Title of the paper:

A review of mammographic positioning image quality criteria for the craniocaudal projection.

Short Title:

Review mammographic positioning image quality criteria: CC projection

Abstract

Detection of breast cancer is reliant on optimal breast positioning and the production of quality images. Two projections, the mediolateral (MLO) and craniocaudal (CC), are routinely performed. Determination of successful positioning and inclusion of all breast tissue is achieved through meeting stated image quality criteria. For the CC view, current image quality criteria are inconsistent. Absence of reliable anatomical markers, other than the nipple, further contribute to difficulties in assessing the quality of CC views.

The aim of this paper was to explore published international quality standards to identify and find the origin of any CC positioning criteria which might provide for quantitative assessment. The pectoralis major (pectoral) muscle was identified as a key posterior anatomical structure to establish optimum breast tissue inclusion on mammographic projections. It forms the first two of the three main CC metrics that are frequently reported 1. visualisation of the pectoral muscle, 2. measurement of the posterior nipple line (PNL) and 3. depiction of retroglandular fat.

This literature review explores the origin of the three metrics, and discusses three key publications, spanning 1992 to 1994, on which subsequent image quality standards have been based. The evidence base to support published CC metrics is sometimes not specified and more often the same set of publications are cited, most often without critical evaluation.

To conclude, there remains uncertainty if the metrics explored for the CC view support objective evaluation and reproducibility to confirm optimal breast positioning and quality images.

Introduction

Mammography is radiographic imaging of the breast. It is undertaken with presenting signs and symptoms of breast disease and on asymptomatic women through population based breast cancer screening programmes. In both settings, although the prevalence of disease may differ, the emphasis is on detection of breast cancer although a range of breast pathologies may be demonstrated.

The goal of breast screening programmes is the early detection of breast cancer, with programme effectiveness primarily measured in reduction of breast cancer mortality rates. [1] To detect breast cancer at its earliest stage, the screening service must achieve optimum image quality at the lowest possible risk from the radiation dose. [2-4] Quality Assurance (QA) programmes are essential to ensure compliance with the guidelines, image quality standards, protocols, and criteria that guide breast screening and diagnostic mammographic services. [5, 6] The adequacy of image quality standards can be inferred from the sensitivity and specificity of imaging.

Published national and international quality standards continue to provide differences in described image quality criteria and impact upon clinical image assessment comparisons and effective research into mammography. [7, 8] An example is the inclusion of a classification system by which image quality can be visually assessed and evaluated. One of the most reported is a system where images are ranked as perfect, good, moderate or inadequate (PGMI). [9, 10] Whilst there had appeared to be greater conformity for the MLO criteria reported, [11, 12] a recent study by Taylor et al has proposed a new scoring system of perfect, good, adequate or inadequate with new positioning quantitative metrics added for the MLO view. [13] In the meantime, ambiguity and differences in description and expectations from specific criteria for the CC view continue.

QA goals need to be continually reassessed to ensure they reflect changing technology,[14] evidence base and the "skills of breast positioning, compression, and technique selection". [15] [p.807] The focus of this review is image quality control (QC) criteria to assess CC breast positioning accuracy which is integral in ensuring that all breast tissue is included.

Background

The CC projection

Before we consider the importance of image quality criteria for the CC projection, it is necessary to examine the importance of the CC projection itself. Two view mammography combining the MLO and the CC projections creates a three dimensional representation of the breast. Two view mammography is described for both initial and incident (or subsequent) screening rounds by the UK BreastScreening Programme, American College of Radiology, BreastScreen Australia and BreastScreen Aotearoa. [6, 16-19]

The inclusion of the CC projection aims to increase early detection of breast cancer, increase sensitivity and reduce the incidence of interval cancers. Two views allow for visualisation of breast pathologies which manifest in a single view, either the MLO or CC, as a 'one-view' finding of an abnormality and require further evaluation. [20-22] Similarly, mammographic features that appear benign in one projection may appear differently and more suspicious on the other. [23] Breast tissue missed on one projection should be included on the other, otherwise repeat positioning or supplementary projections may be required adding to the radiation burden of the examination.

Mammographic positioning and equipment

For clarity and conciseness, in this article we have used the generic term ‘radiographer’ to apply to the health professional responsible for conducting the mammographic examination. Incorrect positioning by radiographers can result in poor quality images due to inadequate demonstration of breast tissue, insufficient compression, and presence of artefacts. All of these factors will impact diagnosis [24] and can contribute to missed breast cancers. [21, 25-31]

During positioning for mammography there are minimal anatomical landmarks for reference to confirm all breast tissue has been included. General radiographic positioning is provided by landmarks, usually skeletal or skin surface anatomy, to confirm the area of interest will be included. The nipple is the anterior reference point for both MLO and CC projections.[32] Positioning is aimed at demonstrating the pectoral muscle to provide a key image quality criterion to confirm inclusion of posterior breast tissue. [17, 19, 33] There is a lack of anatomical landmarks to determine inclusion of medial and lateral breast tissue. Nevertheless during positioning, in order to include medial tissue on the CC, lateral tissue may be missed [34-36].

A further positioning consideration is the placement of the image receptor (IR) in relation to the inframammary fold (IMF) of the breast.[37] As early as 1992 Eklund and Cardenosa [38] described elevating the IMF during CC positioning “to the limit of its natural ability” [(p.35)] as a contributor to including more upper posterior breast tissue, with Bassett et al. [36] confirming this positioning method. This recommendation is recently described as lacking in consensus in the literature leading to research into the amount of breast tissue, described as the ‘breast footprint’, [39] actually included on the (IR). The configuration of the size and depth of current IR platforms may be contributing to the ease, or difficulty, in achieving adequate positioning of the breast. [2, 40, 41] Training in positioning techniques specifically suited to full-field digital mammography (FFDM) and digital breast tomosynthesis (DBT) has been reported as a contributor to better inclusion of breast tissue. [42]

Compression paddle design has evolved since the early 1990’s and can also influence breast tissue inclusion on the CC. A biphasic (angled) paddle resulted in increased incidence of pectoral muscle inclusion, although there was less impact on the PNL. [43] Comparison of flexible and rigid designs demonstrated inclusion of pectoral muscle more consistently, but tended to push fibroglandular tissue off the image posteriorly. [44]

Given patient and equipment variables, it is not surprising that positioning continues to be seen as a challenge to quality of mammographic practise [45] and has been included as reason for failure to adhere to mammography accreditation and quality standards. [46-52] Indeed the American Food & Drug Administration reported that in 2015 during the first attempt at ACR accreditation, of all clinical images found to be deficient 92% were due to deficiencies in positioning, a compelling and concerning finding. [50]

Literature review

Review Method

Despite published research for the MLO image quality criteria which appears to be widely accepted, [12, 53-55] the literature for positioning in general continues to challenge the validity and ability to confirm and quantify positioning criteria. [12, 13, 54, 56] A paucity of validated evidence for the CC criteria remains, [42, 57, 58] even with the stated importance of the projection. The method of this review has therefore been to establish the origin of image quality criteria pertaining to inclusion of posterior breast tissue on the CC. For this review 'image quality standards' is used to identify quality assurance (QA) guidelines and protocols specific to mammographic imaging. 'Image quality criteria' is used to describe quality control (QC) of mammographic projections.

Current mammographic image quality standards were reviewed first to establish common descriptors of CC positioning criteria used to determine optimal inclusion of posterior breast tissue (see Table 1). Three criteria emerge which reference the pectoral muscle, these are the posterior nipple line (PNL), the '1 cm rule', and retroglandular fat.

To establish the origins of the three criteria identified, a literature search in OvidSP (Medline) and Scopus was conducted by the first author. Attention was given to word inclusion of, but not limited to, mammog*, position*, image quality, nipple line, pec* muscle, retroglandular, craniocaudal (CC), mediolateral oblique (MLO), projection, compression, breast screen.

No limitation was placed on publication year and is current to October 2017. Given the historical context of the literature reviewed, a comprehensive search was achieved through further review of in-text citations, references, and bibliographies. Due to the emergent nature of positioning criteria disparity all articles were considered if they included reference to the CC projection. Mammographic image quality standards emerging from as early as 1989 [59-61] [62] were also reviewed but most often had a restricted reference list.

Origins of CC criteria

Three source articles by Eklund and Cardenosa (1992), Bassett, Hirbawi, DeBruhl, and Hayes (1993), and Eklund, Cardenosa, and Parsons (1994) were identified as the first to explain the CC criteria. [36, 38, 63] Further analysis of the three key articles provided a metric for the percentage of CC images which should include pectoral muscle. A summary of key image quality criteria descriptors for the CC projection includes additional contributing literature (see Table 1). Literature relating to earlier mammographic examination techniques, and initial mammographic quality control guidelines published by the ACR (1992) [59] and for the UKNHSBSP (1989), [64] were also considered but no evidence was identified for the three criteria, nor any alternative discussed.

Variability in attaining correct positioning of the breast and production of good quality images is well recognised in the literature. [11, 13, 42, 57, 58] In spite of this, of the three key articles identified for this review, only the U.S. 1993 study by Bassett et al. describes a study method and materials to test image quality criteria for positioning from which subsequent recommendations were provided. This prospective study comprised 1,000 consecutive bilateral screening mammograms (2,000 CC and 2,000 MLO images) [36] completed by six radiographers experienced in mammography who had completed training to reflect what were then 'new' methods of positioning. Both positioning methods and evaluation criteria were clearly stated for both projections by which the mammograms would be evaluated; for the CC projection three positioning descriptors and six evaluation criteria. The radiographers assessed the quality of their images and repeated any they considered unacceptable. The repeat rate was reported as "consistently below 5%" and it has to be assumed that all reported data arose from images that excluded those repeats. The validity of the results is therefore somewhat reduced.

Inclusion of the pectoral muscle on the CC was stated at 32% (inter-radiographer variability 22% - 60%). When available, mammograms were compared to previous mammograms from within a two year period (59% of cases). Individual radiographer positioning for the same patient was not, however, compared. [36] 79% of the CC views were stated as achieving a PNL measurement “within 1 cm greater or less than the depth on the MLO”, albeit an ambiguous description. Given the current application of the ‘1 cm rule’ it should be noted that 54% of the CC views assessed within this study were actually within 0.5cm of the MLO measurement. For the MLO 90% demonstrated a depth of tissue that was greater or equal to that depicted on the CC images (inter-technologist variability 88% - 94%). A greater ability to position the breast in the MLO position tends therefore to be confirmed. Within the context of this study the PNL is described to the pectoral muscle or edge of film whichever comes first, thus leaving some ambiguity to the overall effectiveness of such metrics and the study outcomes to be considered cautiously. [36]

It is of interest that evaluation of the PNL and use of the ‘1 cm rule’ by Bassett et al. (1993) [36] was attributed to Eklund and Cardenosa (1992) [38] although their article does not in fact refer to those metrics. By 1994, Eklund et al. [63] did include the PNL with the finding that of 300 consecutive mammogram examinations reviewed the MLO PNL averaged 0.62cm greater (range not reported) than that on the CC. Subsequently the authors recommended the MLO PNL to be not greater than 1cm of the CC measurement. Research methodology for the 1993 study and the 1994 review is not evident but clearly stated rationale for establishing positioning and evaluation guidelines is provided. It is considered that concurrent studies during that time might attribute to such cross-over of recommendations, but was not reflected chronologically by the publication dates (see Table 3).

Limitations of CC criteria

Two of the three identified CC criteria can be considered problematic as they do not offer metrics that are consistently achievable. When considering the first non-metric criterion, retroglandular fat is not likely to be identified in a breast that is mostly fatty replaced, nor where there is scattered or only moderate amounts of fibroglandular breast tissue. [63, 65, 66] The retroglandular fat criterion is also of limited value when glandular tissue overlies the pectoral muscle or extends to the edge of the image. Inclusion of the pectoral muscle, the second non-metric criterion, is not consistently achieved. [36, 58, 67]

The PNL measurement is the only quantitative criterion available to assess the adequacy of the CC image, and is applied in conjunction with a '1 cm rule'. When compared between the same side MLO and CC projections, the PNL should be within, or less than, 1 cm of each other. Although described with some frequency within the literature it is not evident in all image quality standards, (see Table 1). There is also a wide range of descriptors for the "nipple line" or "posterior nipple line", [12] and "nipple axis line". [68] Variations include orientation on the MLO, nipple or nipple-skin interface, and posteriorly to the muscle or to the back of the image (see Table 2; Figure 1).

The PNL and '1 cm rule' metrics do provide for comparison of depth of breast tissue and can be used regardless of inclusion of the pectoral muscle on the CC (see Figure 2). Yet in the absence of pectoral muscle to nipple level on the MLO, which can be an uncertainty and common fault, [11, 63], the 1 cm measurement will be to the back of the image for both views (see Figure 3). This then has limited value on its own as posterior breast tissue inclusion is not confirmed despite the PNL metric being met. It has also been documented that breast tissue visualised on CC views can exceed that of the MLO, which might question adequacy of the MLO positioning. [36]

Even though a PNL measurement for a CC remains within 1 cm of the MLO, suggesting satisfactory positioning, it may not confirm that the breast is pulled as far forward during positioning as is possible, [69] nor might it confirm visualisation of fibroglandular tissue that extends posteriorly. [20] If the nipple is not in profile on both MLO and CC then the PNL measurement is also compromised as the anterior anatomical landmark may not be easily identified.

Discussion

Differences in CC criteria is exemplified by BreastScreen Aotearoa (New Zealand) (2106) requirement for inclusion of the pectoral muscle as part of an “excellent” (in place of perfect) CC image whilst there is no reference to the ‘1 cm rule’. [19] BreastScreen Australia (2015) requires the “PNL to be within 1 cm of PNL on MLO view” for a “perfect” CC image. Inclusion of pectoral muscle for this classification is implied diagrammatically but not explicitly stated. In the UK although the PGMI system, or equivalent, is often used for training and ongoing quality improvement, at national level the 2006 UKNHBSP [33] image quality standards do not specifically refer to the PGMI rankings. Criterion for inclusion of the pectoral muscle on the CC is stated as “Pectoral muscle shadow may be shown on the posterior edge of the breast on some CC views depending on anatomical characteristics”. [17] There is a further lack of conformity of criteria for inclusion of the medial and axillary tail of the breast (see Table 1).

Inclusion of pectoral muscle

The literature available to be reviewed often gave reference to what percentage of CC images should include pectoral muscle posteriorly (ranging from 20% - 60%). [36, 42, 58, 67] Although the 1993 study provided a range of 22%-60%, [36] a 2011 audit of 200 pairs of CC and MLO projections used to assess achievement of the "≤ 1cm rule" found only 11% included pectoral muscle. 31.5% successfully met the 'rule' criterion. [58] A 2015 published review of image quality criteria for positioning comparing the imaging technique of newly trained and experienced radiographers in the Netherlands found concordance with 41% depiction of pectoral muscle for the CC projection. The range was not provided and there was no reference to use of the PNL or 1cm criteria. [67]

A high frequency of pectoral muscle inclusion on CC views has been suggested to indicate positioning which is biased towards the lateral aspect of the breast leading to loss of medial tissue, although this does not appear to be have been supported in the literature. [70] As with the MLO, where the posterior aspect of the breast is generally thicker than the anterior, adequate compression over the entire breast might also be compromised. [38, 71] Pectoral muscle inclusion is ranked as necessary for 'perfect' or 'excellent' images for some image quality classification systems, [17, 19] but not included in other image quality standards. The value of a stated percentage for successful inclusion of the pectoral muscle on the CC is questioned as a valid criterion for current use. There is a disparity of recommendations but early research from within the digital mammography environment may contribute to new discussion. [42]

'1 cm rule'

Percentage values for inclusion of the pectoral muscle and PNL with 1 cm metric criteria were originally described for practical use to guide improvement in positioning by Bassett at al. (1993). [36] The criteria were considered objective enough to evaluate mammographic practice. It was suggested that the 1 cm metric was the more consistent determinant of inclusion of posterior tissue. [36] However, as compression 'spreads out' tissue it is reasonable to expect a larger 'footprint' of breast tissue area on the IR, [37] confounding the application of the '1 cm rule'. This is likely to be more evident for the CC, given that posterior inclusion of pectoral muscle is expected to be greater on the MLO.

Given that a greater volume of pectoral muscle can impact on compressibility of breast tissue, [38, 72] the ability of MLO compression to match the footprint for the CC projection may be reduced. With such discordance between MLO and CC subsequent spread of breast tissue, the ability to apply the '1 cm rule' then compromises the ability to compare the 'amount' of breast tissue included. Correspondingly, variability of breast size and shape does not seem to have been considered when applying a metric of length only. In the absence of such a consideration there is no indication of the volume of breast tissue that might be excluded from a mammogram.

Medial and lateral tissue inclusion considerations

A recently published study evaluated positioning for FFDM and DBT with comparison to the film-screen study of 1000 patients by Bassett and colleagues (1993). [42] Although a smaller study (170 patients), improved outcomes for inclusion of medial and lateral breast tissue on the CC view were reported. For the CC, visualisation of cleavage was used to confirm inclusion of medial breast tissue. This criterion was new so a direct comparison with the 1993 study was not possible. Comparison of 'lateral glandular tissue' was able to be provided as a comparative positioning criterion. [42] As with the non-metric criterion of visualisation of retroglandular fat, it is difficult to quantify the presence of glandular tissue as a criterion as there is no associated anatomical marker, and varies both inter- and intra-patient. When tissue more lateral to any glandular tissue is visualised then such glandular tissue cannot be determined as the most lateral breast tissue.

Future Directions

Digital Mammography

Digital mammography offers new opportunities. Automated evaluation methods [73] could combine with current research, namely compression studies, assisting with better understanding of the area of breast included on the IR. Such methods could also record and report volumetric data for the amount of breast tissue imaged. A cautionary note is determination of sufficient anatomical landmarks on the CC view to provide reproducible results. Nonetheless automated evaluation methods could better inform both research [44] and validate image quality criteria for clinical application.

Inconsistent application of known and 'silent' criteria

Consistent with previous research, educational, training and auditing metrics have not necessarily matched national standards. [11, 57] Exploration of both radiographer and radiologist image quality assessment has attempted to rank the importance of positioning criteria, [13] whilst radiographer decision making during image acquisition remains unknown. This review has identified the inclusion of the cleavage as a CC criterion recently added to the body of literature. [42] Within clinical practice a further range of undocumented practice for evaluation of CC positioning and adequate inclusion of breast tissue is likely to be used. It is expected that exploration of this phase during mammographic imaging could determine if there is consistent application and ranking of the identified criteria for the CC. There may be unidentified criteria ‘silent’ from the literature which are likely to be untested. Research would provide the opportunity for identification of such criteria and testing for their validity and inclusion in image quality standards if found effective.

Conclusion

To date, the evidence for the CC positioning image quality standards and criteria, and national guidelines remain unclear. The literature and publications are often inconsistent and subjectively clinical practice may not necessarily be reflecting best practice. [11, 12, 57, 58, 67, 74] Differences in the criteria suggest varying image quality outcomes with the potential for cancer detection performance to be questioned. The call for a uniform and validated system prevails [10, 11, 13, 57] as this would support those in the education and practice of mammography.[42, 75]

Regardless of any such future considerations, the impetus for this review has been to determine optimum positioning for the CC projection with renewed attention required to establish which of the three identified criteria might have merit to successfully confirm inclusion of posterior breast tissue. It would be expected that knowledge arising from such research will inform which of the CC image quality criteria or any others revealed has validity to provide a platform for change of mammographic practice during image quality criteria assessment and subsequent clinical decision making for repeat imaging when the pectoral muscle is not demonstrated.

Anatomical markers are limited to the nipple anteriorly and sometimes the pectoral muscle posteriorly. This impacts on the ability to provide quantitative and reproducible metrics for optimal positioning and evaluation of images. Nevertheless, it is unclear why variation exists in the image quality criteria and whether CC views are achieving the stated aim of imaging ‘all breast tissue’, or perhaps more appropriately, ‘as much as possible’. Despite limitations of suitable anatomical markers, objective criteria are needed for use during positioning, so that resultant images can be evaluated objectively and compared with previous mammographic examinations. It is recommended that the existing mammographic image quality guidelines for the CC projection be consolidated into an evidence-based framework that allows objective evaluation of image quality during mammography.

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Table 1 Descriptor summary for optimum craniocaudal (CC) positioning criteria

NB: Imaging of 'all or maximum breast tissue' with the 'nipple in profile' are recognised as frequently stated criteria and not repeated in this table.

Image quality standards	Positioning descriptor summary
United Kingdom National Health Service Breast Screening Programme (UKNHSBSP), 2006 [33] p.42-43	CC specific criteria: ▪ medial border of the breast (according to local protocols) ▪ some of the axillary tail of the breast ▪ pectoral muscle shadow may be shown on the posterior edge of the breast on some CC views depending on anatomical characteristics
European guidelines for quality assurance in breast cancer screening and diagnosis, 2006 [18] p.173	CC specific criteria: ▪ medial border of the breast is shown ▪ as much as possible of the lateral aspect of the breast is shown ▪ if possible, the pectoral muscle shadow is shown on the posterior edge of the breast
BreastScreen Aotearoa, New Zealand, 2016 [19] p.124-125	CC Excellent images: ▪ medial aspect shown ▪ as much axillary tail as possible ▪ pectoral muscle shadow at chest wall CC Good and Moderate images: ▪ as for Excellent category, except pectoral muscle not shown but breast tissue imaged well back to chest wall
American College of Radiologists (ACR), 2017 [76]	▪ Clinical assessment evaluates retromammary aspects of the breast between the craniocaudal (CC) and mediolateral oblique (MLO) views. ▪ the CC PNL should be no more than 1 cm less (approximately) than that on the MLO view
BreastScreen Australia, 2015 [17] p.180-181	CC Perfect images: ▪ medial border well demonstrated ▪ posterior nipple line (PNL) within 1cm of PNL on MLO view

CC Good images:

- all postero-medial tissue visualised (*axillary portion of breast not to be included at expense of medial portion)

CC Moderate images:

- most breast tissue imaged *(however, all breast tissue must be imaged on MLO image*)

Table 2

Variations of descriptors for the posterior nipple line as applied to the craniocaudal (CC) view

Source	Descriptor of the posterior nipple line for the CC
Bassett, Hirbawi, DeBruhl, and Hayes (**1993**) [36 p.803-804]	Directly posteriorly from nipple to pectoral muscle or edge of film, whichever comes first
Eklund, Cardenosa, and Parsons (**1994**) [63 p.300]	Nipple-skin to back of image (regardless of pectoral muscle inclusion)
American College of Radiology (**2017**) [76]	Nipple to posterior edge of the image
BreastScreen Australia (**2015**)[17 p.180]	Nipple to pectoral muscle

Table Three

Summary of the origins for the three key image quality criteria descriptors for the craniocaudal (CC) view

Author and Year	Inclusion of Pectoral Muscle	PNL and 1cm measurement	Retroglandular fat
Eklund and Cardenosa (**1992**) [38, p.36]	* more than 25%	nil	nil
Hendrick, Bassett and Dodd (**1992**) [59, 9.75]	* approximately 20%	nil	nil
Bassett, Hirbawi, DeBruhl, and Hayes (**1993**) [36, p.805]	32%	Yes	Yes
Eklund, Cardenosa, and Parsons (**1994**) [63, p.300]	* 30 – 40%	Yes	Yes
Bassett, Hendrick and Bassford (**1994**) [77, p.66]	* approximately 30%	Yes	Yes
European Commission (**1996**) [78]	* Yes	nil	Yes
American College of Radiology (**1999**) [79, p.86]	* 30% to 40%	Yes	Yes

* evidence base not cited

Figure Captions:

Figure 1. Descriptors for the posterior nipple line

- CC and MLO: posteriorly to pectoral muscle or back of image
- MLO: there may be variations in the orientation of the PNL

Figure 2. The PNL may be applied for the CC view regardless of inclusion of the pectoral muscle on the CC

Figure 3. Assessment for the CC view requires more than one criterion to confirm positioning image quality. A PNL measurement to the ‘back of the image’ cannot confirm presence of posterior breast issue in the absence of pectoral muscle on both views.