultrasound Experience (n = 13)	0.92 (0.86–0.95)	0.86 (0.82, 0.92)
No Ultrasound Experience (n = 4)	0.88 (0.85–0.93)	0.86 (0.81, 0.89)
CT Experience (n = 3)	0.92 (0.88–0.92)	0.85 (0.85, 0.89)
No CT Experience (n = 12)	0.93 (0.85–0.95)	0.86 (0.81, 0.89)
Sport Activities (n = 7)	0.91 (0.04)	0.86 (0.63, 0.98)
Other Activities (n = 8)	0.86 (0.08)	0.82 (0.57, 0.99)
Gardening Activities (n = 4)	0.88 (0.09)	0.83 (0.57, 0.98)
Other Activities (n = 9)	0.90 (0.05)	0.85 (0.63, 0.99)
Puzzles Activities (n = 4)	0.82 (0.11)*	0.74 (0.63, 0.98)
Other Activities (n = 11)	0.91 (0.04)	0.87 (0.57, 0.99)
Board games Activities (n = 3)	0.91 (0.87–0.93)	0.86 (0.85, 0.86)
Other Games (n = 12)	0.92 (0.85–0.96)	0.86 (0.82, 0.89)

degree (90.4) compared to those who held an alternative undergraduate qualification (78.8).

Finally, lower AFROC values (0.79 vs 0.87, p = 0.042) were noted in readers who previously worked in Interventional Radiology compared to those who did not.

Discussion

A work force skill mix alongside a mammographer career development structure support the NHS breast screening programme. This structure includes tiers from assistant practitioner to consultant radiographer. The roles and responsibilities of each level have been established by Health Education England, Royal College of Radiologists, National Breast Imaging Academy and the Association of Breast Clinicians.[26] Since 1995 Radiographer Advanced Practitioners (RAP) have contributed to the UK mammography interpretation workload and the success of this initiative has been widely documented.[7,27–30] The aim of the current research was not to demonstrate radiographers' ability to report, but instead to explore the factors that may influence reporting performance. A previous paper by our group examined the clinical background of RAPs and showed that factors that had been studied for radiologists such as volume of mammograms read, prior images and emotional mindset were key determinants of interpretive abilities.[20] This research extends this work by examining non-clinical histories as well as other clinical factors previously not investigated.

The specificity of the RAPs in this study showed that those with more than 10 years' experience had 34% lower specificity values than those with less than 10 years' experience. This tends to suggest that RAPs become more cautious in their decision making as they become more experienced, and although this has been rarely documented before in image interpretation, it is well reported elsewhere. For example, it has been shown outside medicine that economists are less likely to undertake risky investments as they become more experienced[31–33]; social media users are more cautious with the material they post as they age[34]; drivers with more years are less likely to undertake reckless driving activities[35]; the general public are more unlikely to challenge an opinion or meet new people as they get older.[36] Within the medical sector, it has also been shown that greater experience can result in a more conservative approach. For example, it has been reported that general practitioners, surgeons and physicians[37–39] will deliberately avoid more complicated or difficult cases as their length of experience increases,[40] with the threat of medical malpractice being commonly cited as the cause. Although causal agents for the experience/caution relationship for radiographers cannot be cited here, the paper does suggest a similar cautious practice in breast imaging. Radiographers as they become more experienced place greater emphasis on ensuring that cancers are not missed thus leading to an inevitable increase in recall rates.[39] This needs now to be acknowledged if readers are to continue to meet the acceptable performance thresholds of less than 10% for prevalent cases and less than 7% for incident cases as set out by the NHSBSP.[41]

Another notable finding that we report here is that readers who had an eye test in the last year had higher sensitivity and lesion sensitivity scores than readers who had not. Whilst the data here does not definitively show a causative link, there does appear to be a real association. Currently, eye testing is not a requirement for readers working for the NHSBSP and in Europe there is no legislation that mandates regular ocular health checks for any worker who uses display monitors.[42] Nonetheless, some governing bodies for example those associated with the air force ensure visual acuity assessments are undertaken at set intervals.[23] Our findings highlight the importance of revisiting the possibility of more regulated eye checks, particularly for occupations that have such important public health safety responsibilities such as reporting radiographers or radiologists.

Other significant findings are summarised in the results. In particular it is interesting to note that radiographers who hold a radiography degree level-qualification compared to others had higher lesion sensitivity values. Whilst the impact of degree level education, which may incorporate more interpretative-type content may be the reason for this improved performance, further work on this and the other incidental findings is required to better understand their impact.

Limitations within this study included recruitment and questionnaire development. The sample size of 15 participants may be regarded as less than ideal, however similar studies in this field have included sample sizes of ten or less readers.[23,43] Nonetheless a larger group of candidates would have allowed much more categorisation into various experience, age and other groups, thus facilitating a more in-depth analysis. The author has since developed a Special Interest Group affiliated with the Society and College of Radiographers which should aid and improve recruitment in the future. It is possible that the questionnaire presentation may have limited data exploration. For future recruitment, questionnaire redevelopment will be implemented and a wider range of activities and interests included.

Implications for practice

These findings have extended current knowledge by highlighting for the first time how various agents such as levels of experience, frequency of eye tests and potentially education levels may be associated with the diagnostic efficacy of radiography advanced practitioners when interpreting mammographic cases. Despite adherence to accreditation standards and recommended practices, varying performance levels can be observed amongst this population of readers as previously seen amongst their radiology counterparts. Identifying factors should help in standardising performance.

Conflict of interest statement

None.

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