Journal of Medical Radiation Sciences

Open Access

ORIGINAL ARTICLE

Full-field digital mammography: the '30% rule' and influences on visualisation of the pectoralis major muscle on the craniocaudal view of the breast

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Keywords
30% rule, breast cancer, craniocaudal view, mammography, pectoralis major muscle

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Received: 6 February 2020; Accepted: 2 May 2020

J Med Radiat Sci **67** (2020) 177–184

doi: 10.1002/jmrs.404

Abstract

Introduction: To investigate compliance to the '30% rule' and key factors which may influence visualisation of the pectoralis major muscle (PMM) on the craniocaudal (CC) view of the breast. **Methods:** A retrospective review of 2688 paired full-field digital mammography (FFDM) CC view mammograms of women attending BreastScreen NSW between August and October 2015 was undertaken. PMM visualisation and measurements of PMM width and length, compressed breast thickness, the posterior nipple line (PNL) and age were recorded. Statistical analysis was performed using descriptive and inferential statistics to investigate associations between key breast measurements, age and PMM visualisation. **Results:** PMM visualisation was reported in 10.4% of images unilaterally (one breast, left or right only), 14.1% bilaterally (both left and right breasts) and 24.5% overall (unilateral and bilateral combined). There was little or no correlations between PMM length or width and age, breast compressed thickness or PNL. Multiple logistic regression analysis found that up to 15% of the variance in visualisation of the PMM was accounted for by the predictors overall. While some predictors provided a statistically significant contribution to the model, the contribution was small and the odds ratio for all predictors approximated 1. **Conclusion:** This research could not replicate the '30% rule', and visualisation of the PMM was determined not to be influenced by the variables investigated. The significance of the 'rule' itself must be challenged where the vast majority of images (70–85%) do not comply, and there is no requirement for repeat imaging if the 'rule' is not met. Further research should be undertaken to validate this study including analysis of diagnostic images for comparison.

Introduction

In Australia, one in seven women is diagnosed with breast cancer during their lifetime. Breast cancer is the second most common disease affecting Australian women and has the highest mortality rate for female cancers after lung cancer.[1] Mammography is the gold-standard diagnostic tool used for the detection and monitoring of breast cancer.[2] The inclusion of as much breast tissue as possible on the craniocaudal (CC) and mediolateral oblique (MLO) images is the aim of routine mammographic imaging with acceptable image quality in Australia being defined by the accrediting bodies, the Royal Australian and New Zealand College of Radiologists (RANZCR)[3] and BreastScreen Australia (BSA) for diagnostic and screening mammography, respectively.[4]

Image quality is assessed using well-recognised criteria, most of which are common for both settings. However, some, such as the '30% rule' (as it is anecdotally called in Australia), which describes the inclusion of the pectoralis major muscle (PMM) on the CC image are requirements of the RANZCR,[3] which is based on the accreditation standards of the American College of Radiologists (ACR),[5] and therefore specific to the diagnostic setting only. Visualisation of the PMM is said to be evidence that all posterior breast tissue has been included.[3] While the BSA National Accreditation Standards (NAS) do not explicitly mention the need for PMM visualisation, the schematic image displaying a perfect 'P' graded image of the CC view, depicts the PMM as being present.[4]

The '30% rule' was first documented 27 years ago, in the film screen (FS) era, by Bassett et al., establishing an overall visualisation rate of 32% .[6] When present, the PMM appears as a semi-ellipse density orientated along the posterior edge of the CC mammogram (Figure 1). The size and the curvature of the PMM boundary on the mammogram vary significantly from person to person, and the position along the chest wall is said to be highly dependent on positioning and physical habitus.[7] To enable the early detection of breast cancer, bilateral or paired mammographic examinations are needed for side by side comparison to enhance cancer detection.[8] Bassett's '30% rule' does not explicitly state a unilateral, bilateral or overall visualisation rate. A clear definition is also not provided by the subsequent literature,[9–17] accreditation standards[3–5,18–20] or key educational texts. This conflicts with clinical approaches to image quality review and radiological interpretation which typically compare paired left and right (bilateral) images. A wide range of percentages (11–48%) for the visualisation of the PMM has been cited in the literature, without benchmarking to any specific percentage, apart from the 32% reported by Basset et al. in 1993[9–17] (Table 1). Internationally, there is a wide discrepancy between accrediting bodies regarding both the need to visualise the PMM on the CC view and its achievability, which raises the question of its value as an image quality criterion (Table 1).

There are varying rationales for the inclusion or non-inclusion of the PMM on the CC image. Popli et al.[22] suggest that positioning errors are a major factor; however, Taylor et al.[23] believe visualisation is dependent on anatomical variants of the individual woman. There is no literature that adequately explains why the PMM is or is not included on the CC view. It is likely that the reason is multifactorial with positioning, individual anatomy and body habitus having the greatest impact.

This study reports for the first time the bilateral, unilateral and overall visualisation rates of the PMM in an Australian setting. Additionally, this study will consider whether variables such as age, breast size (as assessed by the posterior nipple line; PNL) and compressed breast thickness influence the visualisation of the PMM on the image and examine the alignment of the 'rule' to Australian clinical practice.

Methods

A de-identified data set of 2688 paired, full-field digital mammography (FFDM) CC view mammograms of women (only) aged 40 years and over performed at BreastScreen NSW between August and October 2015 was reviewed. The sample size was calculated to provide a confidence level of 95% and a margin of error of 1.89. Images were excluded from the study where the woman had undergone mastectomy, lumpectomy, breast reduction, breast augmentation, radiation therapy or where there was gross chest wall deformity as the presentation of the breast is not considered 'normal' for routine positioning or image quality review.

The PMM was recorded as being either visualised or not visualised and where present the length of the PMM was measured in millimetres (mm) from its most lateral to most medial extent on the posterior edge of the image using a digital ruler and the width at its widest part at 90° to the posterior edge of the image. The PNL was measured in mm from the nipple to the most anterior border of the PMM or posterior edge of the image, whichever came first.[5] The PNL measures the compressed breast length and is not a literal measurement of breast dimension; however, it has been used in previous research as a way of measuring breast size.[24,25] The compressed breast thickness and patient age was accessed from the data embedded within the image. Inter-rater reliability was analysed using 20 randomly selected images and measured independently by each of two raters (Rater 1/ Rater 2) using Cohen's κ. Rater 1 has 28 years of experience in mammographic imaging; Rater 2 was trained specifically in evaluation of the PMM on the CC view of the breast.

Ethics approval was granted by the NSW Population & Health Services Research Ethics Committee (HREC) (Reference: 2018HRE1102; AU/RED Ref: HREC/18/ CIPHS/50) and the Charles Sturt University (CSU) Human Research Ethics Committee (HREC) (Protocol number: H18253).

Statistical analysis

Data were analysed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, NY, USA). Initial assessment of normality was completed prior to further analysis using Q-Q plots and visual inspection of histograms and confirmed using the Shapiro–Wilk test. Based on the results of this preliminary data assessment, subsequent inferential tests used non-parametric methods.

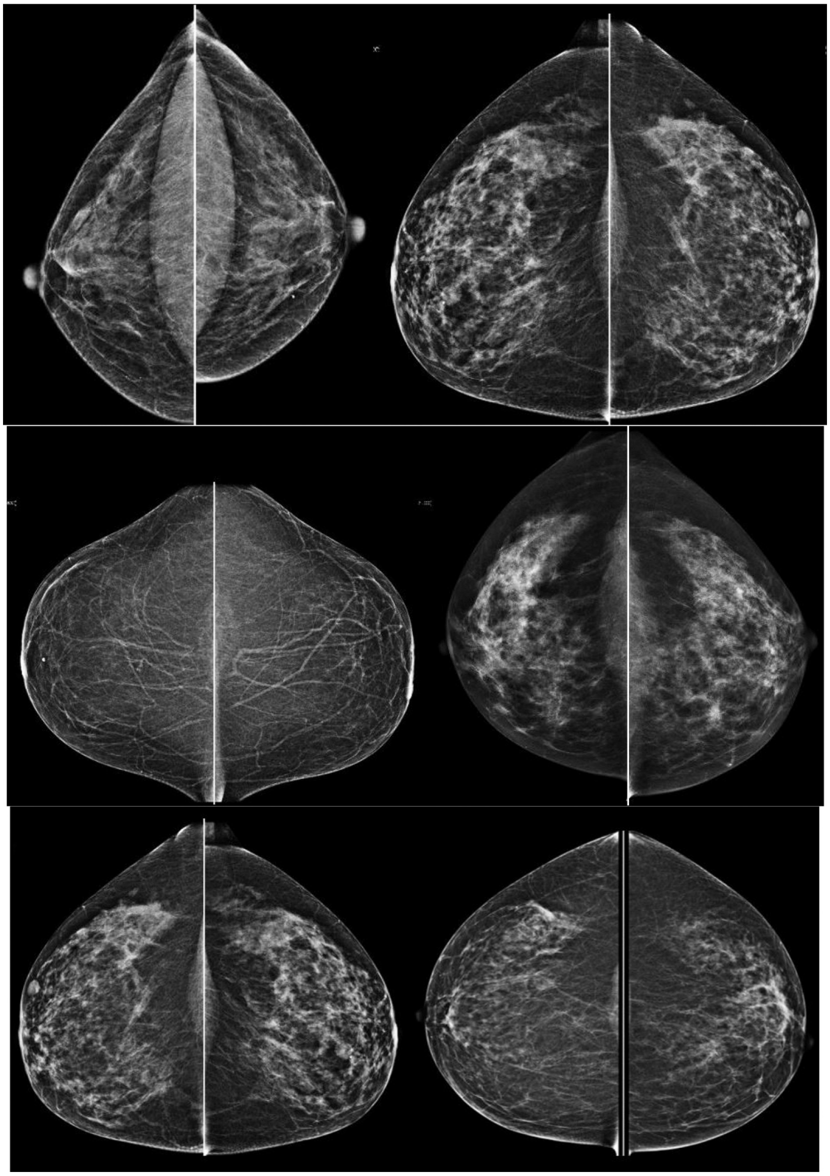

Figure 1. Paired CC view mammograms displaying a variety of pectorals major muscle presentations on the posterior edge of the image.

Visualisation of the PMM was set into four groups: left only (L), right only (R), bilateral (B) and not visualised (NV). The observed proportion of PMM visualisation bilaterally was tested against the theoretical proportion of visualisation with the binomial test. Correlation between age and measured breast variables were assessed with Spearman's rho test; the strength of correlation was described using the following absolute values for the correlation coefficient: 0–0.3 weak, 0.3–0.7 moderate and 0.7–1.0 strong. Logistic regression was used to investigate whether the visualisation was predicted by other factors. Inter-rater reliability analysis was used through intraclass correlation coefficient (ICC) using Cohen's κ to assess variability between L and R sides for PMM visualisation, length and width, compressed breast thickness and PNL.

Results

Women were aged from 40 to 87 years with a mean of 59.5 years (SD = 6), noting that the data set had a lower limit of 40 years. BSA provides free screening to asymptomatic women aged 40 years and over; therefore, there were no images of women aged under 40 years. Summary data for the key variables included in this study are provided in Table 2.

Table 1. The '30% rule' and PMM visualisation summary from the key literature and accreditation bodies.

Published articles	Pectoralis major muscle (PMM) visualisation
Eklund & Cardenosa (1992)[16]	... when properly performed... 25% of patients...
Bassett et al. (1993)[6]	... evaluate quality of breast positioning...pectoral muscle in the CC view (32%)...
Eklund et al. (1994)[10]	... pectoral muscle will be seen in 30–40% of images...elevating inframammary fold...
Helvie et al. (1994)[14]	... 36% showed pectoral muscle...
Bassett (1995)[15]	... CC view properly performed...pectoral muscle visualisation in about 30–40%...
Moreira et al. (2005)[21]	.... pectoral muscle shadow on posterior edge of breast (if possible) ...
Bassett et al. (2010)[9]	... pectoralis muscle seen in only 30% of properly positioned CC views...
Burke & Mercer (2011)[11]	... 11% displayed the pectoralis muscle...
Popli et al. (2014)[22]	... CC view should ideally demonstrate pectoral muscle...
van Landsveld-Verhoeven et al. (2015)[12]	... depiction of pectoral muscle is 41%...
Huppe et al. (2017)[13]	... pectoralis muscle visualised 48%...
Taylor et al. (2017)[23]	... anatomical variables whether the pectoral muscle will be included...
Sweeney et al. (2017)[17]	... pectoralis major identified as key posterior anatomical structure...
Accrediting bodies	
Royal Australian and New Zealand College of Radiologists (RANZCR) (2002)[3]	... CC view properly performed, pectoralis muscle only visualised in 30–40%...
European Union (2006)[20]	... if possible, pectoral muscle shadow shown...
BreastScreen Aotearoa (2013)[18]	... excellent images: pectoral muscle shadow at chest wall...
National Health Service Breast Screening Program (NHSBSP) (2017)[19]	... pectoral muscle shadow on some CC views depending on anatomical variables...
American College of Radiologists (ACR) (2018)[5]	... CC view properly performed, pectoralis muscle only visualised in 30–40%...
BreastScreen Australia (BSA) (2018)[4]	... schematic display of pectoralis major muscle...

Presence of PMM on images

The PMM was present on 20.9% (n = 563) of images of the left breast and for the right breast 17.6% (n = 472). Overall, the PMM was present on 24.5% (n = 657) of image pairs, which included 14.1% (n = 378) where the PMM was present bilaterally (i.e. on both left and right image), 6.9% (n = 185) only in the left image and 3.5% (n = 94) only in the right image. In the majority of images, 75.6% (n = 2031), the PMM was not visible.

The binomial test was used to test whether the observed proportion of the PMM visualisation was as the theoretical proportion (0.3 or 30%). The test showed that the observed proportion of bilateral PMM on images (0.141) and overall PMM on images (0.245) was significantly less (P < 0.001) for both, than the 0.30 expected with the '30% rule'.

Table 2. Descriptive statistics for age, compressed breast thickness, posterior nipple line (PNL) and length and width of pectoralis major muscle (PMM).

Variable	*N*	Mean	Standard deviation	Min.	Max.
R Compressed breast thickness (mm)	2688	57.64	12.76	12	103
L Compressed breast thickness (mm)	2688	57.65	12.84	5	104
R PNL (mm)	2688	97.14	29.31	10.30	255.40
L PNL (mm)	2688	98.32	29.12	12.60	219.50
R PMM length (mm)	476	62.06	25.74	12.60	156.30
L PMM length (mm)	569	61.34	25.70	10.20	153.80
R PMM width (mm)	476	6.28	4.91	0.30	60.50
L PMM width (mm)	569	6.47	5.51	0.20	90.00
Age (years)	2688	59.55	6.06	40	87

Correlation

The bivariate correlation of woman's age on PNL, compressed breast thickness and PMM width and length was assessed using Spearman's r test. The correlations and associated P values are shown in the correlation matrix (Figure 2). There was little or no correlations between age and any of the breast measures or between PMM (length or width) and either breast thickness or PNL. Moderate positive correlations were found between PNL and breast thickness for both left and right breasts, with strong correlations between right and left thickness, and right and left PNL reflecting overall breast symmetry in this group. Similarly, moderate-to-strong correlation was observed between left and right PMM width and length.

Logistic regression

Multiple logistic regression analysis was conducted, simultaneously entering age, PNL, thickness, PMM length and PMM width into the model. The analysis was computed for both left and right visualisation (Table 3).

		Age	R Thickness	L Thickness	R PNL	L PNL	R PMM Length	L PMM Length	R PMM Width	L PMM Width
Age	Correlation Coefficient	1.000								
	Sig. (2-tailed)									
	N	2688								
R Thickness	Correlation Coefficient	−0.083**	1.000							
	Sig. (2-tailed)	0.000								
	N	2688	2688							
L Thickness	Correlation Coefficient	−0.085**	0.946**	1.000						
	Sig. (2-tailed)	0.000	0.000							
	N	2688	2688	2688						
R PNL	Correlation Coefficient	0.088**	0.495**	0.484**	1.000					
	Sig. (2-tailed)	0.000	0.000	0.000						
	N	2688	2688	2688	2688					
L PNL	Correlation Coefficient	0.093**	0.490**	0.494**	0.962**	1.000				
	Sig. (2-tailed)	0.000	0.000	0.000	0.000					
	N	2688	2688	2688	2688	2688				
R PMM Length	Correlation Coefficient	−0.132**	0.055	0.058	0.033	0.016	1.000			
	Sig. (2-tailed)	0.004	0.230	0.208	0.476	0.728				
	N	476	476	476	476	476	476			
L PMM Length	Correlation Coefficient	−0.025	0.074	0.074	0.080	0.053	0.687**	1.000		
	Sig. (2-tailed)	0.558	0.079	0.076	0.056	0.207	0.000			
	N	569	569	569	569	569	382	569		
R PMM Width	Correlation Coefficient	−0.053	0.114*	0.118*	0.215**	0.208**	0.794**	0.513**	1.000	
	Sig. (2-tailed)	0.250	0.013	0.010	0.000	0.000	0.000	0.000		
	N	476	476	476	476	476	476	382	476	
L PMM Width	Correlation Coefficient	0.021	0.114**	0.097*	0.261**	0.229**	0.528**	0.794**	0.595**	1.000
	Sig. (2-tailed)	0.622	0.007	0.020	0.000	0.000	0.000	0.000	0.000	
	N	569	569	569	569	569	382	569	382	569

Figure 2. Correlation matrix forage, compressed breast thickness, PNL and pectorals major muscle (PMM) length and width. Strength of correlation is indicated by cell colour: no colour = weak, green = moderate and pink = strong. Heavy borders delineate the four major comparison groups. *P* values are indicted by: *$P < 0.05$, **$P < 0.01$.

The Nagelkerke and Cos & Snell pseudo-R^2 values indicated 8.4–11.7% (left) and 9.4–14.7% (right) of the variance in visualisation of the PMM was accounted for by the predictors overall. While some predictors provided a statistically significant contribution to the model, the contribution was small and the odds ratio for all predictors approximated 1.

Interclass correlation coefficient

Inter-rater and Intrarater variability was analysed using Cohen’s κ interclass correlation coefficient and Cronbach’s α. There was ‘very good’ agreement between Rater 1 and Rater 2 on PMM visualisation (L/R) (κ = 1.0), compressed breast thickness (L/R) (α = 1.0), R PNL (α = 0.995) and R PMM length (α = 0.909). L PNL, L PMM length and PMM width (L/R) measurements displayed ‘good’ agreement (α = 0.723, α = 0.702, α = 0.652, α = 0.720, respectively). Inter-rater and Intrarater reliability and variability were tested, and both raters had 100% agreement on left and right PMM visualisation, indicating reliability and thereby validation of the study.

Discussion

In this study, we have demonstrated that the PMM was visualised bilaterally in 14.1% and unilaterally in 10.4% of paired mammograms and overall (unilaterally and bilaterally) in 24.5% of images. This is inconsistent with the higher visualisation rates of 32–48% reported previously.[6,13] The bilateral visualisation rate of 14.1% was, however, closer to the 11% reported by Burke and Mercer.[11] The reporting of the bilateral visualisation rate of the PMM is most important if it is to inform the quality assurance of mammograms in a clinically significant way.

Table 3. Logistic regression analysis for L and R breast. Dependent variable is the presence/absence of pectoralis major muscle (PMM) on image. Age in years, other measures in mm

Independent variable	Coefficient (B)	Standard error (SE)	*P*-value	Odds ratio	CI lower limit	CI upper limit
Right breast						
Age	−0.044	0.021	0.036	0.957	0.919	0.997
R Thickness	−0.025	0.012	0.040	0.975	0.952	0.999
R PNL	0.001	0.006	0.829	1.001	0.990	1.012
R PMM length	0.015	0.009	0.094	1.015	0.998	1.032
R PMM width	0.0129	0.061	0.033	1.138	1.010	1.281
Model χ^2 = 46.981, $P < 0.001$. Pseudo-R^2: Cox & Snell = 0.094 Nagelkerke = 0.147. N = 476.						
Left breast						
Age	0.012	0.016	0.474	1.012	0.980	1.004
L thickness	−0.016	0.009	0.069	0.984	0.967	1.001
L PNL	0.004	0.004	0.283	1.004	0.997	1.012
L PMM length	0.027	0.005	<0.001	1.028	1.017	1.038
L PMM width	−0.005	0.022	0.828	0.995	0.953	1.039
Model χ^2 = 50.048, $P < 0.001$. Pseudo-R^2: Cox & Snell = 0.084 Nagelkerke = 0.117. N = 569						

It has been reported in an American study that posterior breast tissue inclusion, on typically larger breasted overweight and obese women, is often sacrificed for the in profile position of the nipple.[26] The prevalence of overweight and obese adults, men and women in Australia, rose from 57% in 1995 to 63% in 2014–15, where about 58% of women between the ages of 35–44 were overweight and obese, increasing to over 60% between the ages of 75–84.[27] Therefore, a decrease in the visualisation rate of the PMM since Bassets' original study may potentially be explained by the change in body habitus of women in the 21st century correlating to increased difficulty in positioning.[26–28]

Unilaterally, the PMM was visualised on the right breast in 3.5% and the left breast in 6.9%, almost twice as much on the left than the right breast. This may be due to radiographer positioning techniques, where if a medial approach is used, the left breast is traditionally positioned with the radiographer using their right hand. As the majority of people are right-hand dominant, there may also be a connection to the difference in grip strength (10% increase) of right-hand dominant people, thereby increasing left PMM visualisation.[29,30] The investigation of positioning technique, specifically medial or lateral approach, was outside the scope of this study.

The bilateral visualisation rate of 14.1% confirmed the hypothesis that the '30% rule' is not currently achieved in the Australian digital setting, if it is assumed the 32% reported in the literature is based on bilateral visualisation of the PMM, which itself is unclear. The overall visualisation rate of 24.5% reported in this study is close to the rate reported in 1992 by Eklund and Cardenosa of 25%,[16] however is 7.5% less than the rate of 32% reported by Bassett et al.[6] and is 18.5% less than the maximal achievable rate of 48% reported by Huppe et al.[13]

Women's age, in particular older age, was initially considered to be a potential factor impacting visualisation of the PMM. It was thought that the PMM and breast would be more mobile in older women contributing to increased visualisation and/or that curvature of the spine which is known to increase with age[31] may attribute to difficulties in positioning and a decrease in visualisation. However, there was no evidence of correlation between age and the various breast measures with logistic regression analysis demonstrating that for each year increase in age, the visualisation odds only of the right PMM would decrease by 4% (P =0.036). This may be due to younger women being fitter and generally having a more toned (larger) PMM, whereas alterations in body composition and general decline in physiological functioning in older women lead to a concomitant decline in lean body mass and an increase in percentage of body fat.[32]

Analysis of the correlation between various breast measures failed to demonstrate any correlation between the parameters other than those expected due to body symmetry. Similarly where statistically significant predictors were identified in the logistic regression, the predictor contribution was small and of questionable clinical significance. Together, these data suggest that the visualisation of the PMM on routine mammograms in this population is not related to age or to breast thickness or PNL (and hence size).

The mammograms reviewed in this study are from the screening setting only, where the '30% rule' is not part of the BSA NAS quality assurance requirements. Therefore, it could be suggested that the setting of the mammograms used for this study could have impacted the results. However, as the BreastScreen NSW workforce is a standardised and highly trained one and as the aim of all mammography regardless of setting is the maximum inclusion of breast tissue on every image, this hypothesis is unlikely. The most recent studies reporting on the visualisation rate of the PMM conducted in America and the Netherlands by Huppe et al.[13] and van Landsveld-Verhoeven et al.[12] were both set in the screening setting and achieved the '30% rule'.

This raises potential questions about the differences between Australian and overseas practices in positioning for screening mammography. Huppe et al.[13] reported that the radiographers included in their study had participated in updated positioning training from the standardised protocol by a positioning expert, whereas van Landsveld-Verhoeven et al.[12] reported that their newly trained radiographers (those who have had more recent and updated positioning training) achieved higher scores for general image quality and fewer errors, than those who were practicing for longer. However, both achieved the same scores for PMM visualisation (41%).

Part of the focus of the training for radiographers in Huppe et al.'s study was the inclusion of more posterior and medial tissue on the CC view, and they established that by positioning from the medial side of the breast, using both hands to pull the breast onto the image receptor (IR) and setting the height of the IR adequately, more PMM could be included on 48% of images.[13] As some traditional positioning techniques use a one-handed approach to pull the breast onto the IR, and with positioning often executed from the lateral side of the breast, these improvements to positioning techniques may indeed prove to be valuable in increasing PMM visualisation. On the other hand, if in the previously published studies [9–17] 52–89% of images are reported to not visualise the PMM, it becomes a questionable aim. A 'rule' that does not apply to 52–89% of images should not be viewed as a criterion, let alone a 'rule' for quality assurance.

Limitation in this study includes that results are based only on images provided via routine screening of women aged 40 years or older; with no formal requirement to meet the '30% rule'. It is unknown whether the findings of this study apply to younger women or to those in diagnostic settings. Nevertheless, previous studies have also reported visualisation rates from screening settings which allow comparison with the literature. Participants of this study included women from various demographic groups; however, this was not considered during the analysis. It is also possible that the study may have inadvertently excluded some groups who traditionally have lower participation rates in screening activities.

Further research needs to be conducted investigating the Australian diagnostic setting, the benefits of additional positioning training for radiographers with a focus on positioning ergonomics and the impact on radiographers and women when implementing those improved practices.

CONCLUSION

In this study, we demonstrate that the '30% rule' is not being achieved in routine screening mammograms; overall visualisation of the PMM was 24.5% with only 14.1% showing the PMM in both right and left images. There were no significant associations between PMM visualisation and age, compressed breast thickness or breast size as determined by PNL. The results of this study, in combination with the variability in reports of PMM visualisation by others, strongly suggest that this 'rule' needs to be re-examined to determine whether a criteria aimed to be met only 30% of the time is a sufficient image quality assurance criteria and whether this 'rule' is clinically relevant. The '30% rule' should not be retained as a part of radiographers' vernacular when referencing good image quality within an image evaluation system. The removal of the term 'rule' is advocated as is the requirement for the '30% rule' to be a criteria for image quality.

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