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Narrative Review

Identification of factors associated with diagnostic performance variation in reporting of mammograms: A review☆

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ABSTRACT

Objectives: This narrative review aims to identify what factors are linked to diagnostic performance variation for those who interpret mammograms. Identification of influential factors has potential to contribute to the optimisation of breast cancer diagnosis. PubMed, ScienceDirect and Google Scholar databases were searched using the following terms: 'Radiology', 'Radiologist', 'Radiographer', 'Radiography', 'Mammography', 'Interpret', 'read', 'observe' 'report', 'screen', 'image', 'performance' and 'characteristics.' Exclusion criteria included articles published prior to 2000 as digital mammography was introduced at this time. Non-English articles language were also excluded. 38 of 2542 studies identified were analysed.

Key findings: Influencing factors included, new technology, volume of reads, experience and training, availability of prior images, social networking, fatigue and time-of-day of interpretation. Advancements in breast imaging such as digital breast tomosynthesis and volume of mammograms are primary factors that affect performance as well as tiredness, time-of-day when images are interpreted, stages of training and years of experience. Recent studies emphasised the importance of social networking and knowledge sharing if breast cancer diagnosis is to be optimised.

Conclusion: It was demonstrated that data on radiologist performance variability is widely available but there is a paucity of data on radiographers who interpret mammographic images.

Implications for practice: This scarcity of research needs to be addressed in order to optimise radiography-led reporting and set baseline values for diagnostic efficacy.

Introduction

In 2021, female breast cancer became the most commonly diagnosed cancer contributing to an estimated 2.3 million cases.[1] Early detection of invasive disease that contributes to 80% of diagnosed breast cancers, provides the opportunity for a treatment pathway which enables the best chance of survival.[2] To facilitate early detection, screening programs involving mammography offer a non-invasive solution to detect malignancies of less than 1 cm.[3] Such nationally organised screening services are common practice in several developed countries.[4] In the United Kingdom (UK) for example the National Health Service Breast Screening Programme (NHSBSP) invites women to attend breast screening appointments after their fiftieth birthday.[5] A high standard of image interpretation allowing for optimum cancer detection[6] and the ability to identify potentially abnormalities from benign appearances are the cornerstone of a skilled image interpreter.[7] In the UK, breast radiologists have been the primary specialist involved with interpreting mammograms, however from 1995 due to the increasing demand for mammography interpretation and the paucity of radiologists, radiographers have been trained to also interpret screening mammograms.[8] Such training has been well documented and includes rigorous programmes of academic standing and clinical supervision to develop cancer detection skills that are comparable with radiologists.[7–9]

Identifying criteria that impact upon image interpretation for all mammographic readers has been achieved with programmes such as the Personal Performance in Mammographic Screening (PERFORMS) in the UK and the Breast Screen Reader Assessment Strategy (BREAST) in Australia. The focus of both programmes have primarily based on radiologist data, with analyses demonstrating factors impacting diagnostic efficacy such as annual reading volume,[10,11] sleeping patterns,[12] time of day,[13] training programs,[14,15]

☆ How much does diagnostic efficacy vary across readers of digital breast images and what are the agents linked to performance variation?

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types of lesions,[16] social networking[17] and even gender.[16] The aim of this review is to analyse the literature and explore if similar agents that impact radiologist performance have been identified amongst Radiography Advanced Practitioners (RAP).

Methods

We the authors declare that Ethics Committee approval is not required.

To support evidence-based practice and to ensure a comprehensive literature search, the researcher followed PICO (Population, Intervention Comparison and Outcome) criteria.[82] It allows the investigator to identify components of clinical evidence for literature reviews and is endorsed by the Cochrane Collaboration.[18] Search categories are demonstrated in Table 1.

PubMed ScienceDirect and Google scholar database were searched. Search terms are demonstrated in Table 2 following the PICO tool. The first digital mammography unit that was Food and Drug Administration (FDA) approved was introduced at the turn of the century, this supported the reviewers decision to include studies from 2000.[19] Eligibility criteria for the study were all peer reviewed articles discussing digital radiological breast image interpretation. Inclusion criteria were any reader that interprets and reports on mammograms and the factors that affect how they interpret breast images. Exclusion criteria were articles published prior to 2000 or not written in the English language. Articles identified were loaded onto EndNote X7.7.1 for Windows 2008 and duplicates were removed. The search was limited to articles in English.

Titles and abstracts were reviewed as per inclusion and exclusion criteria by the author and her supervisors. Full text copies were further investigated once the inclusion criteria were met. For relevance to the search aim, all articles that met the inclusion criteria were inputted into a table format and circulated amongst all reviewers. Any disagreements were resolved via discussion.

2542 studies were retrieved using the search strategy described in Table 1. Duplicates were removed and inclusion and exclusion criteria were applied. The full text of 49 articles were assessed and a further 16 were excluded. Reference lists of the remaining 33 articles were hand searched and an additional five studies were included. This is presented in the PRISMA flowchart in Table 3. Articles included within the study included image test sets, evaluation of performance, retrospective data and interviews.

Results and discussion

Narrative synthesis

The efficacy of mammography relies on accurate interpretation by expert readers. It is well known that this interpretation can vary significantly, depending on a variety of factors.[10] Sensitivity, that is the ability to identify cancer for example can be as low or as high as 53–94% depending on the number of mammographic readings per year[20] and the interpreter's reading conditions.[21] The ability to detect cancer can also improve after two or three years of reading experience, but can also be the reader's steepest learning curve.[22] In addition, specificity or recognition of normal images can also vary significantly with values ranging from 74% to 98% depending on the clinician's mammographic reading volume and experience.[23,24] Also, false positive rates are dependent on professional backgrounds with values being as low as 15.6% vs 47.1% for certain reader groupings.[25] A full understanding of these variations are required if optimal diagnoses are to be achieved ensuring the best possible service to women undergoing screening.

It is important to acknowledge that the introduction of new technologies can impact positively on reader performances. For example, 79% of reader sensitivity in cancer detection improves with the use of digital breast tomosynthesis (DBT) compared with the sole use of digital mammography (DM),[26] with a reduction in recall rates by 11% also been demonstrated with newer technology.[27] Nonetheless, the greatest level of performance variation seems to be more dependent on reader characteristics rather than technology, with many investigations documenting the impact of reader experiences and practices. Factors such as hours reading per week, experience, fatigue and time spent interpreting mammograms[23,24,28–30] have all impacted significantly upon performance. Recent studies have even associated social network size with volume of mammograms read, stating that the combination of these factors can explain 63.4% of variance in reader performance. The importance of the reader characteristics on the efficacy of screening mammography cannot therefore be overstated and with evidence arriving regularly on this issue, it is the aim of this review to summarise current knowledge around factors affecting reader performance.

Volume of reporting

Volume of mammographic reporting has been demonstrated as the most important factor affecting the sensitivity of a radiologist's performance.[31] Variations in volume differ across the globe. In the UK, a minimum number of 5000 screening mammographic cases have to be interpreted in order to qualify to interpret for the NHSBSP.[32] In Australia 2000 cases[33] and 960 cases over a two year period in the United States[34] are the minimum number of readings that are required to achieve accreditation. The bases for these differences are not apparent, however the literature does concur that radiologists who annually read less than 1000 cases have lower performance scores[35,36] compared with those with higher annual volumes. In particular it is demonstrated that readers in Canada who interpreted under 500 mammography cases per year experienced an accuracy rate of 58% less than their peers who interpreted greater than or equal to the 500-target.[37] In addition, the same study highlighted a 32% increase in accuracy in readers who interpreted an annual number of 4000 cases or more compared with radiologists that read between 500 and 999 annual mammograms. An Australian study supported this performance relationship by reporting that readers who read more than 2000 reads per year demonstrate higher levels of sensitivity than their peers who read less than 1000 annual cases.[29]

Radiologist's experience and training

The literature reports that optimum performance is not just affected by numbers of reads per year but is also impacted by

Table 1
Search categories and PICO headings.

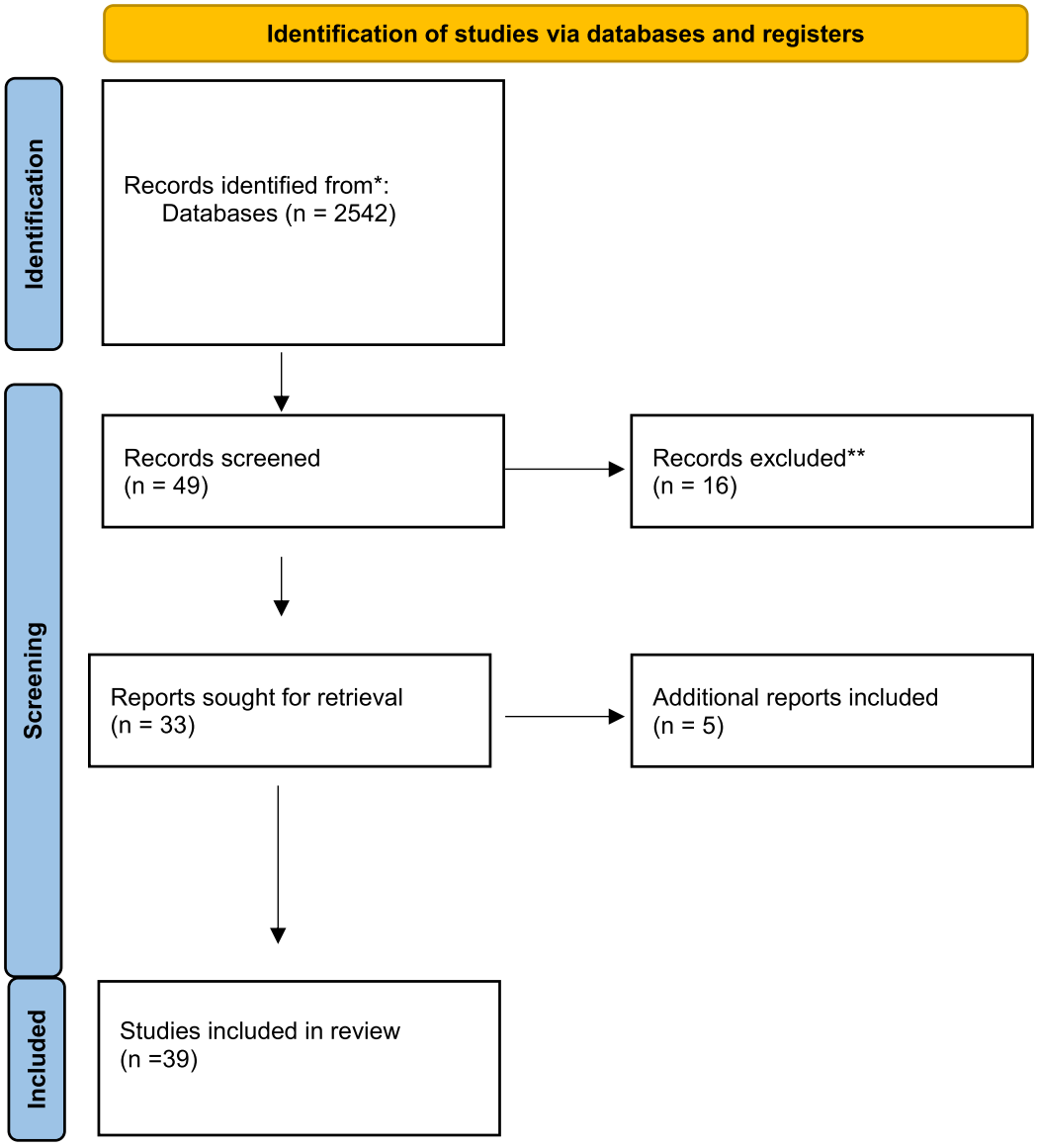
Search Categories	PICO
Readers: Radiologists, Radiographers, Radiography Advanced Practitioners	Population
Digital Breast Images	Intervention
Agents: Volume, Experience and training, availability of prior images, social networking, fatigue, and time of day	Comparison
Diagnostic efficacy: Sensitivity, Specificity, ROC, JAFROC	Outcome

Table 2
Search terms used in the PICO search.

	PubMed	ScienceDirect	Google scholar
P	Radiology, Radiologist, Radiographer, Radiography*and Mammography* Advanced Practice*	Radiology, Radiologist, Radiographer, Radiography and Mammography, Advanced Practice	Radiology, Radiologist, Radiographer, Radiography*and Mammography*, Advanced Practice*
I	Interpret*, read*, observe*, report*, screen, image	Interpret, read, observe, report, screen, image	Interpret*, read*, observe*, report*, screen, image
C	Performance AND characteristics	Performance AND characteristics	Performance AND characteristics
O	Breast cancer detection and accuracy	Breast cancer detection and accuracy	Breast cancer detection and accuracy

Footnote: * is a truncation symbol to retrieve terms within PubMed and Google Scholar.

Table 3
Identification of studies via databases using PRISMA 2020.



variations in experience levels and continuing education.[29] It has been shown that sensitivity improves during a radiologist's initial years of interpreting mammograms and continues to improve as they gain more years of experience.[22] Studies have demonstrated that with increasing years of experience *and* continuous professional development (CPD), readers may reduce the number of benign recalls (false-positive rates) while maintaining high cancer detection rates.[23,40,41] However it is important to note that the years of reading experience cannot compensate for a low number of cases read in one given year[35,38]: when reading volume is low, sensitivity can *decrease* with years of experience.[23,38] It is interesting to note that this dependency of performance on volume

despite years of experience has been emphasised in many non-radiologic domains such as general medical practice,[39] auditing,[40] chess and music.[41]

Specific training programmes have been shown to impact image interpretation. It has been highlighted that fellowship training has a positive relationship with sensitivity,[42] however it also demonstrated that radiologists who have completed a fellowship programme have a significantly higher recall and false positive rates against those who do not.[43] An interesting result from another study documented that radiologists who underwent fellowship training in breast imaging interpretation reached optimum cancer detection levels during their first year of practice.[22] This highlights the importance of targeted CPD.

Availability of prior images

The availability of prior images is another important consideration. Studies have shown that when previous mammograms were available, performance can improve. However, the picture is a little unclear particularly for sensitivity: in one study performed in 2011, sensitivity was 87.4% and 78.9% with and without prior mammograms respectively,[44] however in a 2014 study no impact was shown in cancer detection rates with invasive, ductal, lobular or non-invasive disease when compared with one or even multiple priors.[45] In terms of specificity, the situation is more clear: a recent study in 2016 focussing on recall rates when mammograms were interpreted without prior mammograms or with previous mammograms from a single or multiple years showed that recall rates were 16.6%, 7.8% and 6.3% respectively.[46] This was supported by further work where recall rates of non-cancerous areas that had distortion or asymmetric appearance were reduced by an average of 44% when previous images were used for comparison.[47]

Social networking

Studies have analysed the impact of social networking on image interpretation. It has been demonstrated that knowledge dissemination can facilitate improved performance.[48] Results have shown that valuable feedback presented through a variety of communication technologies can build a social support network and contribute to improved cancer detection. A study investigating the social dynamics of a group of breast radiologists, outlined a strong association between social and professional interactions with optimum performance. The study outlined how radiologists with a wide circle of peers had a positive correlation with improved image interpretation.[49] An example of such interactions is attending Multi-disciplinary Team (MDT) meetings: a study undertaken in 2014 established the benefits of radiologists attending and participating in regular MDT meetings where sharing experiences with members of their cancer care team not only impacted patient care delivery and workplace isolation but also their image interpretation skills.[50] A study by Taba et al. (2016) highlighted that network factors account for 48% of variation in image interpretation over personal characteristics that scored 15.5%,[17] larger than any other technical or experiential parameter studied in that work. However, this study did acknowledge that setting up effective image-based social networks amongst radiologists can be challenging, emphasising the importance of technology to facilitate feedback and enhance learning.

Fatigue

While several studies have evaluated the impact of fatigue on observer performance when interpreting medical images[30,51–55] not many of these papers have focused primarily on breast imaging. From the limited mammography-based work, visual fatigue has been shown to have an important impact on interpretation behaviour[14,53] with readers' decision times being much longer in later afternoon compared with morning sessions resulting from a reduced visual capability to focus on different mammographic targets.[54] An Australian study reviewed the impact of hours spent awake on radiologist's ability to interpret images and showed that a reader who had less than 6 h sleep the night before an interpretation session, demonstrated significantly lower lesion sensitivity than other readers with more than 6 h sleep: lesion sensitivity for example of less experienced radiologists varied from 71.03% with higher hours slept compared with 44.6% from less hours slept. This study also showed that the influence of fatigue on performance appeared to only affect less experienced readers and that coping mechanisms are developed by the experienced reader to withstand fatigue.[56] However Krupinski et al. warn against compensatory mechanisms to counteract symptoms of fatigue such as taking less time when reporting, since this type of mitigating action when interpretating images increases the number of diagnostic errors made.[51] More research on the impact of fatigue and the efficacy of corrective strategies is required.

Time of day

The time of day when a reader interprets medical images, has been shown to impact performance in a variety of ways,[13,57–60] for example several studies have shown that mid-morning achieves an increased performance outcome compared with late afternoon.[61,62] A more recent study involving 197 readers analysed performance over six different periods of the day and highlighted that the best time to interpret images was between 2pm and 4pm, with the lowest overall performance calculated between 4pm and 6pm[13]: in particular, specificity was lower in late morning and late afternoon reading sessions, compared with early afternoon, whilst sensitivity was higher in late morning but like specificity lower in late afternoon. This late morning discrepancy between sensitivity and specificity interestingly may be been linked to a more risk averse approach adopted at different times of the day shown outside radiology[63]: decision makers such as judges, audiologists and gamblers, increase their risk aversity as hunger increases which could explain over-recalling amongst radiologists approaching lunch: i.e. increased sensitivity with reduced specificity.[64–66] Whilst these studies do suggest a dependent time effect on performance, it is important to acknowledge that other studies[60,67] have failed to show significant differences according to time of day, however this could possibly due to the sample sizing since far fewer clinicians were involved in these studies compared to the work described above.

What about non-radiologist reader populations?

The above discussion shows that new technology, volume of readings, radiologists' experience and training, availability of prior imaging, social networking, fatigue and time of day of image interpretation all have an important impact on diagnostic efficacy when diagnosing breast cancer with mammography. There is however one major omission to date: the work has focussed on radiologists, and whilst this is understandable since they predominantly interpret mammograms world-wide, other professional groups involved with mammographic reading have been largely ignored.

Once such group are radiographers. Since 1995, as a result of an increasing demand for mammography interpretation and the paucity of radiologists with a breast specialty, UK radiographers have been trained to interpret mammograms. A report published by the Royal College of Radiologists (RCR), detailed that 48

consultant radiographers and 261 RAP's were currently employed in breast imaging within the UK[68] and evidence has demonstrated that this initiative has improved healthcare services.[67,69,70] This role extension for radiographers is not unique to the UK: in Denmark RAP's have become a key group of individuals delivering reporting services[71]; in South Africa, Australia, Mexico and United Arab Emirates ongoing discussions are in place exploring the potential reporting role of radiographers.[72–76] Therefore, it is clear that professionals other than radiologists are starting to undertake breast cancer reporting activities, yet little or no ongoing data is available on the specific characteristics that promote optimum performance. This deficiency in the literature needs to be addressed if mammographic screening facilities that employ non-radiologists for reporting, wish to provide the best services.

Quality assurance programmes emphasise the importance of examining an image interpreter's cancer detection rates and recall rates thus allowing the monitoring of both the sensitivity and specificity of the reader. This encourages that women who require further investigation are recalled, whilst minimising the number of women recalled where no abnormalities are evident.[77] As part of the NHSBSP each UK health care professional who interprets mammograms can participate in an assessment scheme known as PERFORMS. Readers utilise a workstation available to them, where an image test set has been uploaded and record their findings on an adjacent computer using the PERFORMS website. Readers can locate, identify, and rate each image in terms of level of suspicion using the UK RCR screening classification scale or the Breast Imaging Reporting and Data System (BIRADS) rating scale. The PERFORMS platform collates data bi-annually after the reader interprets a series of Mammograms. The reader's imaging decision is judged against expert Radiological opinion, known case pathology and peer opinions providing information on areas of difficulty the reader may have found challenging.[78] Participation in PERFORMS have always been recommended by the RCR and more recently Public Health England have mandated that all readers reporting mammograms participate annually in External Quality Assurance activities (EQA schemes) to compare with real life interpretation performance.[79]

The capacity of radiographers to interpret mammograms has been well documented. As a result of the success of the NHSBSP and the shortage of breast radiologists, radiographers have been trained to image interpret mammograms accurately[8,77] and previous work shows that radiography image interpretation skills within the NHSBSP reflect that of radiologists.[10,11] These results align well to that obtained within other jurisdictions.[78,79] Radiographers have been included in the cohort of research analysing the characteristics of all readers interpreting mammograms[32,80] however, it has been documented through this review and older studies that there is a paucity of research investigating the factors that impact radiographers interpreting mammograms.[81] Out of the 38 studies in this review, five included radiographers independently. Only two of these studies included radiographers qualified in image interpretation and their primary focus was a qualitative exploration of their role. This demonstrates a disproportionate attention to radiologists with an oversimplistic assumption that the factors that affect their medical colleagues are the same factors that impact radiography image interpretation when educationally and experientially they are different. As a matter of urgency this gap in knowledge on causal agents linked to radiography reporting performance needs to be addressed.

Limitations

This review was limited to articles available in the English language and therefore findings may not be generalisable worldwide, however the studies included do represent a multinational cohort across continents.13 out of the 38 studies included in this review included radiographers and as a result a review of all readers was limited due to underrepresentation.

Conclusion

This review has demonstrated a range of factors that impact radiologic image interpretation. Additionally, the not uncommon, variations in diagnostic sensitivity and specificity of breast radiology emphasise the necessity of regular auditing. The causes for varying performance are multifactorial and whilst data on radiologist performance variability are widely available, there is a paucity of similar data on radiographers who in some jurisdictions play a critical role in reporting mammographic images.

This is one of the most important outcomes of this review: highlighting the underrepresentation of mammographic-based interpretation performance-based research amongst radiographers. Whilst it is imperative that we understand the factors responsible for radiologists when interpreting mammograms and these maybe relevant to radiographers, the inherent differences between these two populations should suggest that simple interpolation between the groups must be avoided. Until we have a comprehensive system of performance assessment for individual radiographers coupled with detailed data analyses, we cannot be assured of optimised reporting. This review underpins the need for further research into radiographer reporting variations and identification of causal agents.

Conflict of interest statement

None.

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