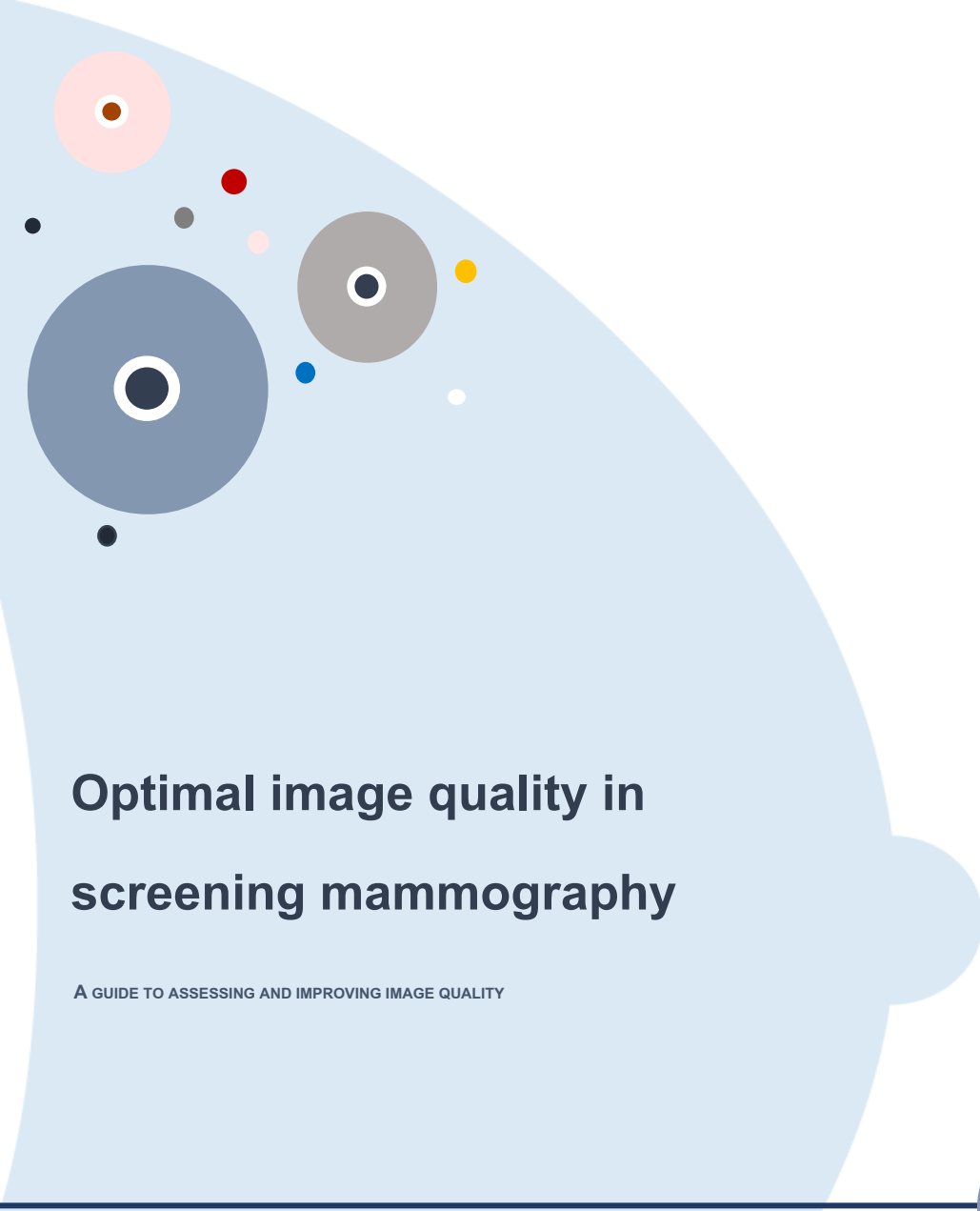
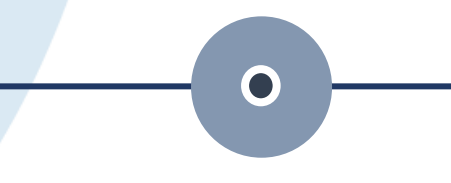




Optimal image quality in screening mammography

A GUIDE TO ASSESSING AND IMPROVING IMAGE QUALITY



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A GUIDE TO ASSESSING AND IMPROVING IMAGE QUALITY IN BREAST CANCER SCREENING

Prologue

Breast cancer is the most common cancer among women, with more than 6,000 women diagnosed with breast cancer in Flanders every year (Cancer Registry, 2011-2023)¹. Screening by means of mammography allows tumours to be detected at an earlier stage, often resulting in less invasive treatment and reduced mortality¹⁻⁵. A crucial prerequisite, however, is that the image quality of the mammograms is optimal⁶⁻¹⁰. This manual provides guidance to help achieve just that.

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Introduction

The importance of mammographic image quality

When screening for breast cancer using mammography, it is very important that the images are of good quality. The aim is to identify tumours at the earliest possible stage in a largely healthy population. Images of suboptimal or insufficient quality hinder rapid detection of cancer, increase the number of interval cancers, and can lead to false-positive results⁶⁻⁹. That is why European guidelines require breast cancer screening centres to establish a protocol to achieve optimal mammographic image quality and to monitor this quality on a regular basis⁶. Radiographers working in breast cancer screening centres are expected to independently produce high-quality mammograms (taking into account the woman's anatomy and health), keep the radiation dose as low as possible, assess and improve image quality, and decide whether a retake is needed¹¹.

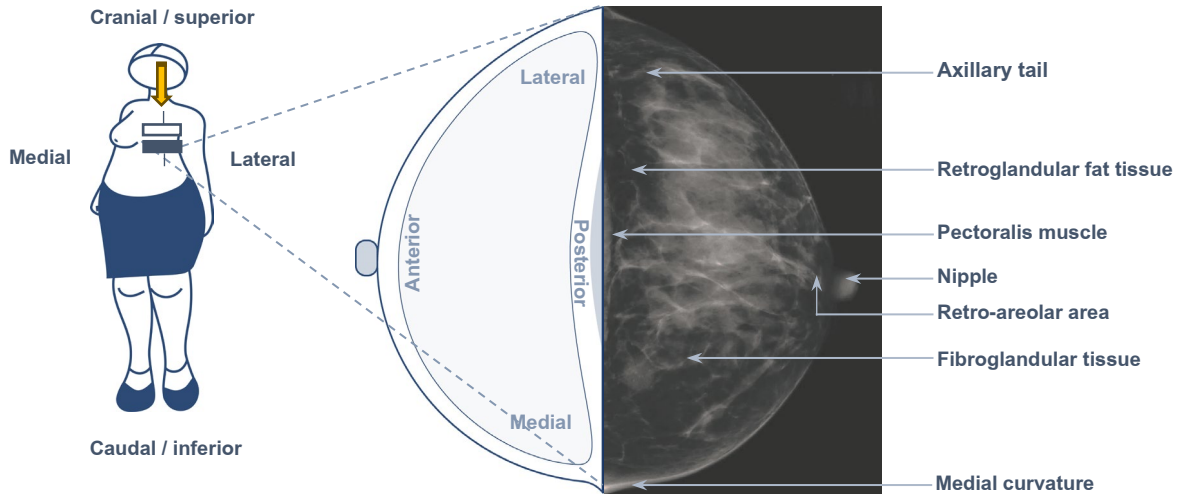
Assessing the quality of a mammogram and deciding whether an image needs to be repeated is not always straightforward. Nevertheless, it is important that this is done appropriately and consistently. Poor-quality images hinder accurate assessment, but repeating images unnecessarily increases radiation exposure, costs, and discomfort¹². Furthermore, a radiographer can only improve if he or she can identify areas where improvement is possible¹⁰. Several studies show that the assessment of mammographic image quality is often highly subjective and that there is considerable variability among assessors¹³⁻¹⁵. A group of 41 experts has therefore reached a consensus on which quality criteria are important and when an image should be considered good, suboptimal, or inadequate.

This manual

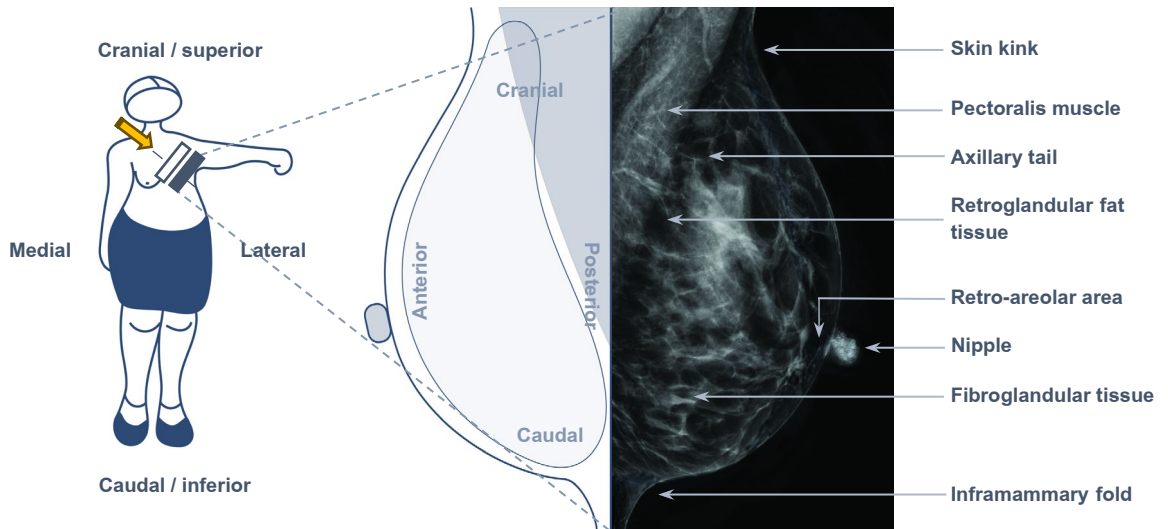
This guide provides a detailed overview of the quality criteria required to assess the quality of a mammogram. The “rationale” section explains why each quality criterion is important. It then specifies what must be met to obtain a “good” score for each quality criterion, when an image is considered “suboptimal” and when it is “insufficient” and must be repeated. This is further clarified through illustrations. The impact factor indicates how important each quality criterion is in the decision to repeat an image. Additionally, several “tips and tricks” are provided which may assist in improving image quality. For more information about correct positioning, please consult the manual published by the National Reference Centre for Population Screening in the Netherlands (LRCB), entitled “The Right Focus: Manual on Mammography Positioning Technique” by Cary van Landsveld-Verhoeven¹⁶ and the manual “Digital Mammography: A Holistic Approach” by Claire Mercer, Peter Hogg, and Judith Kelly¹⁰.

Terminology

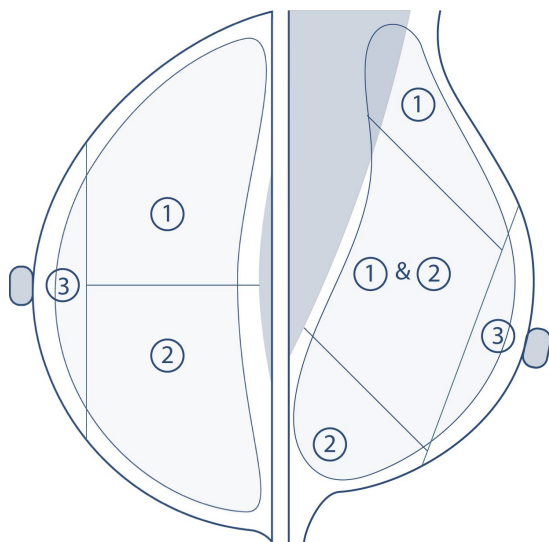
Craniocaudal view (CC)



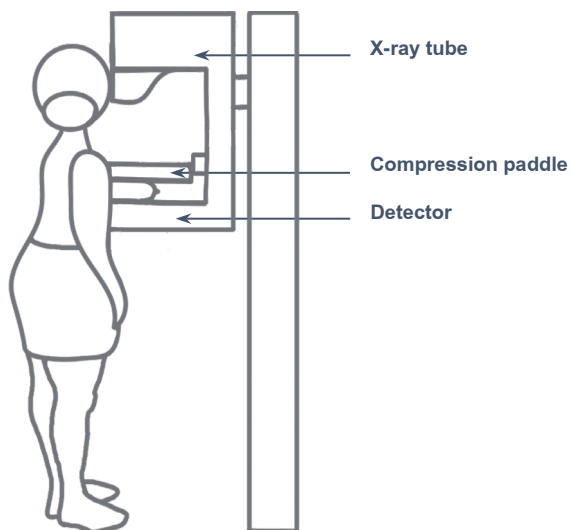
Mediolateral oblique view (MLO)



Corresponding areas between CC and MLO views



The mammography system



Abbreviations

AEC	Automated Exposure Control
AGD	Average Glandular Dose
AT	Axillary Tail view
CC	Cranio-Caudal view
CvKO	Centre for Cancer Detection (Flanders)
daN	decanewton (compression force)
FB	From Below, Caudo-Cranial view
kPa	kilopascal (compression pressure)
kV	kilovolt (tube voltage)
LM	Latero-Medial view
LRCB	National Reference Centre for Population Screening in the Netherlands
mAs	milliampere-seconds (tube load)
mGy	milligray
MLO	Medio-Lateral Oblique view
ML	Medio-Lateral view
N	newton (compression force)
NP	Nipple view
PNL	Pectoralis-Nipple Line (line drawn from the nipple perpendicular to the pectoralis muscle)
XCCL	Extended Lateral Cranio-Caudal view
XCCM	Extended Medial Cranio-Caudal view

Image quality criteria

The quality criteria in this manual are based on guidelines from Europe, Australia, Canada, New Zealand and the United States, supplemented by data from various studies and handbooks, including “The Right Focus: Manual on Mammography Positioning Technique” by van Landsveld-Verhoeven C. and “Digital Mammography: A Holistic Approach” by Mercer C. and Hogg P. and Kelly J.^{6-8,10-66}.

Quality criteria for the craniocaudal view (CC)

1. On the lateral side, as much fibroglandular tissue as possible is visualised
2. The pectoralis muscle is visible and located centrally
3. The nipple is on the midline
4. The medial side is maximally visualised

Quality criteria for the mediolateral oblique view (MLO)

5. The detector plate is set at the correct height, and the breast is imaged 2–3 cm beyond the skin crease
6. The pectoralis muscle appears wide (10–30°), deep (to the nipple level) and convex (outwardly curved)
7. The inframammary fold (breast–abdomen transition) is visible and forms a rounded arch

Quality criteria for CC & MLO views

8. The nipple is shown in profile, with the anterior area of the breast immediately behind the nipple clearly visible
9. The fibroglandular triangle is fully extended, with the retroglandular fat visible
10. No interfering skin folds or air artefacts are present
11. No interfering artefacts due to imaging or processing are present, nor artefacts caused by overlying structures such as hair, shoulder or chin
12. Alternative views are available when standard images are inadequate

Symmetry and uniformity

13. The perpendicular distance between the nipple and the pectoralis muscle differs by no more than 1 cm between the CC and MLO views
14. The left and right breasts are shown symmetrically
15. The images are uniform compared with previous screening images (if available) and are of equal or better quality

Physical-technical image quality criteria

16. No motion blur is present
17. Image contrast is optimised and noise is minimised at the lowest achievable radiation dose
18. Compression is around 120 newtons, depending on breast size and firmness
19. The image identification is complete and correct

Perfect imaging quality cannot always be achieved

There is considerable anatomical variation among women in terms of breast structure, including differences between the two breasts in the same woman and variation in nipple shape. In addition, certain medical conditions such as cystic breasts, pectus excavatum (funnel chest), kyphosis, frozen shoulder, paralysis, skin conditions, and learning disabilities may make it impossible to meet all quality criteria.

Such reasons for “not good but cannot be improved” and/or striking anatomical variations are best noted in the woman's record. This prevents women from being recalled unnecessarily.

If at the time of taking the images the radiographer determines that the mammogram should be repeated, it is preferable to do so immediately to avoid the need for a recall at a later stage. Of course, a balance must be struck between the additional radiation dose and the likelihood of a more successful mammogram. If there is significant doubt, consult a colleague, the radiologist, or the woman herself.

If images are repeated or additional views are taken, all images, even those of poor quality, should be included in the record for the radiologist. Some quality criteria score better on one image, while others score better on another. The final quality score takes all images into account. As the breast is often positioned (slightly) differently in a second image, it is also easier for the radiologist to distinguish between a true lesion and tissue overlap⁶⁷.

1. On the lateral side, as much fibroglandular tissue as possible is visualised

Rationale

The fibroglandular tissue should be imaged as completely as possible to avoid missing any lesions¹⁶. However, it is not always possible to visualise the entire extent towards the axilla (axillary tail) on a standard CC image without creating a deficit on the medial side⁴⁷.

Good

The lateral part of the fibroglandular tissue including its extension towards the axilla (= axillary tail) is maximally visualised^{16,17,19,21,47,48,59}.

Suboptimal

A small portion of the mammary gland is not visualised on the lateral side but is fully visible on the MLO view²¹. If there is any doubt and the woman is still positioned at the mammography system, it is acceptable to repeat the mammogram⁶⁸.

Insufficient

A small portion of the lateral breast is missing on both CC and MLO views, or a more substantial part of the lateral breast is not depicted²¹.

Retake

If a significant portion of the lateral breast is not visible, the CC view should be repeated, or an extra-lateral CC may be performed (see Criterion 12: Alternative views). If a small portion of the lateral breast is missing on both CC and MLO views, it is generally advisable to repeat the MLO.

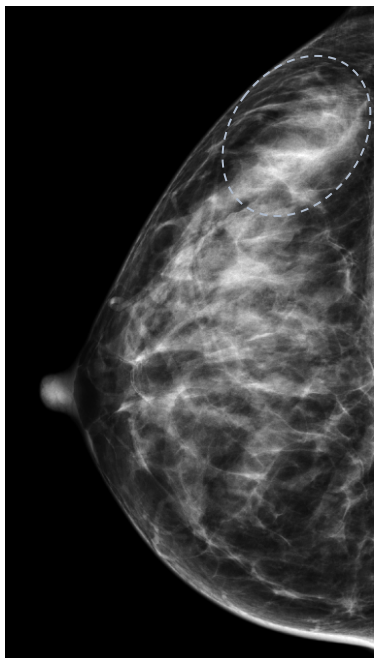
Impact factor of this criterion ★★★★★☆ (3.78)

Tips and tricks

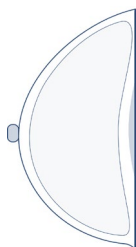
- Select a compression paddle of the appropriate size¹⁶.
- Position the woman correctly in front of the detector, with a slight medial rotation of about 5–10 degrees, ensuring the entire breast lies on the plate and the nipple is facing straight forwards in the 12 o'clock position¹⁶.
- For the CC view, ask the woman to turn her head medially, lift her chin slightly, and relax the shoulder on the side of the breast being imaged¹⁶.
- When supporting the breast from the medial side, bring the lower hand sufficiently laterally and place the upper hand high on the breast, with the fingers directed towards the humeral head. Use both hands to guide the breast forwards. Once the woman is in firm contact with the detector, draw the breast slightly further forwards ("pull-through") while maintaining tension, then gently but firmly smooth the breast forwards¹⁶.

- Check the light field to ensure the lateral breast tissue is correctly included, and gently smooth out any skin folds laterally and anteriorly, using a finger underneath the breast if required¹⁶.

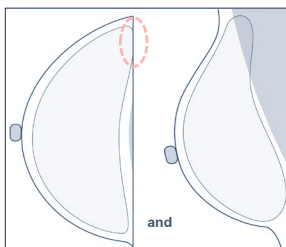
In focus



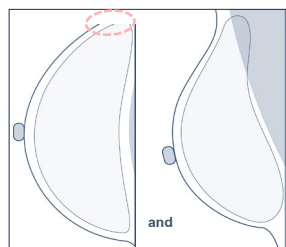
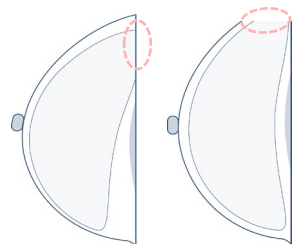
← Lateral breast showing the full extent of the axillary tail.



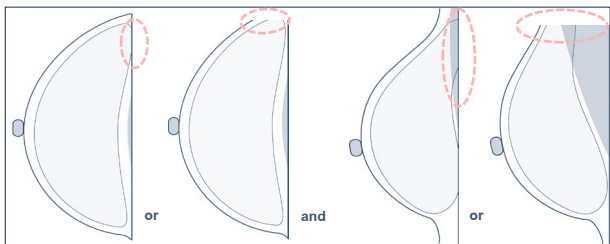
Good



Suboptimal



Insufficient



Insufficient

2. The pectoralis muscle is visible and located centrally

Rationale

Visualising the pectoralis muscle is a useful indicator that the posterior breast tissue has been fully included. When the muscle appears centrally on the image, this usually suggests that comparable amounts of medial and lateral breast tissue have been captured. Because of normal anatomical variation or the presence of pathology, the pectoralis muscle cannot always be visualised⁶⁷. With accurate medial positioning, however, it can be shown in more than 30% of women^{33,38,69}.

Good

The pectoralis muscle is visible and positioned centrally⁴⁷.

Suboptimal

Although the pectoralis muscle is not visualised, the posterior breast tissue has been clearly included^{17,50}.

Insufficient

The pectoralis muscle is not visualised, with inadequate inclusion of the posterior breast tissue and/or the muscle is not centrally placed, leading to poor medial or lateral tissue coverage²¹.

Retake

If inclusion of the posterior (and/or medial or lateral) tissue is inadequate, a repeat CC view is required.

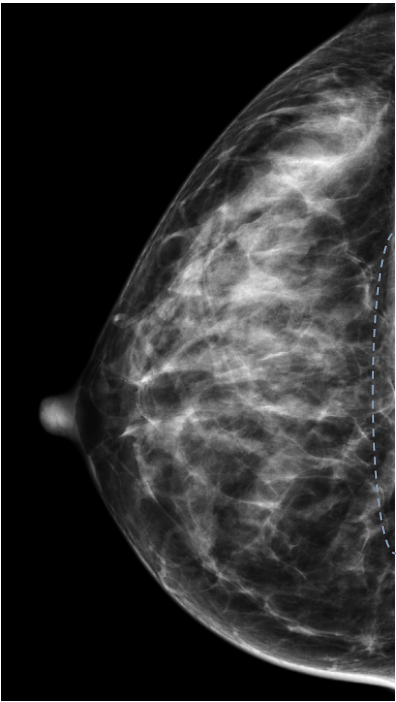
Impact factor of this criterion ★★★★★ (3.48)

Tips and tricks

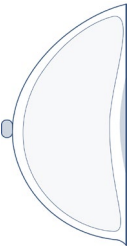
- Ensure the breast is elevated sufficiently when adjusting detector height⁴⁵. Position the woman about a hand's breadth from the detector to allow optimal forward displacement of the breast¹⁶.
- Ensure the breast midline corresponds with the detector midline¹⁶.
- Use both hands to guide the breast forwards. Once the woman is in firm contact with the detector, gently but firmly draw the breast slightly further forwards ("pull-through") while maintaining tension; this helps include additional tissue, including the pectoralis muscle. Then smooth the breast firmly forwards with the lower hand while using the upper hand to hold the breast securely against the detector¹⁶.
- Bring your free arm around the woman's back and gently lower the shoulder on the side being imaged. Use your elbow to guide her slightly closer to the mammography system.
- Allow the compression paddle to gradually take over from your supporting hand¹⁰. Use the same hand to smooth the tissue forwards and confirm adequate compression¹⁶.
- If the pectoralis muscle is not visualised, compare the pectoralis–nipple line on the CC view with the pectoralis–nipple line on the MLO view⁶⁸.

→ Document any woman-specific anatomical or pathological limitations preventing pectoralis muscle visualisation⁶⁷.

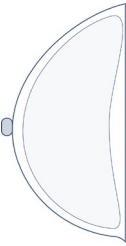
In focus



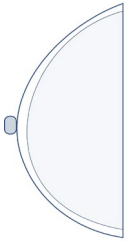
← The pectoralis muscle is visible and centrally located



Good



Suboptimal



Insufficient

3. The nipple is on the midline

Rationale

To ensure comparable medial and lateral breast coverage, the perpendicular line from the nipple to the pectoralis muscle is used as a midline guide^{16,17,19,21,59}.

In certain cases, pronounced asymmetry of the breast tissue due to anatomical or pathological factors may make it impossible to achieve symmetry^{50,59}. This should be documented in the woman's record.

Good

The imaged breast is evenly divided by the midline, represented by the perpendicular line from the nipple to the pectoralis muscle^{16,17,19,50,59}.

Suboptimal

While the nipple is not aligned with the midline, the medial and lateral breast tissue is well included.

Insufficient

Deviation of the nipple by over 10° from the midline leads to incomplete visualisation of the medial or lateral breast tissue^{24,65}.

Retake

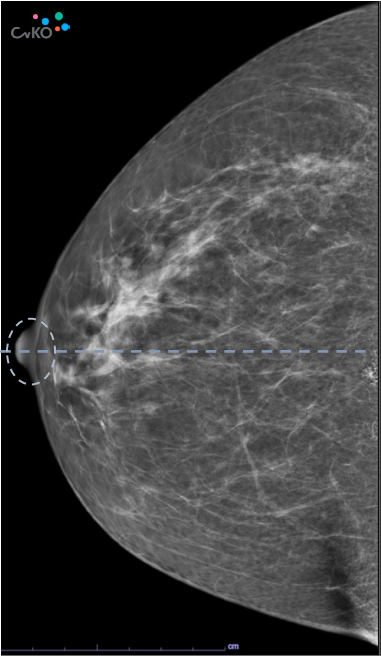
When inadequate centring results in exclusion of the medial breast or a significant part of the lateral breast tissue, the CC view should be repeated, or an additional exaggerated medial or exaggerated lateral CC view may be obtained (see Criterion 12: Alternative views). If a small portion of lateral glandular tissue is missing on both CC and MLO views, repeating the MLO image is usually recommended.

Impact factor of this criterion ★★☆☆☆ (3.13)

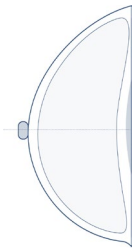
Tips and tricks

- Ensure accurate positioning in front of the detector with a gentle medial rotation of 5–10°, allowing the breast to rest fully on the plate with the nipple facing straight forwards in the 12 o'clock position¹⁶.
- Ensure the breast midline is aligned with the detector midline for the CC projection¹⁶.
- Immediately before exposure, confirm correct nipple alignment and inclusion of both medial and lateral breast tissue using the light field¹⁶.
- Where breast tissue is asymmetrically distributed, rotate the woman relative to the detector to achieve optimal visualisation of the medial tissue while including as much lateral tissue as possible. Document the rotation angle and the indication for this positioning⁶⁷.

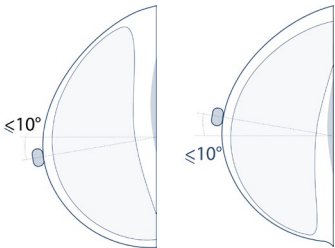
In focus



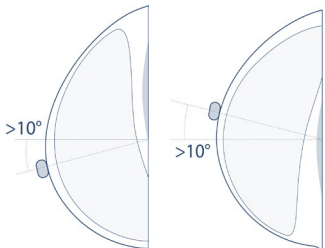
← The nipple is on the midline



Good



Suboptimal



Insufficient

4. The medial side is depicted maximally

Rationale

Complete depiction of the fibroglandular tissue is essential to avoid missing any lesions¹⁶. The presence of the medial curvature (see illustration) is an indicator of optimal medial breast imaging⁴⁷.

Complete inclusion of the medial breast tissue is not always achievable without affecting lateral coverage⁴⁷. Because medial tissue is more challenging to visualise on the MLO projection, thorough imaging of the medial side on the CC view is particularly important⁶⁷.

Good

The medial side of the breast is completely visualised^{16,19,21,28,47,48,59}. Ideally, the junction between the breast and the chest wall appears as a smooth skin curvature⁴⁷.

Suboptimal

A limited area of the medial breast is not visualised⁶⁷.

Insufficient

A substantial portion of the medial breast tissue is not included^{21,47,50}.

Retake

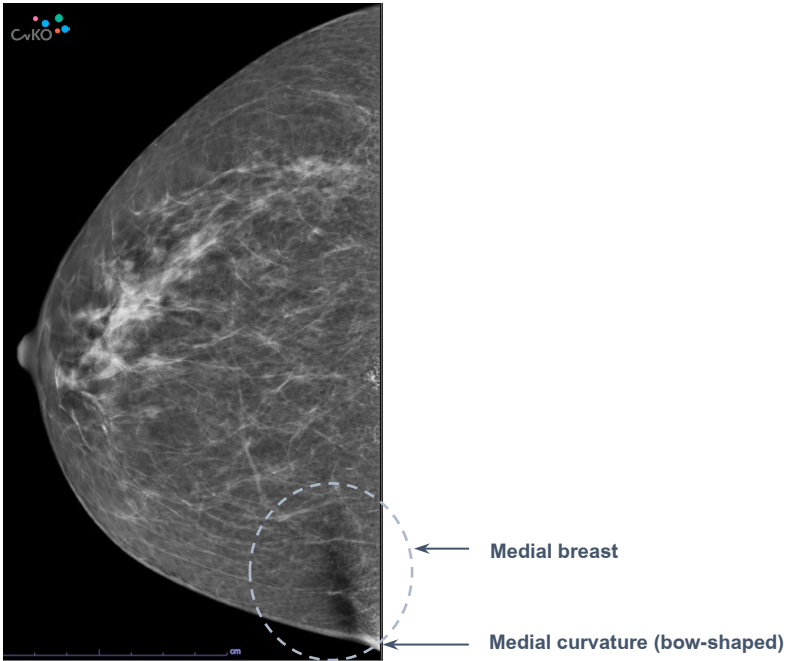
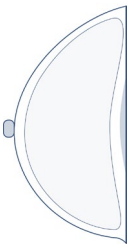
In cases of inadequate inclusion of a large portion of the medial breast tissue, a repeat CC or an additional XCCM view is recommended (see Criterion 12: Alternative views).

Impact factor of this criterion ★★★★★☆ (3.78)

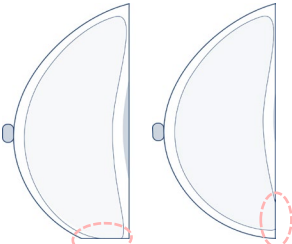
Tips and tricks

- Select a compression paddle of the appropriate size¹⁶.
- Avoid excessive medial rotation of the woman; limit rotation to a maximum of 5-10°¹⁶.
- Align the midline of the breast with the midline of the detector¹⁶.
- Ensure the woman stands approximately one hand's breadth away from the detector. Bring the breast forwards using both hands. Once the woman meets the detector, gently but firmly draw the breast slightly further forwards ('pull-through') while maintaining tension. Using the lower hand, smooth the breast firmly forwards. With the upper hand, maintain steady pressure, then bring your free arm around the woman's back and guide her closer to the mammography system by applying gentle pressure with your elbow. Afterwards, use the upper hand to smooth the breast firmly forwards again, working primarily with the heel of the hand and focusing on the medial aspect¹⁶.
- Let the compression paddle slowly replace manual support while ensuring adequate compression¹⁰.
- Use the light field to confirm correct positioning of the medial tissue¹⁶ and smooth out any skin folds.

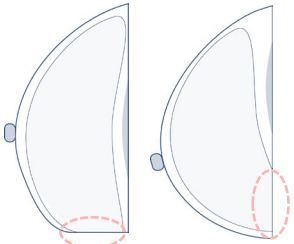
In focus



Good



Suboptimal



Insufficient

5. The detector plate is set at the correct height, and the breast is imaged 2–3 cm beyond the skin crease

Rationale

Adequate elevation and upward–forward smoothing of the breast produces a gentle dome shape with a small skin indentation at the breast–shoulder junction⁴⁷. When the detector height is set correctly, 2–3 cm of tissue above this indentation will be included, ensuring proper evaluation of the superior breast.

If the detector is set too high, the firm pectoralis muscle or the arm may impede uniform compression, leading to blurring (especially inferiorly), insufficient extension of fibroglandular tissue, breast descent, and inadequate visualisation of the inframammary fold¹⁶.

Good

The detector is set at the correct height, with the upper part of the breast extending 2–3 cm above the skin crease.

Suboptimal

The skin indentation above the breast is seen, but the tissue superior to it is not included. The glandular tissue, however, is maximally visualised.

Insufficient

If the detector is set too low, the upper part of the breast is not adequately included^{16,28}. If it is set too high, it can produce image blur, breast drooping, and inadequate extension of the glandular tissue¹⁶.

Retake

A repeat image is recommended when blurring is observed, the breast droops resulting in insufficient visualisation of the inframammary fold, or the glandular tissue is inadequately extended. When the superior breast tissue is absent from the image, or in the presence of an extensive axillary tail, an additional targeted view of the upper breast may be performed.

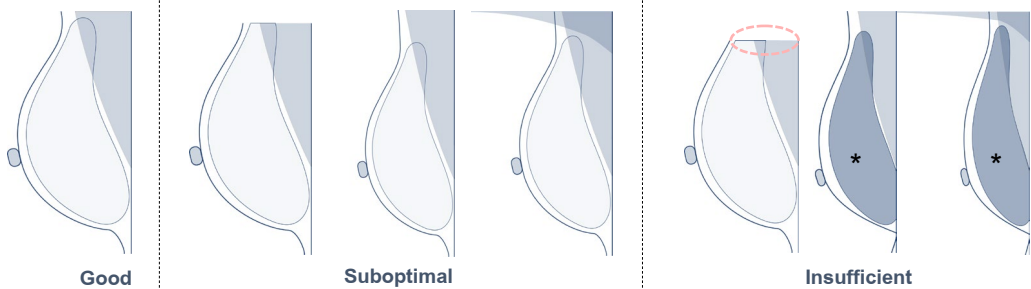
Impact factor of this criterion ★★★★★ (3.39)

Tips and tricks

- Select the appropriate compression paddle⁶⁷.
- Adjust the detector height carefully, ensuring the upper edge lies below the posterior axillary line, typically two finger breadths beneath the humeral head. Once compressed, the compression paddle should align centrally beneath the clavicle¹⁶. Following correct positioning, the nipple should lie close to the detector midline. Before compression, gently smooth the breast forwards and upwards to confirm correct height and centring. Be aware that on certain mammography systems the compression paddle shifts upwards when the unit is angled, requiring adaptation of the two-finger guideline⁶⁸. In this situation, the primary focus should be on ensuring that the nipple is centred on the detector.

- Extend the breast firmly forwards. When the paddle has secured the upper breast, smooth in the direction of the nipple and then upwards. Maintain forward nipple orientation, allow gentle rounding of the superior breast, and ensure optimal visualisation of the inframammary fold¹⁶.
- Use the light field to confirm that the breast is rounding properly and that sufficient breast tissue is visible above the skin crease. Ensure the detector is not set too high, as this can hinder uniform compression¹⁶.

In focus



* Insufficient compression results in inadequate extension of the glandular breast tissue, giving a denser appearance.

6. The pectoralis muscle appears wide (10-30°), deep (to the nipple level) and convex (outwardly curved).

Rationale

A wide appearance of the pectoralis muscle suggests maximum inclusion of the posterior breast and the glandular tissue extending towards the axilla⁴⁷.

However, attempting to include the pectoralis too extensively may compromise uniform compression and reduce image quality^{16,47}.

Good

The angle formed between the anterior margin of the pectoralis muscle and the posterior image border is typically around 20° and should fall between 10° and 30°. The muscle should extend to nipple level, which can be assessed by drawing an imaginary line through the nipple parallel to the lower edge of the image¹⁶. The pectoralis muscle is shown as either convex²⁸ or straight²².

Suboptimal

The pectoralis muscle does not extend to the level of the nipple but reaches the pectoralis–nipple line (the perpendicular line through the nipple)⁴⁷ and/or the muscle contour is mildly concave. Posterior and/or lateral fibroglandular tissue is sufficiently demonstrated^{17,21}.

Insufficient

The pectoralis muscle fails to reach the pectoralis–nipple line⁴⁷ and/or the angle lies outside the acceptable range of 10–30°²². The muscle contour is strongly concave or demonstrates an angular kink, possibly due to the axilla being trapped at the detector edge. Posterior and/or lateral or axillary fibroglandular tissue is insufficiently demonstrated^{17,21}.

Retake

If the pectoralis muscle is insufficiently deep or wide, or shows a pronounced concave contour, the MLO should be repeated. The repeat acquisition should prioritise optimal demonstration of the pectoralis. As an alternative, an axillary tail (AT) view may be performed (see Criterion 12: Alternative views).

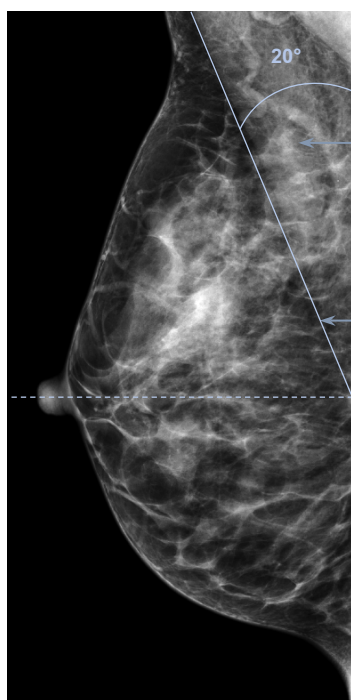
Impact factor of this criterion ★★★★★ (3.65)

Tips and tricks

- Set the detector at the appropriate angle²⁷. For women of average build this is generally around 45°; larger women with narrow breasts may require a steeper angle (e.g. 55–65°), whereas smaller women with firm breasts often require a shallower angle (e.g. 35–40°)¹⁰. Consistency of detector angle across screening rounds is essential for reliable image comparison^{16,44}. Any deviation from the standard 45° angle should be recorded.

- Ensure the woman stands approximately one hand's breadth away from the detector, allowing her to lean forwards more easily¹⁰. The woman's arm should rest on top of the detector, positioned well forwards and as relaxed as possible¹⁶. However, avoid positioning the arm too high, as this may overstretch the pectoralis muscle, resulting in a concave appearance.
- Use the light field to confirm adequate inclusion of the axillary region¹⁶.
- With your free hand, guide the woman closer to the mammography system while using the other hand to firmly smooth the breast forwards and upwards.
- Wide inclusion of the pectoralis muscle may not be achievable in all women due to anatomical build or pathology^{50,54}. Document this clearly.

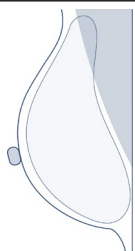
In focus



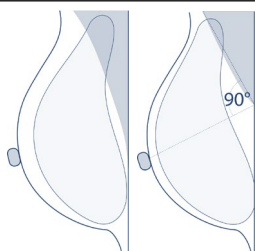
20° angle

Convex (bulging) or straight

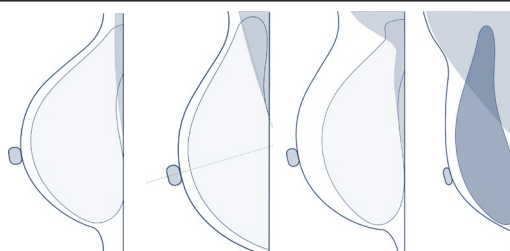
To nipple level



Good



Suboptimal



Insufficient

7. The inframammary fold (breast–abdomen transition) is visible and forms a rounded arch

Rationale

Adequate imaging of the transition between the breast and the abdominal wall, also referred to as the inframammary fold, allows maximal visualisation of the posterior-inferior breast tissue⁴⁷.

Good

The inframammary fold is visualised free from overlap by adjacent tissue^{19,47,59} or air projection⁵⁵. Visualisation of only a very small segment of the inframammary fold (“thumbnail”), although not perfect, is considered adequate¹⁶.

Suboptimal

The inframammary fold may be partially obscured by adjacent tissue or an air projection; however, this does not interfere with adequate assessment of the posterior-inferior breast tissue²¹.

Insufficient

The transition between the breast and the abdominal wall is either not visualised or is markedly obscured by surrounding tissue or an air projection, precluding assessment of the posterior-inferior breast²¹.

Retake

Provided that the remainder of the MLO image is satisfactory, a mediolateral or lateromedial view may be used, as this projection often facilitates visualisation of the breast–abdominal wall transition. If the MLO is repeated, the focus should be on adequate depiction of the inframammary fold.

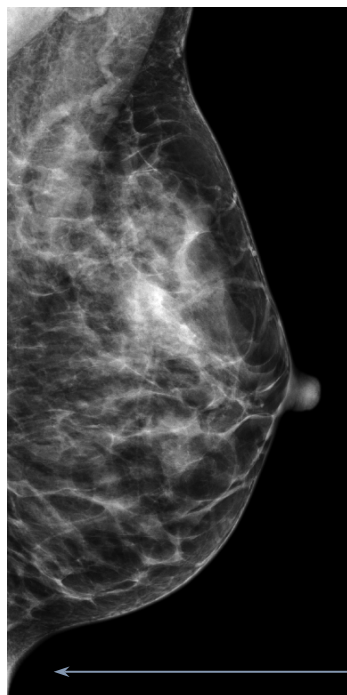
Impactfactor of this criterion ★★★★★☆ (3.39)

Tips and tricks

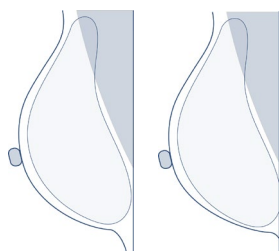
- Position the arm on the side being imaged on top of the angled detector and set the detector at the correct height.
- The woman should stand approximately one hand's breadth from the detector^{10,16} and be rotated 30–45° medially to allow easy sliding of the breast onto the detector.
- Hold the breast medially, as close to the rib cage as possible. Position yourself behind the woman, use your free arm to support the arm on the imaging side, and guide the woman forwards as far as possible, positioning her close to the mammography system¹⁶.
- Use the light field to confirm inclusion of the inframammary fold; adjust detector height or rotation if required¹⁶.
- Smooth the breast firmly forwards. Once the upper breast is adequately compressed, smooth further forwards towards the nipple and upwards¹⁶ to optimise nipple projection, slight superior contouring, and visualisation of the breast–abdominal wall transition.

- After compression, smooth the breast–abdominal wall transition downwards by placing one or two fingers between the breast and the detector plate¹⁰.
- Occasionally, correct imaging of the inframammary fold is not achievable because of anatomical factors or disease. This should be clearly documented in the record. Imaging may be especially challenging in very slim women with small, dense breasts, and in markedly obese women where abdominal manipulation is limited⁶⁷.
- Where appropriate, a mediolateral or lateromedial view may be obtained to allow better visualisation of the inframammary fold (see criterion 12. Alternative views).

In focus



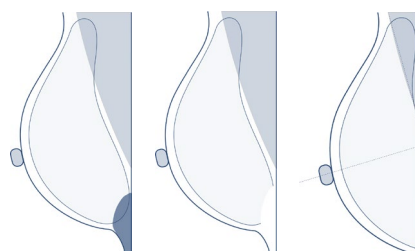
The inframammary fold



Good



Suboptimal



Insufficient

8. The nipple is shown in profile, with the anterior area of the breast immediately behind the nipple clearly visible

Rationale

If the nipple is imaged within the breast and overlies glandular tissue, it may obscure a potential abnormality in the retroareolar region²¹. The nipple may also simulate a lesion.

Good

The nipple is shown outside the breast in profile, allowing clear visualisation of the retroareolar space^{10,21,47,59}. For flat or inverted nipples, image quality may still be rated as adequate provided the nipple is projected in profile within the skin. Any nipple inversion or other anatomical variation should be recorded⁶⁷.

Suboptimal

The nipple is not shown outside the breast but touches the skin line. On the corresponding CC or MLO view of the same breast, the nipple is shown free and in profile⁶⁸.

Insufficient

The retroareolar region cannot be adequately assessed on either the CC or the MLO view²¹ and/or the nipple is fully projected within the breast, separate from the skin line, and overlies glandular tissue.

Retake

Provided that the remainder of the image is of good quality, imaging of the anterior part of the breast or a CC nipple view is acceptable¹⁶.

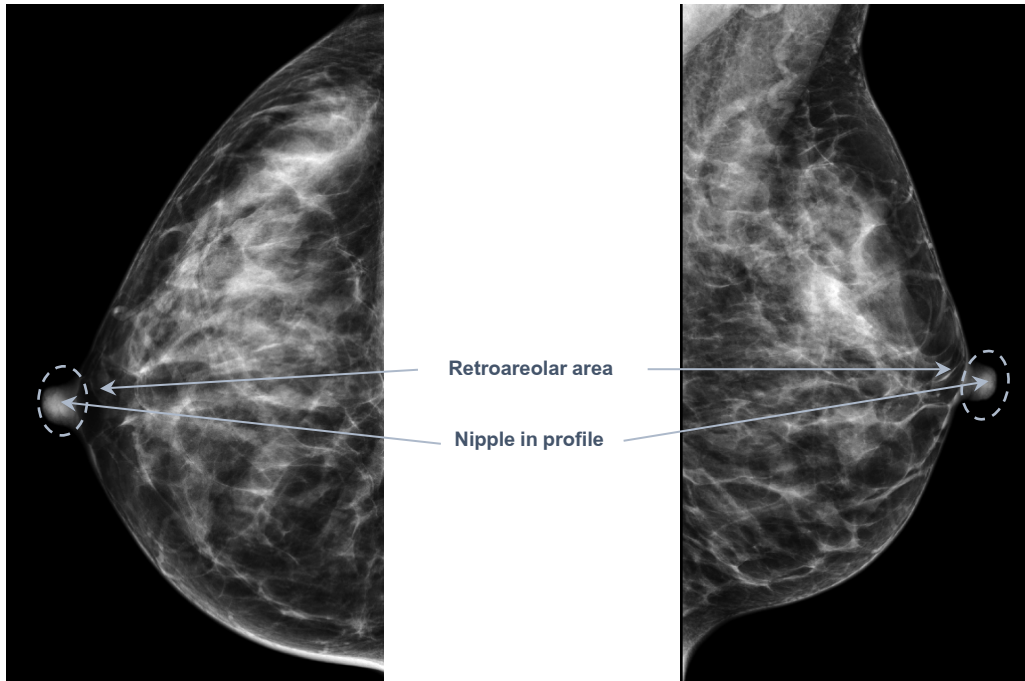
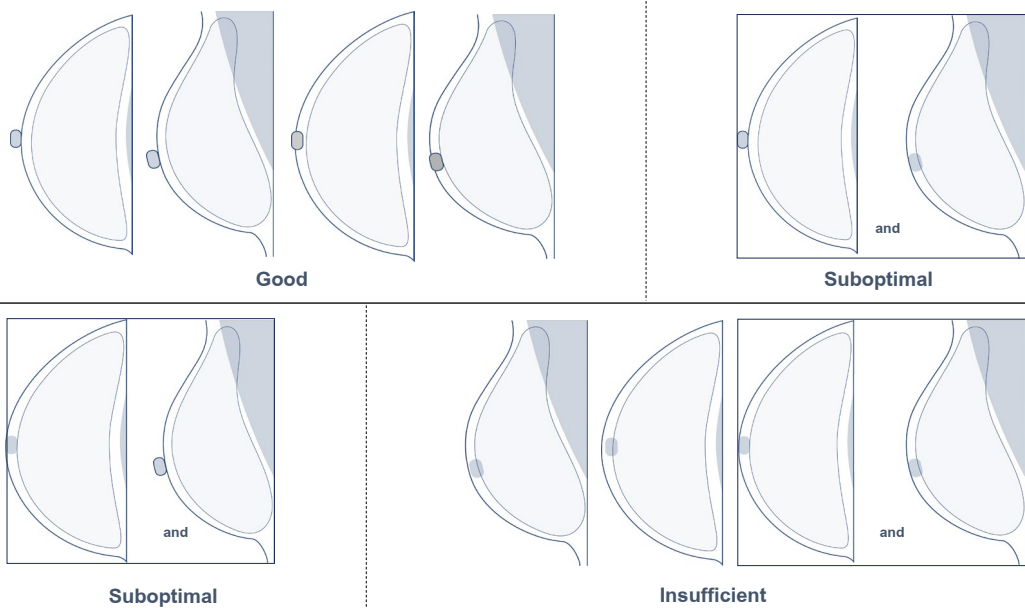
Impact factor for this criterion ★★★★★ (3.43)

Tips and tricks

- A detector positioned too high in the CC view may cause the nipple to point downward, whereas a detector positioned too low may cause the nipple to point upward.
- If the nipple points too far laterally on the MLO view, attempt to include more lateral tissue on the detector. If the nipple points too far medially, attempt to include additional medial tissue on the detector¹⁰ or adjust the woman's rotation angle.
- Prior to final positioning, gently smooth the breast and assess the direction of the nipple. Adjust the detector height if required (CC) or alter the woman's rotation slightly (MLO).
- Position the woman at a sufficient distance (a hand's breadth) from the detector to allow proper forward positioning¹⁰.
- Just before acquiring the image, use the light field to verify that the nipple is correctly positioned¹⁶.

- When an additional nipple view is performed, this should be marked in the computer system (NP). A smaller compression paddle can often be used, leading to reduced radiation dose and lower required compression force due to the smaller breast area.

In focus



9. The fibroglandular triangle is fully extended, with the retroglandular fat visible

Rationale

Optimal forward positioning and maximal spreading of the breast, combined with adequate compression, reduce overlap of glandular tissue and enhance the visibility of lesions and architectural distortion^{10,16,47}.

Visible retroglandular fat indicates adequate forward positioning of the breast and optimal imaging of the posterior breast tissue. Retroglandular fat may not always be visible, particularly in very dense breasts⁵⁰. In very fatty breasts with little glandular tissue, the distinction between breast tissue and the retroglandular fat is not always clearly visible⁵⁸.

Good

Fibroglandular tissue is evenly distributed over a broad area^{10,16,19}, and the darker, less dense retroglandular fat between the glandular tissue and the pectoralis muscle is visible²¹.

Suboptimal

The fibroglandular tissue is not evenly distributed, but without disturbing overlap.

Insufficient

Uneven distribution of fibroglandular tissue leads to disturbing overlap and/or the posterior fibroglandular tissue is not fully included.

Retake

Comparison with the contralateral breast, with the corresponding MLO or CC view, or with prior images of the same breast may help determine whether fibroglandular and retroglandular tissue are adequately visualised (see criteria 13-15).

If there is markedly reduced spreading of fibroglandular tissue compared with other views, or if retroglandular tissue is not visible, a retake should be considered. A retake is also advised when disturbing overlap is present in a particular region.

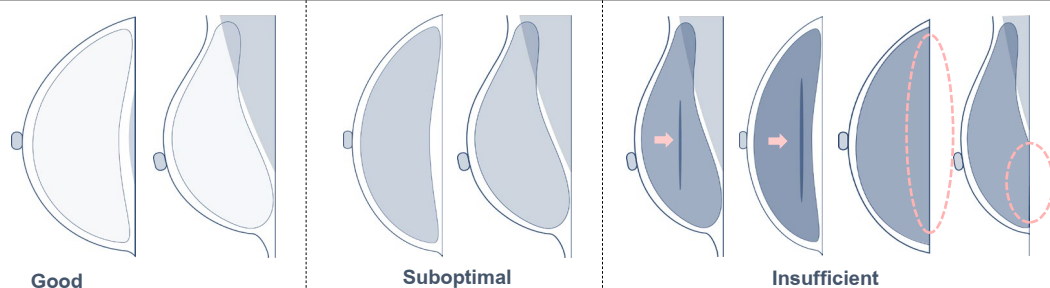
Impact factor of this criterion ★★★★★ (3.70)

Tips and tricks

- The woman should ideally stand at a distance of approximately one hand's breadth from the detector plate for both CC and MLO views, allowing the breast to be brought forward more effectively and completely¹⁶.
- In the CC view, the breast is brought forward using both hands, with the upper hand starting high on the breast (fingers held together) and the lower hand positioned close to the rib cage. The breast is then firmly spread forward, first using the lower hand and subsequently the upper hand¹⁶.
- Ensure correct compression, allowing the compression paddle to gradually take over from the hand^{10,16}.

- During MLO positioning, bring the arm on the side being examined as far forward as possible and rest it on the detector plate. Use your free arm to support the woman across the back and shoulders and position her as close as possible to the mammography system. Firmly draw the breast forward and upward¹⁶.
- When imaging very large breasts, work with two radiographers where possible and/or acquire the images in multiple segments (mosaic view; see Criterion 12: Alternative views)¹⁶.
- During MLO positioning, ensure that the detector plate is not set too high, as this may cause impingement of the pectoralis muscle or the arm. This can result in uneven compression, with insufficient pressure on the central region and reduced spreading of the glandular tissue¹⁶.
- Discrepancy in the visibility of retroglandular fat between the MLO and CC views of the same breast suggests insufficient forward positioning or spreading on the view lacking retroglandular fat.
- Firm forward positioning of the breast may be very painful and can lead to skin fissures, tears or wounds¹⁰ in women with underlying skin conditions, such as eczema or intertrigo (red, sensitive, irritated skin in skin folds, including beneath the breasts). The breast should therefore be inspected beforehand under adequate lighting, and skin sensitivity should be considered. If fissures or skin tears do occur, appropriate wound care is recommended.

In focus



10. No interfering skin folds or air artefacts are present

Rationale

Projections of skin folds or air inclusions may obscure underlying tumours⁴⁷.

It is not always possible to achieve a completely fold-free image. As not all skin folds or air projections impede correct assessment, image repetition is not always required. Small folds at the level of the pectoralis muscle, skin edge or axilla that do not project over the glandular breast tissue, or air projections in which correct assessment of the breast tissue is possible by adjusting contrast and brightness ("windowing"), are therefore considered less problematic⁶⁷.

Good

There are no disturbing superimposed skin folds or air bubbles and air gaps^{16,19,21,47,48,59}.

Suboptimal

Although disturbing skin folds and/or air projections are present, adequate assessment of this breast region is possible on the other view of the same breast^{58,67}.

Insufficient

Disturbing skin folds and/or air projections are present, preventing accurate assessment for abnormalities^{16,17,21}. This region of the breast is also not adequately assessable on the other view (CC or MLO)⁶⁷.

Retake

Even if the obscured breast area is assessable on the other view, a retake is recommended when no prior images are available or when suspicious abnormalities are present. In case of doubt, and if the woman is still present, repeat imaging should be performed.

Impact factor of this criterion ★★★★★☆ (3.78)

Tips and tricks

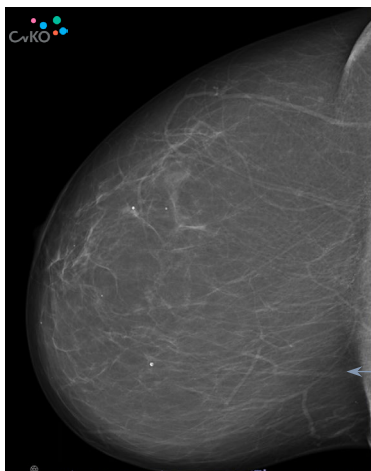
- Ensure correct detector plate height during CC positioning¹⁶. A detector set too low may result in skin folds inferiorly, whereas a detector set too high may cause folds superiorly.
- In the CC view, do not lift the breast excessively onto the detector plate, as this can cause air inclusions beneath the breast. Use the lower hand to slide the breast over the detector plate instead¹⁶.
- As the hand is removed from between the breast and the detector plate in the CC view, smooth the breast forward to clear skin folds and air inclusions¹⁶.
- For the CC view, ensure that the woman's head is turned medially, the chin is slightly elevated, and the shoulder on the imaging side is lowered¹⁶.
- Ensure that abdominal tissue does not obstruct positioning. Asking the woman to move her buttocks backward and lean the upper body slightly forward with a straight back may help. If abdominal folds are suspected,

gently smooth the abdominal tissue downward from below where the detector plate contacts the abdomen, avoiding displacement of breast tissue.

- In the CC view, check the medial and lateral aspects for skin folds or air inclusions and smooth them out, preferably in a forward direction¹⁶.
- In the MLO view, avoid setting the detector plate too high, as this may cause impingement on the pectoralis muscle or arm. This results in uneven compression, reduced pressure at the breast–abdominal interface, and an increased risk of folds^{10,16}.
- During MLO positioning, ensure that no posterior back tissue is included when positioning the breast¹⁶. Place your free arm around the woman and briefly check the lateral aspect of the breast.
- In the MLO view, avoid lifting the breast too high or spreading it excessively upward, to prevent a skin crease from becoming a skin fold.
- After compression during the MLO view, smooth the breast–abdomen transition. Insert one or two fingers between the breast and the detector plate¹⁰ and gently smooth the glandular tissue forward¹⁶.
- In the MLO view, ensure optimal contact of the axilla and upper breast with the detector plate, and smooth any skin folds upward just before full compression¹⁰.
- Ensure that the woman stands at the appropriate distance from the detector plate (one hand's breadth). Standing too close may prevent adequate smoothing of the breast and skin¹⁰.
- When an air projection or skin fold is visible, use windowing to determine whether the glandular tissue can be adequately assessed through the projection or fold⁶⁷. If windowing is not available on the mammography displays, the image should be reviewed on a diagnostic workstation in case of doubt¹⁰.

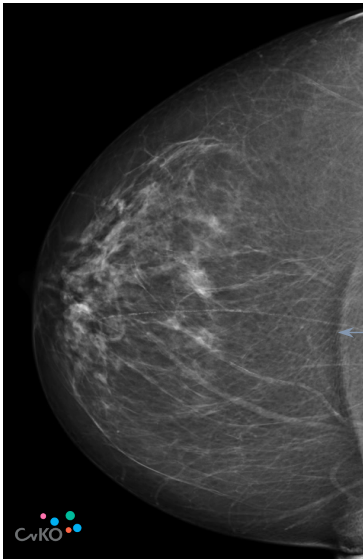
In focus

Common folds in CC views



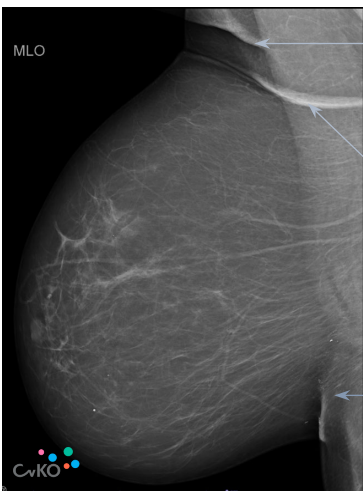
← Inadequate smoothing of the lateral aspect can lead to skin folds (white) or air inclusions (black).

← The breast is lifted high and placed onto the detector rather than being slid over it, which may lead to air inclusions (black).



Obstruction by the abdomen or insufficient smoothing of the breast with the lower hand may result in skin folds (white) or air inclusions (black).

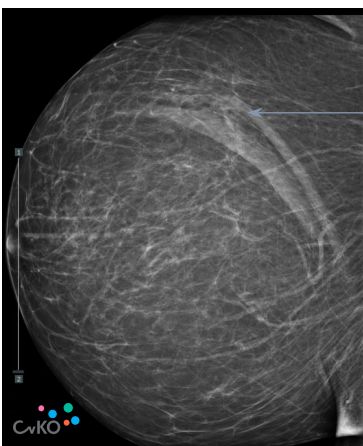
Common folds in MLO views



Inadequate contact of the axilla with the detector plate may result in an air projection (black), or insufficient forward positioning may lead to skin folds (white).

Excessive elevation or upward smoothing of the breast may cause a skin crease to become a skin fold (white).

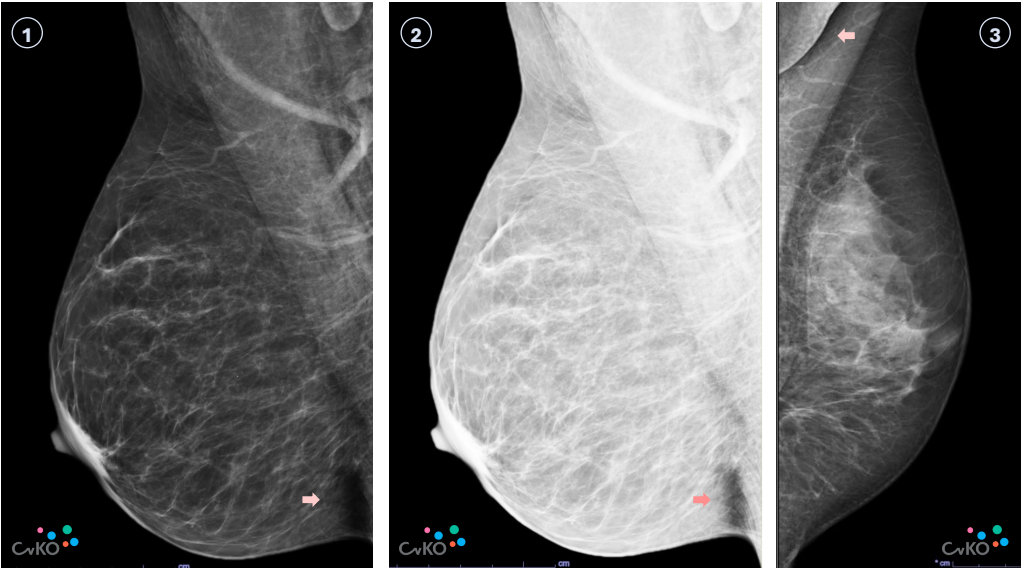
Insufficient smoothing or compression of the inframammary fold may result in air inclusions (black) or skin folds (white). Occasionally, abdominal tissue may interfere (white).



Insufficient forward smoothing of the breast may result in an air gap (black) or a skin fold (white). Occasionally, skin from the back may be included (white).

Skin folds not requiring repeat imaging

When glandular breast tissue can be adequately assessed by windowing despite an air projection, repeat imaging is not required (Figs. 1 and 2). The same applies to axillary and pectoralis folds that do not obscure glandular tissue (Fig. 3).



11.No interfering artefacts due to imaging or processing are present, nor artefacts caused by overlying structures such as hair, shoulder or chin

Rationale

Artefacts, defined as unintended image imperfections, can obscure breast tissue and potential tumours. Certain artefacts may simulate a tumour, for example by taking on the appearance of calcifications⁴⁷.

Breast prostheses and medical implants, such as pacemakers or port catheters, as well as skin abnormalities such as warts or scars, are not considered artefacts. Their presence and location should, however, be clearly documented⁶⁸.

Good

No disturbing artefacts are present^{16,17,19,21,28,47,48,50,59}.

Suboptimal

Although disturbing artefacts are present, adequate assessment of this breast region is possible on the other view (CC or MLO) of the same breast^{58,67}.

Insufficient

Disturbing artefacts are present and obscure breast tissue, preventing correct assessment for abnormalities^{16,17,21} and/or the artefacts present mimic a potential lesion¹⁶. Assessment of this breast area is also not possible on the corresponding projection (CC or MLO)⁶⁷.

Retake

Even if the obscured breast area is assessable on the other view, a retake is recommended when no prior images are available or when suspicious abnormalities are present. In case of doubt, and if the woman is still present, repeat imaging should be performed.

Impact factor of this criterion ★★★★★☆ (4.00)

Tips and tricks

- Enquire whether the woman has used deodorant or other cosmetics in the breast or axillary area. Ensure that these are removed²⁶.
- Ask the woman to remove glasses and jewellery and, if possible, to tie her hair back.
- Inspect the breast under adequate lighting prior to imaging¹⁶. Record the presence of skin warts, scars, eczema, and other skin abnormalities.
- After positioning and prior to image acquisition, use the light field to check for potential artefacts¹⁶.

- In the MLO view, the woman may need to gently move the contralateral breast aside so that it does not appear in the image, taking care not to displace the breast being imaged. Check that her fingers are not visible.

If required during MLO positioning, reposition any dependent upper-arm skin lying on the detector behind the detector plate just before compression.

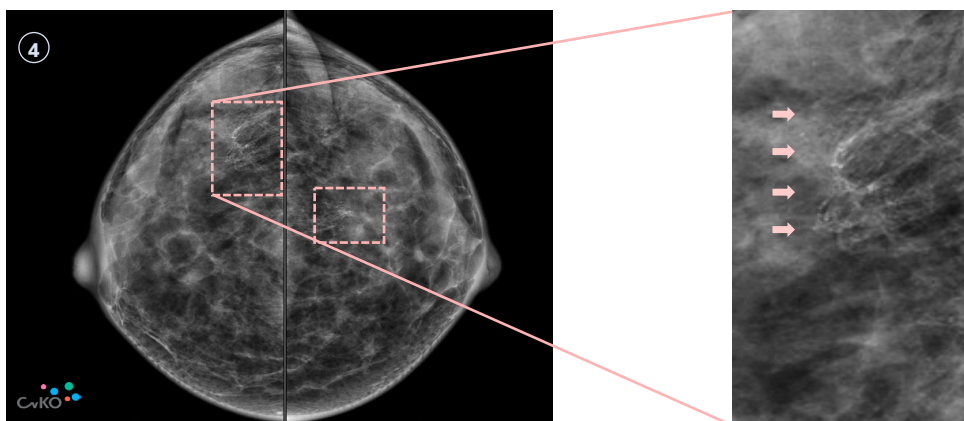
- During CC positioning, ensure that the head is turned medially with the chin slightly raised to prevent projection of the chin. Gently lower the shoulder on the side of the breast being imaged to avoid projection of the shoulder.
- Correct MLO positioning includes rotation of the head towards the side of the breast being imaged with slight posterior tilt to prevent chin projection.
- Carry out physical and technical quality control of both hardware (such as the mammography system and displays) and software (such as image processing software), and take appropriate action based on the results or request support as needed¹⁹.
- Maintain adequate basic knowledge of the mammography system and image processing^{11,16}.

In focus

Frequently encountered artefacts include superimposition of hair, the chin, shoulders, the contralateral breast, fingers, jewellery, glasses, deodorant or other cosmetics⁴⁷. In addition, artefacts may be related to image acquisition and processing, such as grid patterns caused by anti-scatter grid malfunction, ghost images ('residual images from previous exposures visible in the current image'¹⁶), blooming ('white spots due to incomplete pixel discharge from earlier exposures'¹⁶), defective pixels, vibration artefacts resulting in horizontal dark and bright lines, and damaged filters^{16,26,48,62,63,66}.

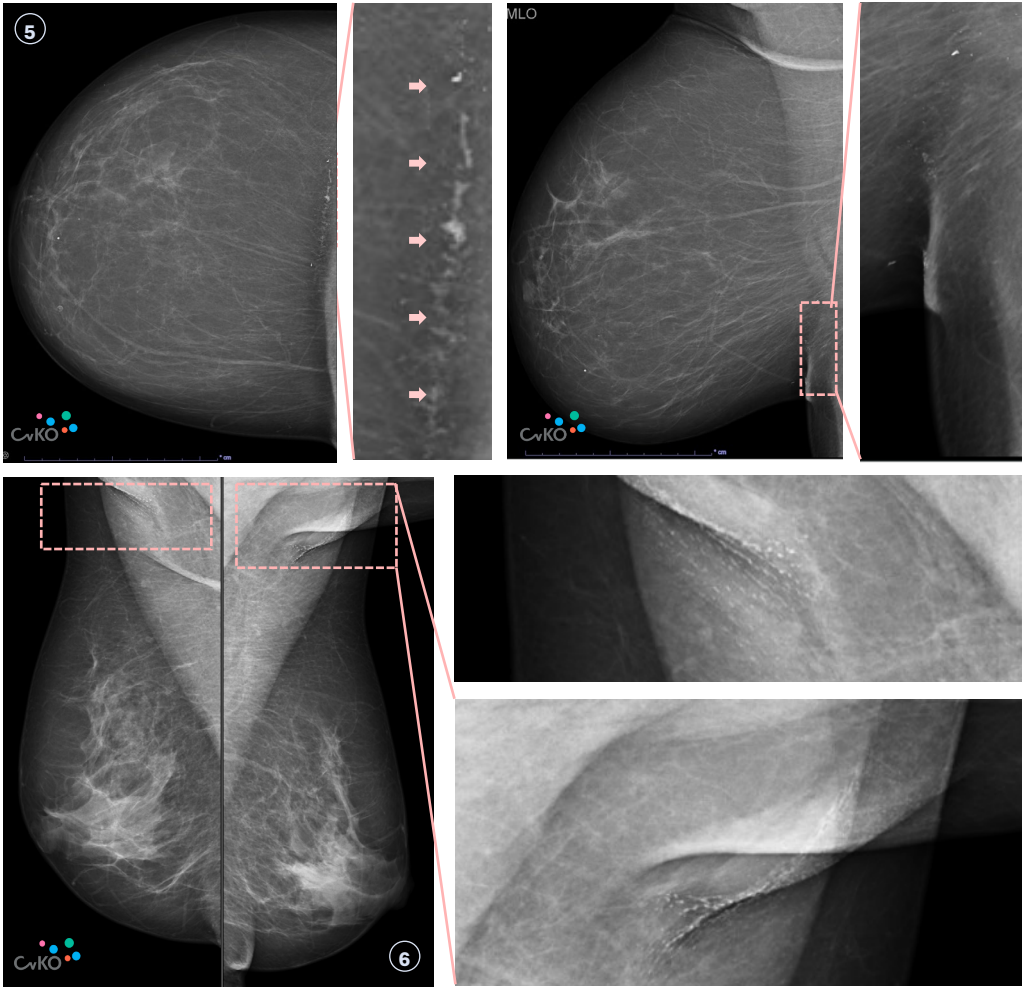
Hair

Figure 4 shows projected strands of hair. Hairspray or other hair products may mimic calcifications.



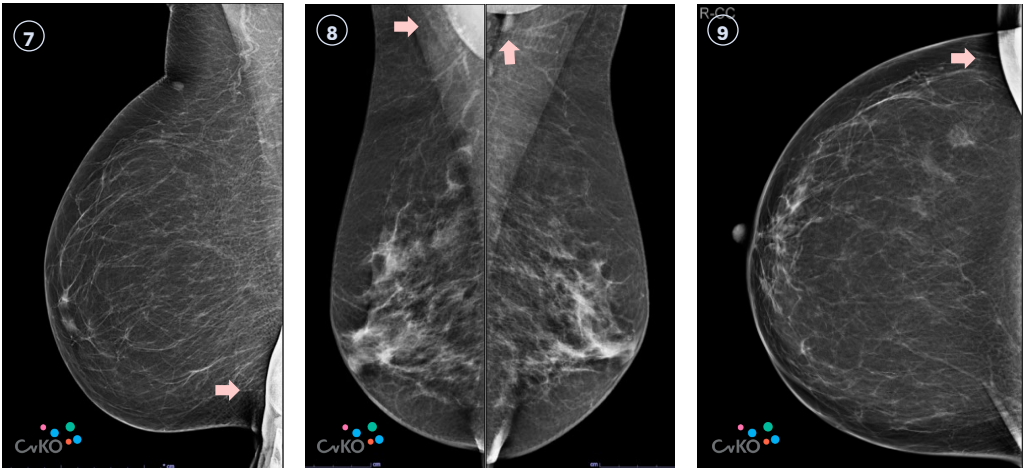
Ointment or deodorant

In Figure 5, ointment artefacts are visible in the inframammary fold. These artefacts were seen on both CC and MLO views. Figure 6 demonstrates the presence of deodorant in the axillae.



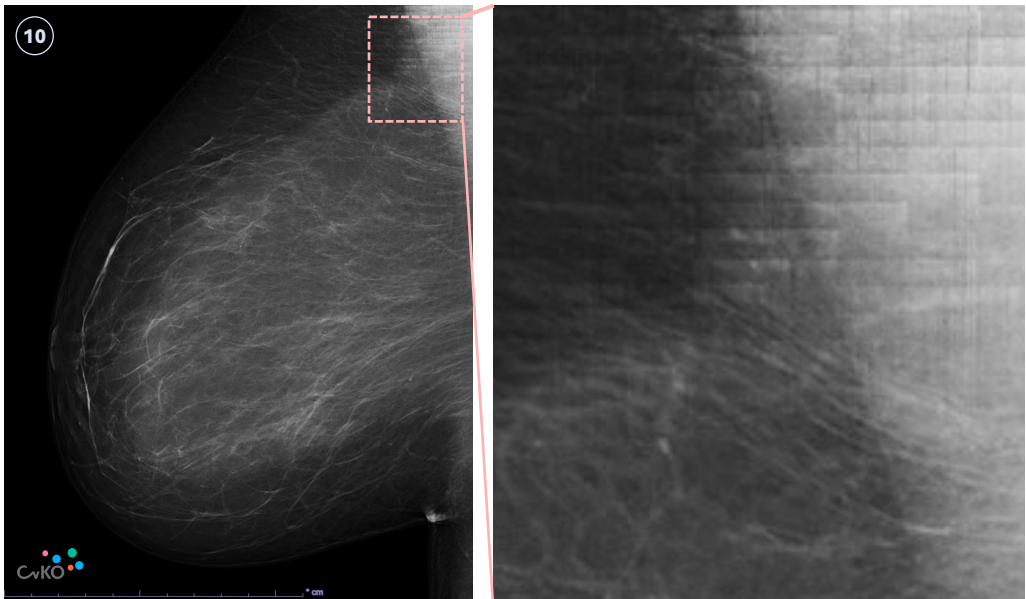
Fingers, chin and shoulder

When asking the woman to hold the contralateral breast aside, ensure that her fingers are not included in the image (Fig. 7). In cases of neck or back pain, it is not always possible to sufficiently turn the chin away from the imaging field (Fig. 8). In such situations, the detector should be rotated upside down and a caudocranial (FB) view should be acquired instead. In the CC view, it is important to prevent the shoulder from being projected into the image (Fig. 9).



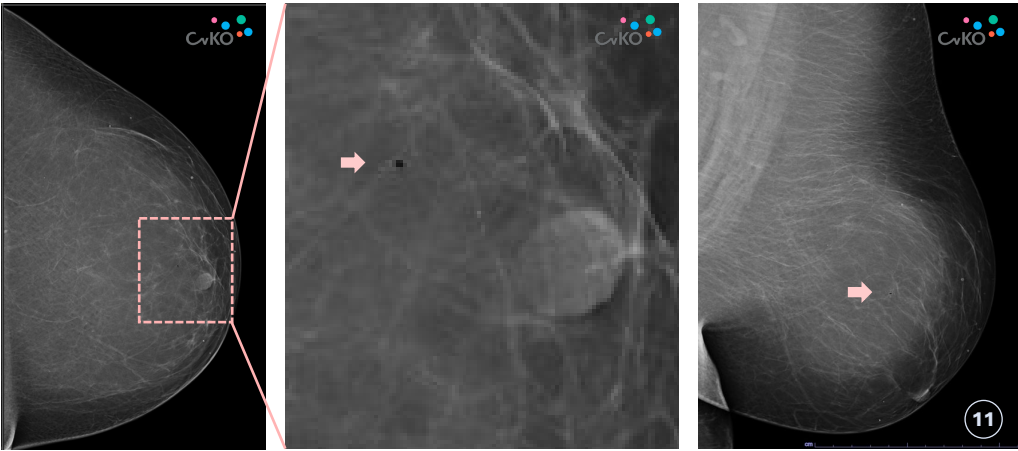
Grid artefact

Figure 10 shows a projection of the anti-scatter grid.



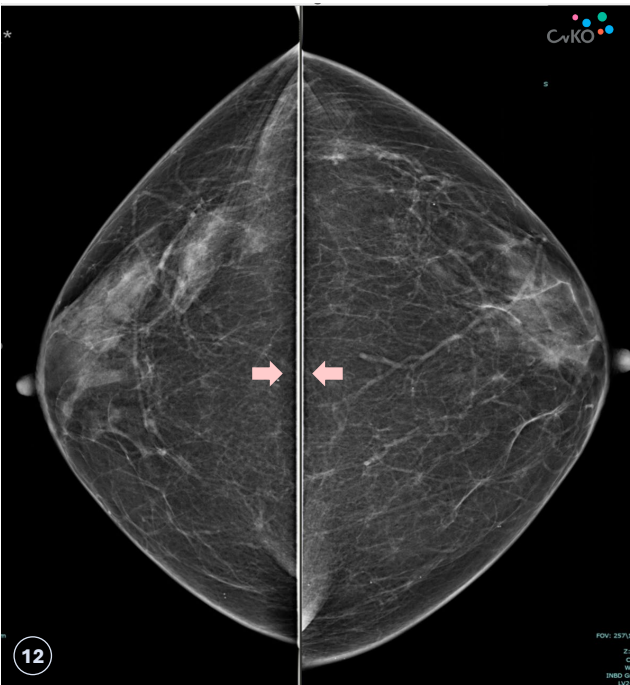
Detector-related artefacts

In Figure 11, a pixel-type detector defect is visible. This defect appears on all images.



Misalignment artefacts

Inaccurate alignment of the detector plate or the collimator (the part of the X-ray tube that defines the size of the radiation field and the light field via a diaphragm) may result in a mismatch between the radiation field, the light field and/or the detector plate. As a result, part of the detector plate does not receive radiation, leading to missing areas of breast tissue on the image and the appearance of distracting white lines. In addition, the raised edge of the compression paddle on the thoracic side may occasionally tilt into the image.



12. Alternative views are available when standard images are inadequate

Rationale

Due to the shape or size of the breast, or as a result of surgery, disease, or the presence of a prosthesis, it is not always possible to fully and/or clearly visualise the breast tissue using standard views. Appropriate alternative views are then required^{16,61}.

Good

Appropriate alternative views of good quality are obtained when standard views do not suffice^{16,50}.

Suboptimal

Alternative views are of suboptimal quality.

Insufficient

Alternative views are absent⁵⁰ or are of insufficient quality.

Retake

Multiple retakes of the same image due to failure to meet a specific criterion are not advised. If image quality remains suboptimal after one retake, a targeted alternative view is preferred, such as a mediolateral view or low MLO view to better demonstrate the inframammary fold, a nipple view when nipple visualisation alone is inadequate, or an Eklund view in the presence of breast prostheses that limit adequate compression on standard views. In some women, anatomical factors or disease may justify proceeding directly to a highly targeted alternative view⁶⁸.

Impact factor of this criterion ★★★★★ (3.39)

Tips and tricks

- Supplementary and alternative views are concisely described in the LRCB manual “Een juiste instelling. Handleiding insteltechniek mammografie”¹⁶. A complementary poster published by the LRCB is also available (www.lrcb.nl/product/poster-insteltechniek-mammografie-uniformiteit-voor-de-vergelijkbaarheid). In addition, the handbook “Digital Mammography: A Holistic Approach” by Mercer C. et al. contains a chapter on supplementary views¹⁰.
- Review whether additional views were required at the previous screening and, if necessary, attempt to acquire the same alternative views to allow comparison between images¹⁶.
- During image selection, the correct view designation should be selected on the display (e.g. NP for nipple view, FB for caudocranial view). View nomenclature may vary between manufacturers.

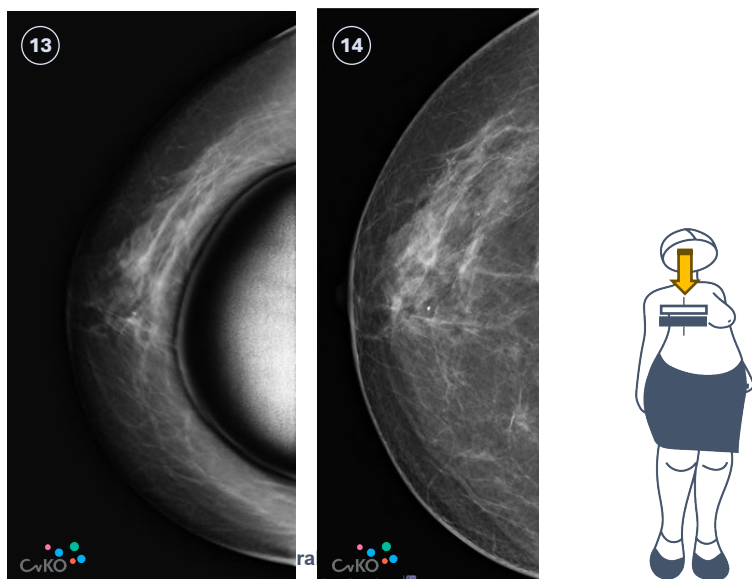
- In women with very small breasts, or when performing a nipple view, a half-size or mini compression paddle may be used. This reduces the radiation dose and lowers the risk of the compression paddle impinging on the radiographer's hands or wrists. These smaller compression paddles are not always supplied as standard.
- In women with very large breasts, positioning by two radiographers simultaneously may be advisable.
- In the presence of medical implants (such as a pacemaker or port catheter), adequate compression is not always possible. In such cases, an additional view of the part of the breast without the medical implant may be acquired with sufficient compression. In contrast to breast prostheses, pacemakers and port catheters should not be manipulated or displaced⁶⁸.
- When in doubt, consult a colleague or the radiologist⁶⁷.
- When an additional image is acquired immediately, quality assessment should be based on the combined evaluation of both images. The intention is that all quality criteria are fulfilled by the image pair⁶⁸. For this reason, images of suboptimal or insufficient quality should not be deleted, as they may show certain areas of glandular tissue more clearly or assist in differentiating true lesions from tissue overlap.

In focus

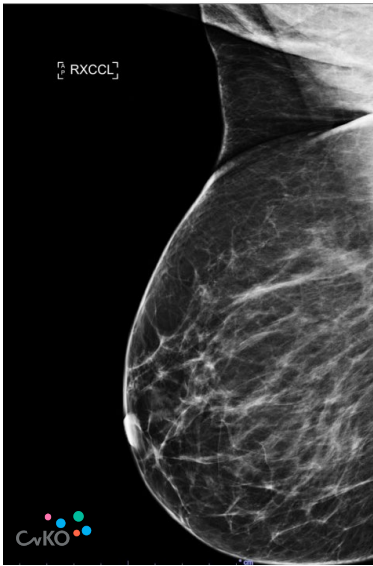
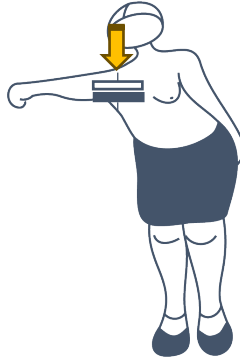
Eklund view

This view is applied in women with breast prostheses that prevent adequate compression, mainly in the case of subglandular prostheses (located in front of the pectoralis muscle)¹⁶. The prosthesis is gently displaced posteriorly towards the chest wall, while the glandular tissue is brought forward as much as possible, and only the tissue anterior to the prosthesis is compressed and imaged^{10,16}.

Fig. 13 shows a standard CC view with reduced compression and motion blur. Fig. 14 shows an Eklund view of the same breast, with the prosthesis displaced towards the chest wall.

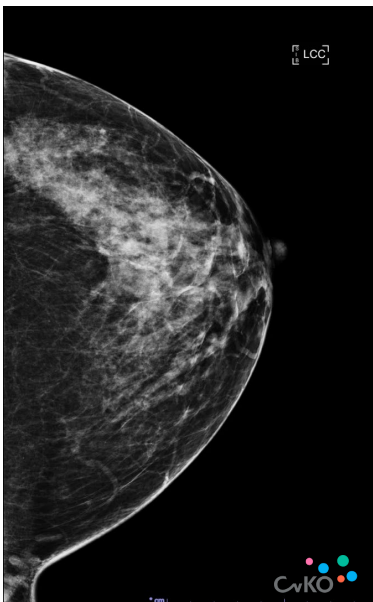


If the lateral portion is insufficiently visualised on a standard CC view, an additional exaggerated craniocaudal lateral view (XCCL) may be obtained, with emphasis on the lateral breast tissue^{16,18}.



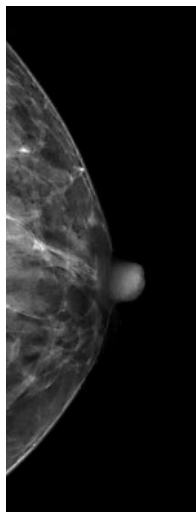
Exaggerated craniocaudal medial (XCCM) view

If the medial portion is insufficiently visualised on a standard CC view, an additional exaggerated craniocaudal medial view (XCCM) may be obtained, with emphasis on the medial breast tissue^{16,18}.



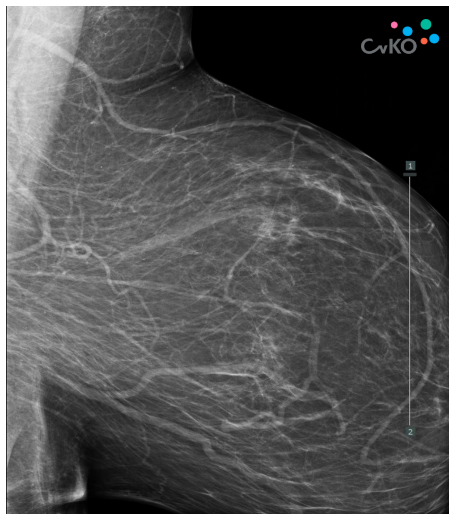
Nipple (NP) view

A nipple view (NP) may be used as an additional view in women in whom the nipple is difficult to visualise free and in profile^{16,18}. Owing to the reduced breast surface, use of a smaller compression paddle¹⁶ and lower compression force is recommended.



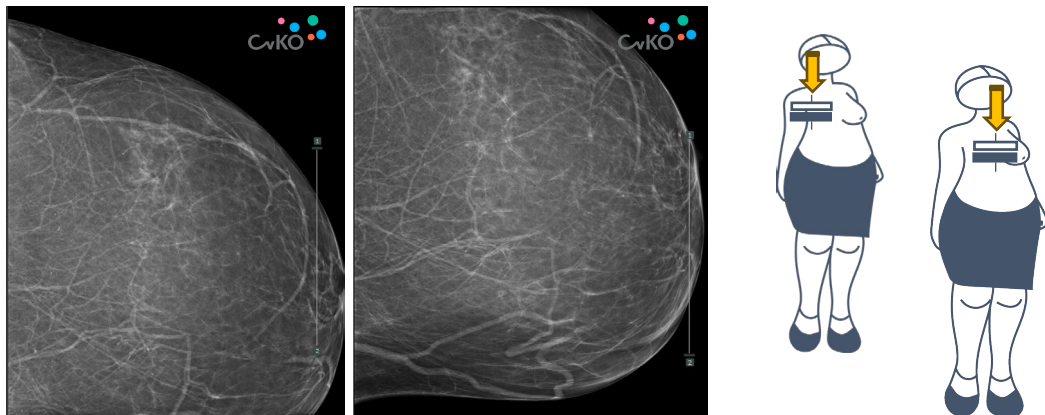
Axillary tail (AT) view

If the axillary tail of the glandular breast tissue is insufficiently visualised on a standard MLO view, an additional axillary tail (AT) view may be obtained, with emphasis on the upper posterior lateral portion of the breast¹⁶.



Mosaic CC view

In women with voluminous breasts, mosaic views can be acquired, in which the breast is imaged in multiple slightly overlapping images¹⁰. For CC imaging, one CC view emphasising the medial breast and another emphasising the lateral breast are obtained. Occasionally, an additional nipple view is necessary^{16,34}.



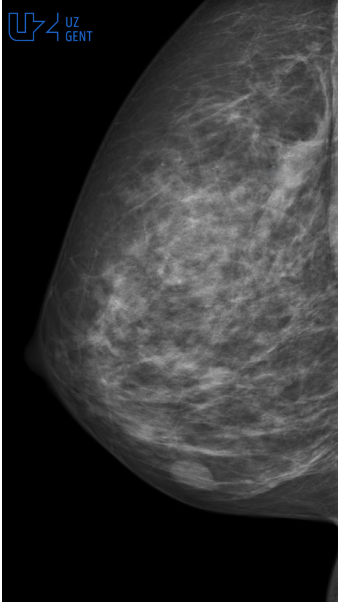
Mosaic MLO view

For the MLO projection, one MLO view focusing on the lower posterior part of the breast and a second MLO view focusing on the upper posterior part (or an axillary tail view) are obtained, with an additional nipple view if required^{16,34}.



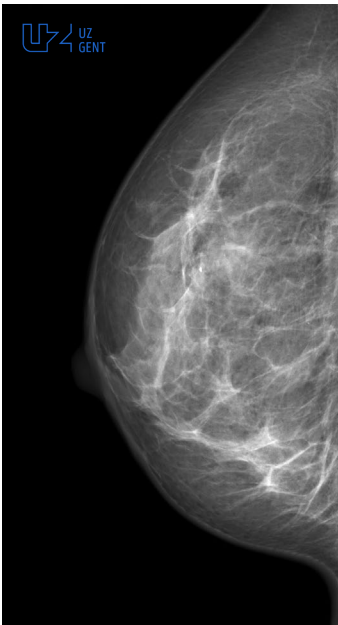
Lateromedial (LM) view

This view may be used in women with pectus excavatum (funnel chest) or to improve visualisation of the inframammary fold¹⁶.



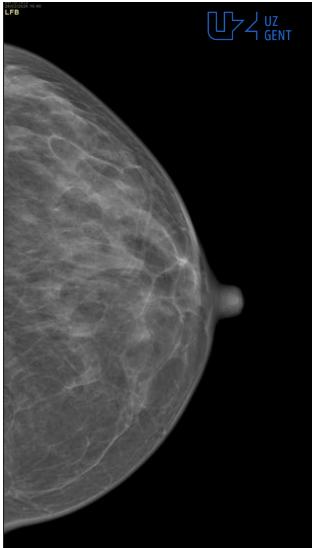
Mediolateral (ML) view

In diagnostic mammography, this view is primarily used together with the CC view to better localise a lesion. In screening, it may be used to better visualise the inframammary fold¹⁶.



Caudocranial (from below, FB) view

In cases of severe kyphosis (hunchback)¹⁶ or neck complaints where the head shield interferes with positioning, the unit can be rotated 180°, allowing caudocranial views to be acquired instead of craniocaudal views.



13. The perpendicular distance between the nipple and the pectoralis muscle differs by ≤ 1 cm between the CC and MLO views

Rationale

If the pectoralis–nipple line (PNL) is approximately equal in length on both views, the breast has usually been brought forward to a similar extent, and the tissue has been spread equally well on the CC and MLO views¹⁶.

The pectoralis–nipple line (PNL) is defined as the central line drawn from the nipple to the posterior breast, perpendicular to the pectoralis muscle, or to the posterior image border when the muscle is not visible on the CC view²¹. Measurement is performed from the nipple–skin junction to the anterior margin of the pectoralis muscle or, if absent, to the posterior edge of the image.

Good

The pectoralis–nipple line differs by no more than 1 cm between the CC and MLO views²¹.

Suboptimal

The pectoralis–nipple line differs by more than 1 cm between the CC and MLO views²², however, all breast tissue is adequately spread and maximally included.

Insufficient

The pectoralis–nipple line differs by more than 1 cm between the CC and MLO views^{22,50} and adequate tissue spreading or complete inclusion is not achieved on one of the views.

Retake

When the pectoralis–nipple line differs by more than 1 cm between CC and MLO views^{22,50} and tissue spreading or inclusion is inadequate, retake of the image with insufficient glandular tissue representation is advised.

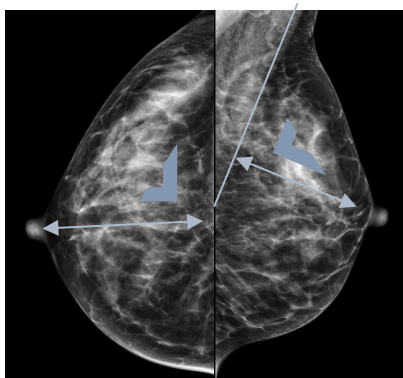
Impact factor of this criterion ★★★★★ (3.35)

Tips and tricks

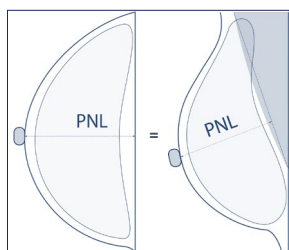
- PNL measurements should be performed using the digital ruler provided in the tools menu. Because CC and MLO images are not always displayed at identical magnification on the reading screen, the use of an external ruler may result in inaccurate measurements⁶⁸.
- In the presence of a breast prosthesis, the PNL is measured from the nipple–skin junction perpendicular to the anterior surface of the prosthesis⁶⁸.
- If the nipple is projected within the breast, the PNL is measured from the skin surface just beyond the nipple⁶⁸.

- If the pectoralis muscle does not extend sufficiently on the MLO view, the PNL is drawn perpendicular to the extension of the pectoralis muscle and measured to the posterior edge of the image⁶⁸.
- If this criterion cannot be met due to factors such as specific breast anatomy, breast pathology, or the presence of implants, this should be documented in the record.

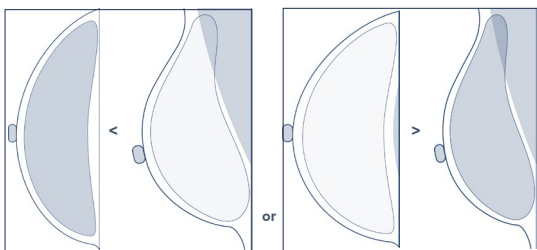
In focus



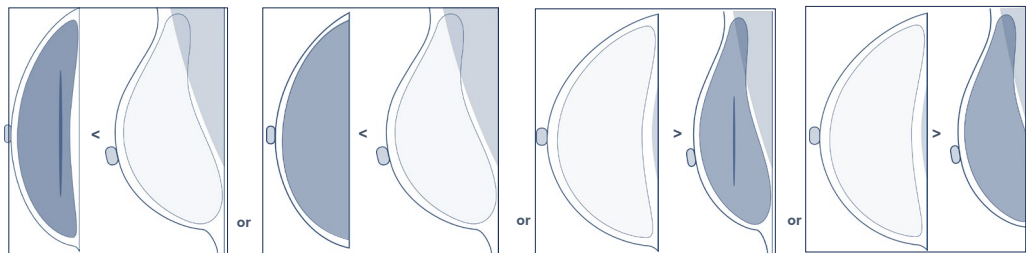
Pectoralis-nipple line in CC and MLO views



Good



Suboptimal



Insufficient



PNL with a short pectoralis muscle



PNL with atypical nipple position



PNL with a prosthesis

14. The left and right breasts are shown symmetrically

Rationale

When left and right mammographic images are symmetrical, this usually confirms correct positioning and proper alignment of the automatic exposure control (AEC). Symmetry improves radiological interpretation by enabling effective comparison between breasts and facilitating identification of subtle structural and architectural abnormalities⁷⁰.

In some cases, pronounced differences between the breasts may be present due to anatomical variation or disease, making symmetrical images impossible. This should be documented in the record⁶⁷.

Good

For CC views, equal pectoralis–nipple line lengths, mirrored nipple positions, and symmetric inclusion of medial and lateral breast tissue are present on left and right images. For MLO views, pectoralis–nipple line length, nipple position, pectoralis muscle width and length, and inclusion of superior and inferior breast tissue are symmetric. Contrast, image sharpness, and dose are comparable. Minor non-disturbing asymmetry may be scored as good.

Suboptimal

Asymmetry is present, but the images are comparable and allow detection of structural and architectural differences. The pectoralis–nipple line (PNL) differs by more than 1 cm between the views, but all glandular tissue is adequately visualised.

Insufficient

The images are too dissimilar to allow comparison, potentially obscuring subtle structural and architectural differences. The pectoralis–nipple line differs by more than 1 cm between the left and right views, and glandular tissue is inadequately spread or incompletely visualised on one image.

Retake

When images are too dissimilar to allow comparison, retake of the image with quality impairment is advised. If the asymmetry results from anatomical variation or pathology, repeat imaging may not be indicated; the underlying reason should then be recorded in the record⁶⁸.

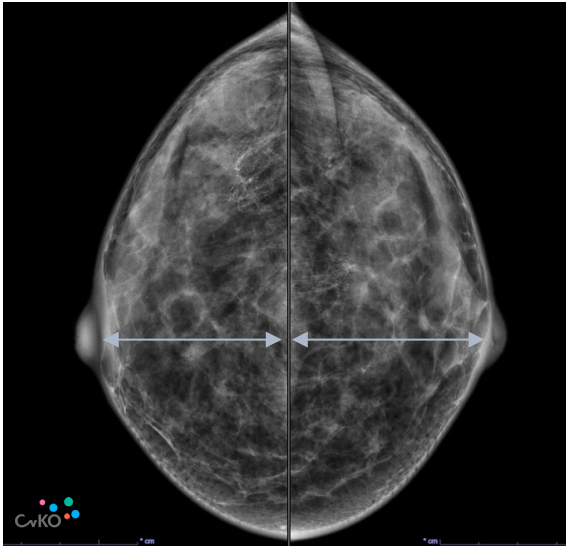
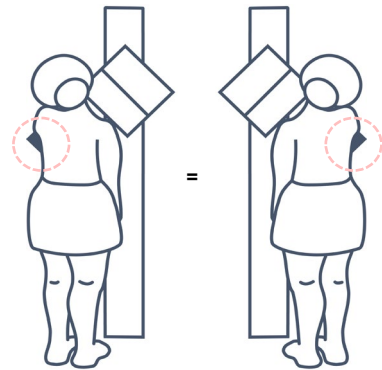
Impact factor of this criterion ★★★★★☆ (3.35)

Tips and tricks

- Select the correct compression paddle size.
- Align the breast midline with the detector plate midline for the CC view¹⁶.
- In the MLO view, the nipple is usually positioned close to the midline of the detector plate. Depending on the system, the detector plate generally needs to be positioned slightly lower than for the CC view.
- In the MLO view, ensure similar woman rotation relative to the detector plate on both sides; the visible triangular area of the detector plate below the axilla should be equal on the left and right (see illustration).

- For both CC and MLO views, bring the breast sufficiently forward onto the detector plate and apply adequate compression¹⁶.

In focus



The visible triangular area of the detector plate is symmetrical on the right and left MLO views

15. The images are uniform compared with previous screening images (if available) and are of equal or better quality

Rationale

Image comparison facilitates early detection of tumours^{16,70} and identification of stable lesions as benign⁵⁰. Prior to mammography, previous images should be reviewed for quality issues, and any potential improvements should be addressed where feasible^{16,67}.

Good

Sequential screening images are technically and positionally consistent (= uniform), enabling accurate comparison and improving detection of structural and architectural changes in the breast.

The difference in the pectoralis–nipple line between previous and current images is less than 1 cm²¹.

Suboptimal

Image quality is inferior compared with the previous examination and/or, due to alternative technique or positioning, the images differ; however, the images remain comparable and changes in breast structure and architecture can still be detected. The pectoralis–nipple line (PNL) differs by more than 1 cm between the previous and current images, but all glandular tissue is adequately visualised.

Insufficient

Image quality is markedly worse than on the previous examination, precluding adequate assessment. Differences related to alternative technique or positioning render the images non-comparable, with a risk of missing subtle structural and architectural changes¹⁶.

The PNL differs by more than 1 cm between the previous and current images, with overlapping glandular tissue or incomplete visualisation of the glandular tissue.

Retake

If the previous images were of poor quality and the current images are of better quality, but comparison is therefore difficult, this criterion may be regarded as “not applicable”. The aim is not to reproduce poor-quality images in order to maintain uniformity.

If the woman has undergone marked changes due to factors such as weight loss, disease, or surgery, and uniform images cannot be achieved, this should also be considered “not applicable”, even if assessment for suspicious lesions is more challenging for the radiologist. As this cannot be influenced by the radiographer, repeat imaging is not meaningful. This must be documented in the record. The same applies when a mammogram is acquired on a substantially different mammography system⁶⁸.

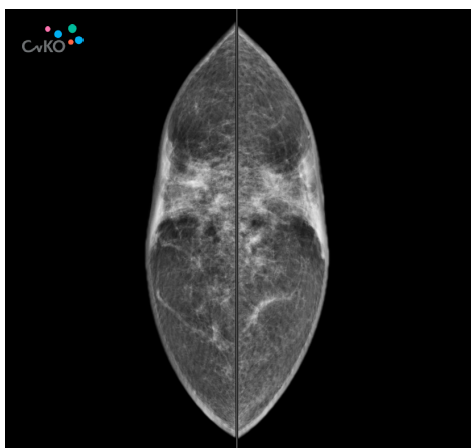
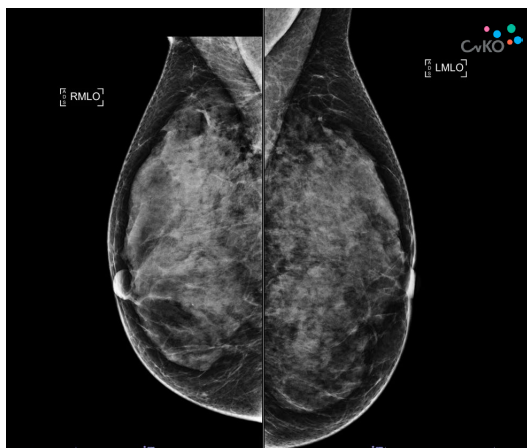
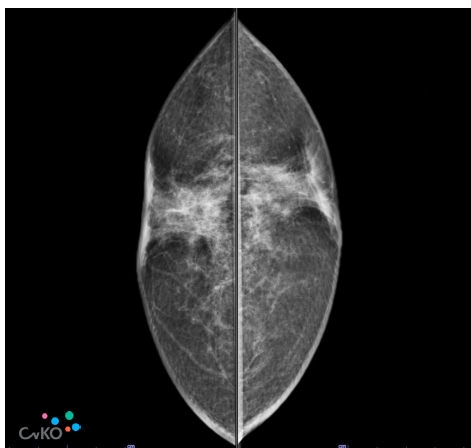
Impact factor of the criterion ★★★★★☆ (3,70)

Tips and tricks

- Check previous mammograms before commencing the examination¹⁶.
- Any use of alternative views or special mammography settings (such as adjusted MLO angulation) should be documented for future reference¹⁶.
- Enquire whether the woman has undergone notable changes since her last mammogram due to diet, disease, or surgery.

In focus

The lower CC and MLO views are from the most recent screening, whereas the upper CC and MLO views were obtained two years previously. Improved tissue spreading on the recent images allows more complete depiction of glandular tissue and visualisation of retroglandular fat. On the RMLO view, the pectoralis muscle is better demonstrated.



16.No motion blur is present

Rationale

Image sharpness (spatial resolution) refers to the ability to distinguish between two very small objects located close together and to visualise them as separate entities¹⁰.

Image sharpness must be of sufficiently high quality, as calcifications can be very small (microcalcifications) and lesions are not always well defined. Correct evaluation of calcification characteristics, lesion morphology, and architectural distortion is crucial in differentiating benign from malignant lesions.

Good

Cooper's ligaments, ducts, blood vessels, and any lesions are sharply delineated. Calcifications are clearly distinguishable, with well-defined morphology and distribution²⁹.

Suboptimal

Although the image shows slight blurring globally or in limited areas, sharpness is adequate for the assessment of suspicious findings. Cooper's ligament network can be identified, and calcifications or lesions remain well defined.

Insufficient

The image is blurred overall or in some regions and is inadequate for evaluation of suspicious lesions⁴⁷.

Retake

If uncertainty exists but unsharpness is strongly suspected, and the woman remains at the mammography system, repeat imaging is justified. In addition, advice may be obtained from the radiologist or another radiographer.

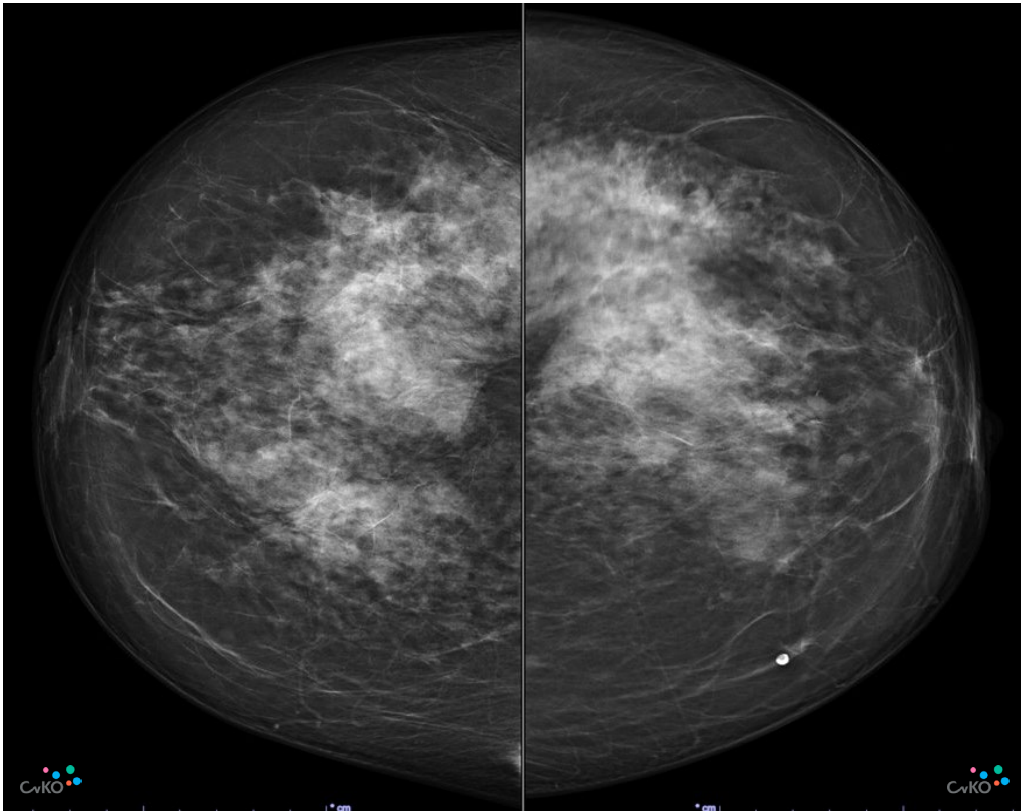
Impact factor of this criterion ★★★★★ (4.39)

Tips and tricks

- Adequate compression provides better fixation of the breast, resulting in reduced motion^{10,16}.
- Adequate compression, combined with an increase in tube voltage (kV), allows shorter exposure times and may improve image sharpness²⁶.
- Adequate compression also reduces the distance between the breast tissue and the detector, resulting in less magnification and reduced local unsharpness¹⁰.
- Asking the woman to remain still and hold her breath during image acquisition can improve image sharpness. This is particularly important when adequate compression cannot be achieved⁶⁷.
- During MLO positioning, ensure that the detector plate is not set too high, so that it does not impinge on the pectoralis muscle or the arm^{10,16}. This can lead to uneven compression, with reduced pressure on the breast itself and an increased risk of unsharpness, particularly in the inferior region¹⁶.
- The size and number of pixels in the detector influence image sharpness. The number of pixels per cm² may vary between systems, resulting in differences in image sharpness¹⁰.

- Regular physical and technical quality control of both hardware and software is important for this quality criterion^{6,11,18,19}.
- Image sharpness is often best evaluated on the radiologist's workstation, as mammography system displays meet less stringent requirements. When unsharpness is suspected, images may be reviewed on a high-quality diagnostic monitor^{10,67}.

In focus



Sharp image (RCC view)

Motion-blurred image (LCC view)

17. Image contrast is optimised and noise is minimised at the lowest achievable radiation dose

Rationale

Malignant lesions can be very subtle, cause minimal clinical changes, and resemble background glandular tissue. Very high contrast resolution and minimal image noise are required to distinguish subtle lesions from background structures, with contrast resolution defined as the ability to clearly display different breast structures in varying grey levels¹⁰. Excessive noise produces a grainy appearance in the image⁴⁷.

A healthy population is exposed to radiation during screening, and glandular breast tissue is especially radiosensitive. For this reason, radiation dose should be kept as low as reasonably achievable^{21,39} without compromising image quality⁶⁷.

Good

Good contrast results in clear differentiation between glandular and fatty tissue due to differences in grey values. Subtle lesions or architectural abnormalities can be identified against normal breast tissue^{10,47,59}. Skin delineation is visible, calcifications are clearly denser than the surrounding tissue²⁹, and little noise is present.

The average radiation dose, commonly recorded as AGD (average glandular dose), should be below 2 mGy per exposure for an average breast (compressed breast thickness of 5.5 cm), with a target value of approximately 1.4 mGy. The maximum permissible dose and target value depend on the compressed breast thickness and breast density³⁶, with higher doses required for thicker and/or more dense breasts. See also the appendix 2. Recommended dose limits.

Suboptimal

Image noise is present or contrast is suboptimal; however, glandular tissue, fatty tissue, and pathological changes can still be clearly distinguished. The radiation dose may be marginally above the acceptable threshold.

Insufficient

Image noise precludes adequate assessment of the presence of lesions⁴⁷.

Incorrect tube current or tube voltage settings do not allow adequate visualisation of soft-tissue detail or differentiation between glandular tissue, fatty tissue, and pathological changes⁴⁷.

The radiation dose is markedly above the acceptable limit. If image quality is otherwise adequate, repeat imaging should of course not be performed.

Retake

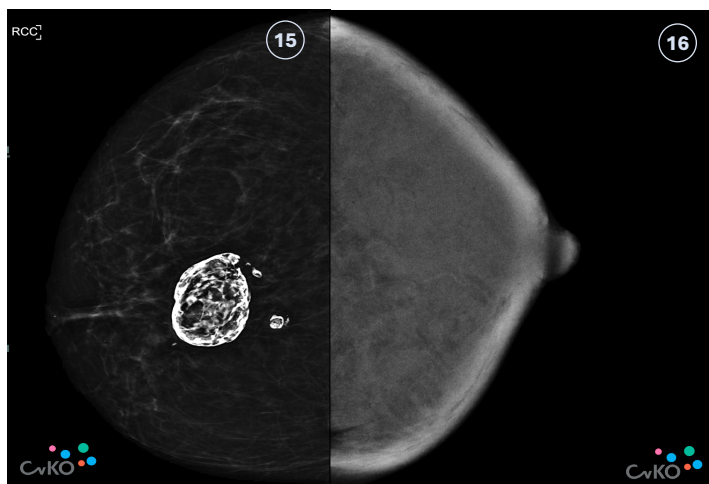
In case of doubt, but with a strong suspicion of problems, and if the woman is still present at the mammography system, repeating the image is appropriate⁶⁸. Advice may be sought from the radiologist or a colleague.

Tips and tricks

- Proper use of the automatic exposure control (AEC) system ensures selection of the correct tube voltage (kV), tube loading (mAs), and anode/filter material for a given breast thickness. These parameters play a key role in defining radiation dose, contrast, and image noise¹⁰. Additional information is available in the appendices.
- In exceptional cases, kV and mAs need to be set manually, for example in the presence of certain breast implants or in breasts that have undergone surgery or radiotherapy⁶⁴. Guidelines for manual settings are provided in the appendices; these may vary between systems.
- The applied radiation dose should be reviewed regularly, particularly in case of manual exposure setting.
- Adequate compression reduces breast thickness. This allows a reduction in tube loading and, in particular, tube voltage, leading to a lower radiation dose with increased image contrast. Thinner breasts also generate less scattered radiation, which further improves contrast^{10,16}.
- This quality criterion relies on regular physical and technical checks of mammography hardware and software^{6,11,18}, in addition to routine monitoring of the radiation dose.
- Contrast and image noise can sometimes only be reliably assessed on the radiologist's display. Displays in the mammography room meet less stringent requirements. If contrast problems or excessive noise are suspected, images may be reviewed on a high-quality diagnostic monitor⁶⁷.

In focus

Fig. 15: Due to the presence of a large, calcified lesion, the AEC misestimated breast density, leading to low contrast resolution within the glandular tissue. Fig. 16: Incorrect tube current and voltage caused by a technical defect resulted in excessive image noise.



18. Compression is around 120 newtons, depending on breast size and firmness

Rationale

Adequate compression, combined with proper spreading of the breast, ensures that breast tissue is evenly distributed with minimal overlap of glandular tissue⁴⁷. This improves visibility of lesions and disturbances of normal breast architecture^{10,16}. Proper spreading and compression also allow improved inclusion of the posterior part of the breast in the image¹⁰.

Compression reduces breast thickness, allowing a lower radiation dose and a shorter exposure time. Lower-energy X-ray beams can be used, and scatter radiation is reduced, resulting in improved image contrast^{10,16}. In addition, compression limits breast motion, preventing image blurring^{10,16,47}.

Breast compression is, however, uncomfortable and may be painful¹⁶, and represents a major factor contributing to non-attendance or dropout from screening programmes⁵². Excessive compression is therefore not desirable¹⁰.

Good

The compression force is typically around 120 newtons (N) or 12 decanewtons (daN)⁶⁷. For small breasts, a lower force is usually applied (60-90 N)⁴², whereas higher forces are generally used for voluminous breasts (150-200 N); the maximum compression force is set at 200 N¹⁰ or higher¹⁶. When the system uses compression pressure (with force already normalised to breast surface area), the optimal value is approximately 10 kilopascals (kPa) with correct positioning¹⁰.

When increasing compression no longer results in a reduction of breast thickness, further compression provides no additional benefit⁵⁷.

Suboptimal

The applied compression force is very low, yet image quality is sufficient for assessment and tissue spreading is adequate. The compression force is too high and may have caused additional discomfort.

Insufficient

The applied compression force is inadequate, leading to general or focal image unsharpness or disturbing overlap of glandular breast tissue.

Retake

A retake is recommended in cases of general or localised blurring and/or disturbing tissue overlap.

Impact factor of this criterion ★★★★★☆ (3.74)

Tips and tricks

- Clearly explain the importance of breast compression to the woman, emphasising improved image quality and reduced radiation dose, and assess breast tenderness¹⁶.
- Correct positioning should be ensured, as the presence of skin folds and uneven breast spreading may increase pain during compression and result in non-uniform compression pressure^{16,47}.
- Setting the detector plate sufficiently high for the CC view (to 1-2 cm above the breast-abdomen junction) improves pressure distribution between the compression paddle and the detector plate and results in more uniform pressure across the breast, with reduced discomfort^{10,53}. However, ensure adequate inclusion of the posterior-lower breast region and prevent downward tilting of the nipple.
- Correct detector height adjustment is also important in the MLO view. If the detector plate is positioned too high, the compression paddle may impinge on the firm pectoralis muscle or the arm, which can result in insufficient and uneven compression of other parts of the breast¹⁶.
- Gradual application of compression force is recommended^{16,47}.
- Seek ongoing feedback from the woman and halt compression once her tolerance limit is reached^{16,47}.
- If adequate compression cannot be achieved, ask the woman to remain still and hold her breath during image acquisition, as this may improve image sharpness⁹.
- Advise premenopausal women experiencing breast tenderness to schedule imaging approximately one week after menstruation¹⁶.
- Administration of paracetamol about 30 minutes prior to imaging may be considered¹⁶.
- Skin injuries such as abrasions or fissures may lead to increased pain during compression or aggravation of the skin problem. The option to defer mammography should then be offered¹⁸.
- Breast thickness reduction should be monitored during compression, and compression should be discontinued once further reduction becomes negligible⁵⁷.
- Excessive compression may also lead to less optimal image interpretation, potentially because tumour masses or architectural distortions become less distinguishable^{37,52,71}.
- Enquire about the presence of prostheses or medical implants, as these can increase discomfort during compression and pose a minimal risk of implant damage or displacement. Gradually build up the compression force until the breast is firmly stabilised, taking into account any anxiety and the woman's tolerance. During image acquisition, ask the woman to hold her breath and remain still to minimise motion unsharpness when lower compression force is applied.
- Certain mammography systems offer a remote control for adjusting compression. After an initial compression force of about 40-60 N has been applied by the radiographer, the woman may take control of further compression if desired. Research indicates that women generally tolerate higher compression levels when they can adjust the force themselves²⁴.
- It is important to know the maximum compression force of the mammography system, which should ideally be set to at least 200 N^{10,16}.

19. The image identification is complete and correct

Rationale

Accurate and complete identification of images ensures correct attribution of the mammogram and corresponding diagnosis to the appropriate person and breast. It also facilitates future retrieval of the images for comparison purposes.

Good

Complete and correct image identification is ensured and includes at least the following:

1. The woman's first and last name^{6,25,47}
2. Date of birth^{6,25,47}
3. Additional identification details, such as a national identification number or a personal identification code^{6,19}
4. Examination date and time^{6,25,47}
5. Laterality (left or right breast)^{6,25,47}
6. Image type: craniocaudal, mediolateral oblique, or alternative views^{6,25,47}

The following additional data must be available, although not necessarily visible on the image itself:

7. Exposure parameters, including target–filter combination, kV, mAs, and exposure time^{6,25}
8. Applied compression force (N) and breast thickness during compression (mm)^{6,10}
9. Relevant positioning details, such as the detector angle used for the MLO projection^{16,25}
10. Radiation dose (milligray) or other parameters used to estimate radiation dose⁶
11. The location where the examination was performed^{6,25}
12. Radiographer identification⁶

The displayed information does not obscure or cover any of the structures under assessment^{6,25,47}.

Suboptimal

One or more of the above-mentioned data are absent or inaccurate, but enough information is present to ensure correct woman identification and proper image interpretation^{6,21,47}. Any missing data should be supplemented if possible.

Insufficient

Repeat imaging is indicated only if the woman's images cannot be retrieved or cannot be correctly interpreted due to incorrect, interfering, or missing labels²¹.

Impact factor of this criterion ★★★★★☆ (3.83)

Tips and tricks

- Before commencing the examination, confirm the woman's name and date of birth and check these against the recorded details.

- Use a predefined order when acquiring images (e.g. right CC, left CC, right MLO, left MLO) and ensure that the digital registration matches this sequence.
- Ensure that any special settings or positioning are documented^{16,25}.
- If alternative imaging views are used, indicate the correct view designation, for example NP for nipple view or XCCL for an exaggerated craniocaudal lateral view.

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Appendices

1. Glossary*

Adverse radiation effects	Harmful health effects associated with exposure to ionising radiation, including increased cancer risk ³⁹ .
AEC	An automatic exposure control system that selects the anode/filter combination, tube voltage, and tube loading for image acquisition as a function of breast thickness and composition. The system is based on information obtained from a short pre-exposure in combination with the indicator of compressed breast thickness ¹⁰ .
Air projection	Due to woman's anatomy, pathology, or suboptimal positioning, air pockets or air gaps may occur between the breast or axilla and the detector plate. These can appear as dark areas on the X-ray image and hinder correct image interpretation.
Alternative views	If standard CC or MLO views are insufficient to fully and/or clearly visualise the breast, several alternative views may be used, such as the Eklund view, nipple view, exaggerated craniocaudal lateral view, etc. ^{10,16} .
Anode	The positive electrode, for example in an X-ray tube ⁷² . When electrons collide with the anode, X-rays are produced ⁷³ .
Anterior	Located at or referring to the front of the body or a structure; at the front ⁷² .
Anti-scatter grid	A grid positioned just above the detector plate that absorbs obliquely incident scatter radiation. The grid is often moving, primarily to avoid grid artefacts being visible on the image ⁷³ .
Architecture	The structural arrangement of cells and tissue within an organ ⁷² .
Artefact	A distorted image ⁷² . Unintended imperfections present in the image.
Axillary tail view	An X-ray image used to better visualise the axillary extension of glandular breast tissue ¹⁶ .
Blooming	White spots in the image caused by incomplete discharge of pixels from a previous exposure ¹⁶ .
Breast cancer screening	An examination aimed at detecting (asymptomatic) breast cancer in order to treat it more effectively at an early stage ⁷² . In Flanders, women aged 50–70 are invited every two years for a mammography examination ⁴¹ .
Breast implant	A structure or material inserted into the breast to increase breast volume, either for cosmetic reasons or following surgical removal of diseased breast tissue ²³ . Also referred to as a prosthesis.
Calcification	Calcium deposition in soft tissues ⁷² .
Cathode	Negative electrode in the X-ray tube responsible for electron emission ⁷³ .
Caudal	Caudal indicates a position or direction towards the lower part of the trunk, opposite to cranial ⁷⁴ .

Caudocranial view	An image acquisition in which the detector is positioned at the head end and the X-ray tube below the breast, with the beam directed from feet towards the head. This view is also known as the “from below” (FB) view ¹⁶ .
Clavicle	Also called collarbone, connects the scapula to the sternum ⁷² .
Collimator	The part of the X-ray system that defines the size of the radiation field and the light field using adjustable diaphragms.
Compression force	The force with which the compression paddle presses the breast against the detector. It is expressed in newtons (N) ¹⁰ .
Compression paddle	The plate used to press the breast against the detector. Compression paddles are available in different sizes and shapes ¹⁰ .
Compression pressure	Compression pressure (kPa) is the compression force (daN) divided by the compressed breast surface area (dm ²) ¹⁰ .
Concave	A hollow or inwardly curved shape ⁷² .
Consensus	Refers to agreement of opinion or unanimity ⁷⁴ .
Contrast resolution	The ability to clearly display different structures in the breast using variations in grey-scale values ¹⁰ .
Convex	A bulging or outwardly curved shape ⁷² .
Cooper's ligaments	A network of ligaments that support the shape and structure of the breast. They are also known as the suspensory ligaments of the breast (ligamenta suspensoria mammaria) and extend from the pectoralis muscle to the skin ⁷² .
Cranial	A position or direction towards the skull, opposite to caudal ⁷² .
Craniocaudal view	An image acquisition in which the X-ray tube is positioned at the head end and the detector towards the foot (tail) end, with the beam directed from head to feet ¹⁶ .
Curvature	The bending of a structure, such as an arc or curve ⁷² .
Cystic breast disease	A benign breast condition characterised by multiple fluid-filled cysts, often accompanied by fibrosis and induration, is known as cystic breast disease or fibrocystic mastopathy ⁷² .
Detector plate	The plate that measures incident radiation at each surface element and converts it into an electrical signal ⁷² , which is subsequently processed into an image ¹⁰ .
Eklund view	This view is used in the presence of breast implants that make adequate compression difficult. During this acquisition, the implant is gently displaced as far as possible towards the chest wall, and only the breast tissue in front of the implant is compressed and imaged ¹⁶ .
Exaggerated lateral craniocaudal view	A craniocaudal image acquisition with emphasis on the lateral portion of the breast ¹⁰ . (XCCL)
Exaggerated medial craniocaudal view	A craniocaudal image acquisition with emphasis on the medial portion of the breast ¹⁰ . (XCCM)
False-negative screening result	A screening result in which an existing cancer is not detected on the screening images ⁷⁷ .
False-positive screening result	When a suspicious abnormality is identified on the screening images, but subsequent diagnostic evaluation demonstrates that no cancer is present ⁷⁷ .

Fibroglandular tissue	Tissue composed of a combination of glandular tissue and connective tissue ⁷² .
Filter	A plate within the X-ray tube that ensures only radiation with the desired energy passes through, thereby reducing harmful radiation and improving image contrast ¹⁰ .
From below view	An image acquisition in which the detector is positioned at the head end and the X-ray tube below the breast, with the beam travelling from the feet towards the head. Also called a caudocranial view ¹⁶ .
Frozen shoulder	A condition characterised by thickening and narrowing of the shoulder capsule, resulting in restricted function of the glenohumeral joint ⁷² .
Ghost images	Residual images from one or more previous exposures that remain visible in the current image ¹⁶ .
Grid artefact	An unintended visible pattern caused by the anti-scatter grid on the image ⁷³ .
Hardware	The electronic and mechanical components in and around a computer system ⁷⁴ , including elements such as the workstation with display and the mammography system.
Humeral head	The rounded articular portion of the upper arm bone (humerus) that articulates within the shoulder joint ⁷⁶ .
Image contrast	Also referred to as contrast resolution; the ability to clearly display the different breast structures using different grey-scale values ¹⁰ .
Image sharpness	Also referred to as spatial resolution; the ability to distinguish between two very small objects located close together and to perceive them as separate entities ¹⁰ .
Inferior	Located lower in position; referring to the lower part ⁷² .
Inframammary fold	The fold beneath the breast, marking the transition between the breast and the abdominal wall ⁷² .
Interval cancer	Breast cancer detected between two routine screening examinations ⁷² .
Kyphosis	Excessive posterior curvature of the thoracic spine ⁷² .
Lateral	Situated at the side or directed away from the midline ⁷² .
Lateromedial view	A breast X-ray image in which the beam travels from the lateral side of the body towards the medial side, with the detector typically positioned vertically near the sternum ¹⁶ .
Light field	Light projected onto the detector plate indicating the position and extent of the irradiation field ⁷³ .
Mammography	Breast imaging using X-ray techniques ⁷² .
Mammography system	A device used to acquire X-ray images of the breast ¹⁰ .
Medial	Situated near the midline of the body ⁷² .
Mediolateral oblique view	A breast X-ray acquisition in which the beam passes obliquely from superomedial to inferolateral. The detector is positioned obliquely against the outer side of the breast ¹⁶ . (MLO)
Mediolateral view	A breast X-ray image in which the beam travels from the medial side of the body toward the lateral side. The detector is usually positioned vertically against the lateral chest wall ¹⁶ . (ML)

Mosaic view	Mosaic imaging may be used in women with large breasts, in which the breast is imaged in multiple, slightly overlapping sections ¹⁶ .
Motion blur	Generalised or localised blurring of the image caused by movement of the object during image acquisition. In mammography, this refers to movement of the breast during exposure ¹⁰ .
Nipple view	An additional projection used when the nipple is difficult to visualise freely and in profile, imaging only the anterior part of the breast ^{10,16} .
Noise	Image graininess that reduces clarity and can obscure anatomical details. Noise may be caused by scatter radiation, low tube current, detector imperfections, etc. ⁷³
NRR-procedure	A procedure of Notice, Remediation, and Revocation of the licence that is initiated when quality standards are not met during mammography screening ¹⁹ .
Pacemaker	An implantable device that delivers electrical impulses to stimulate muscle contraction, for example in the heart ⁷² .
Pathology	Medical discipline dealing with disease and its effects ⁷⁴ .
Pectoralis muscle	Major muscle of the anterior chest wall ⁷² .
Pectoral–nipple line	A midline extending from the nipple–skin junction to the posterior part of the breast, oriented perpendicular to the pectoralis muscle or, if not visible on CC views, perpendicular to the posterior image border ²¹ . (PNL)
Pectus excavatum	A depression of the thoracic wall ⁷² , commonly referred to as a funnel chest.
Physical-technical control	The set of measures taken by a licence holder to verify that the population, workers and the environment are adequately protected against the risks of ionising radiation ⁷⁵ .
Pixel	Each of the individual elements from which the image of the detector plate or display screen is composed ⁷⁴ .
Port catheter	A device for intravenous treatment in deep veins, consisting of a subcutaneously implanted injection chamber sealed with a silicone-rubber membrane and connected to a catheter leading into the vein ⁷² .
Posterior	Located at the back ⁷² .
Profile	Side view ⁷⁴ .
Prosthesis	A structure inserted into the breast to increase breast volume, either for cosmetic purposes or following surgical removal of diseased breast tissue ²³ . Also referred to as an implant.
Radiation dose	The amount of ionising radiation absorbed by tissue during an exposure, expressed in gray (Gy) ⁷² .
Rationale	The underlying reasoning or justification for a particular action ⁷⁴ .
Retro-areolar	The area of the breast located immediately behind the nipple ¹⁶ .
Retroglandular	The darker, less dense area situated between the glandular tissue and the pectoralis muscle (= retroglandular fat) ¹⁶ .
Scatter radiation	Secondary X-radiation consisting of photons that are deflected after interaction with matter and leave the irradiated object in random directions with reduced energy ⁷² .
Skin crease	A crease in the skin at the transition between the breast and the shoulder ¹⁶ .

Spatial resolution	The ability to distinguish between two very small objects located close to each other and to visualise them as separate objects ¹⁰ .
Standard views	The routinely used craniocaudal view (CC) and mediolateral oblique view (MLO) obtained for each breast in screening mammography ⁴¹ .
Suboptimal	Not achieving the optimal quality level, but sufficient for diagnostic image assessment, with clear room for improvement ⁹ .
Superimposed structures	Overlapping projection of tissues along the same beam path, making interpretation more difficult ⁷² .
Superior	Referring to a higher or upper position ⁷² or upper part.
Target-filter combination	The combination of anode material (target) and the metal window that absorbs X-rays with an unfavourable energy profile (filter) selected to produce X-rays with optimal penetrating power ^{10,73} .
Thumbnail sign	When only a very small arc of the inframammary fold is visible ¹⁶ .
Tube current	Electron flow from cathode to anode in the X-ray tube ⁷³ .
Tube loading	The product of the number of electrons generated at the cathode and the exposure time. It is expressed in milliamperere-seconds (mAs) ⁷³ .
Tube voltage	It is the electrical potential difference between the cathode and the anode. It determines the energy and penetrating power of the X-ray photons produced at the anode and, to a lesser extent, also influences the amount of radiation generated. It is expressed in kilovolts (kV) ⁷³ .
Tumour	A tissue mass resulting from cell enlargement or cell proliferation. This mass may be benign, malignant, or of an intermediate type ⁷² .
Vibration artefact	An image artefact characterised by horizontal black and white lines caused by electrical disturbance from the detector cooling system ¹⁶ .
Windowing	The adjustment of the grey-scale range or contrast of a digital image during review on a display screen ¹⁰ .
X-ray tube	A vacuum-sealed glass enclosure containing a cathode with a filament, where free electrons are generated, and an anode, a metal plate positioned opposite the cathode, where X-rays are produced when the electrons strike it ⁷² .

* The definitions closely follow the cited sources, with occasional small adjustments, clarifications, or examples relevant to mammography.

2. Recommended dose limits

In mammography, radiation dose is reported as **AGD** (Average Glandular Dose). The **DRL** (P95) denotes the diagnostic reference level, whereby 95% of images are expected to be acquired below this dose level. The **target value** represents an achievable dose for a standard patient using up-to-date imaging equipment and an optimised acquisition protocol.

The DRLs and target values per compressed breast thickness listed below can be used to support dose optimisation.

Mammography	AGD (mGy) per exposure	
	DRL (P95)	Target value
Overall	2.0	1.4

Compressed breast thickness (mm)	AGD (mGy) per exposure	
	DRL (P95)	Target value
32	1.6	0.9
45	1.8	1.1
53	2.1	1.3
60	2.4	1.5
75	3.2	1.8
90	4.0	2.3

The tables and accompanying text are reproduced from the Federal Agency for Nuclear Control (FANC)³⁶:

<https://fanc.fgov.be/nl/professionelen/medische-professionelen/radiologische-toepassingen/drn>

3. Imaging, image processing and image presentation

The X-ray tube

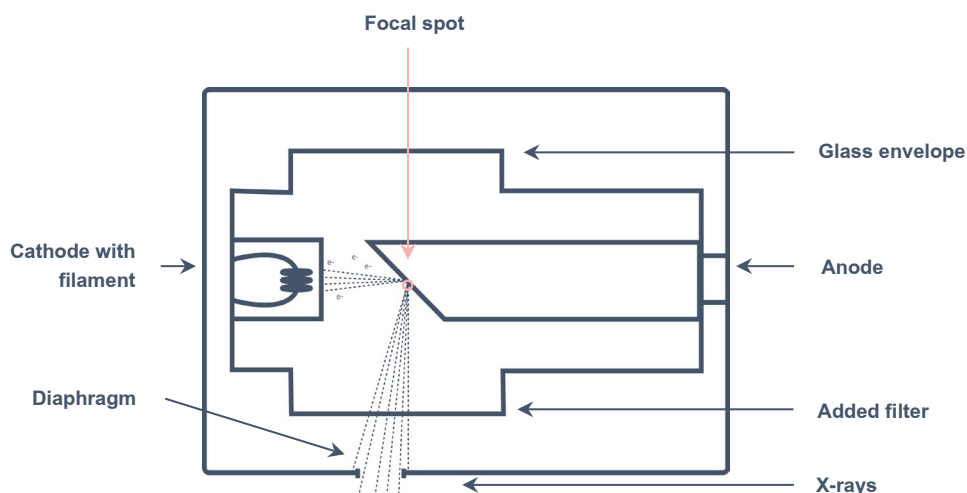
Tube current determines the number of electrons released from the filament and thus the radiation output. **Tube loading** is expressed in milliampere-seconds (**mAs**), representing radiation output multiplied by exposure time. Higher mAs values increase radiation dose, while very low mAs values lead to increased image noise⁴⁷.

Tube voltage, expressed in kilovolts (**kV**), determines the speed at which electrons strike the anode and thereby the energy or penetrating power of the X-ray beam, as well as, to some extent, the quantity of radiation produced. It is the key factor affecting image contrast, with higher kV values resulting in lower tissue contrast. However, at slightly higher kV values, the increased radiation output allows the mAs to be reduced, thereby lowering the radiation dose. A higher tube voltage is also required to penetrate denser and thicker breasts¹⁰.

The choice of **anode material (target)** in the X-ray tube also influences radiation dose, image contrast and noise. Molybdenum produces characteristic radiation of relatively lower energy and is suitable for thin breasts, while rhodium produces characteristic radiation with greater penetrating power and is used for somewhat thicker breasts. In digital mammography, where brightness, contrast and noise can be adjusted during image processing and display, materials such as tungsten can be used, as they produce X-rays of even higher energy. This allows a substantial reduction in the mAs value, resulting in a lower radiation dose¹⁰.

Appropriate **filtration** allows only X-rays of the required energy range to pass through, thereby narrowing the X-ray spectrum. This reduces unwanted, potentially harmful radiation and enhances image contrast¹⁰.

The **focal spot** refers to the area of the anode from which X-ray photons originate. In mammography, the focal spot is ideally circular with a very small diameter (0.1–0.3 mm)⁷³. This minimises image blurring, particularly at the edges of the image. For magnification imaging of lesions, very high image sharpness is required, and a focal spot size of 0.1 mm is chosen. In screening examinations, a slightly larger focal spot is commonly used.



The detector

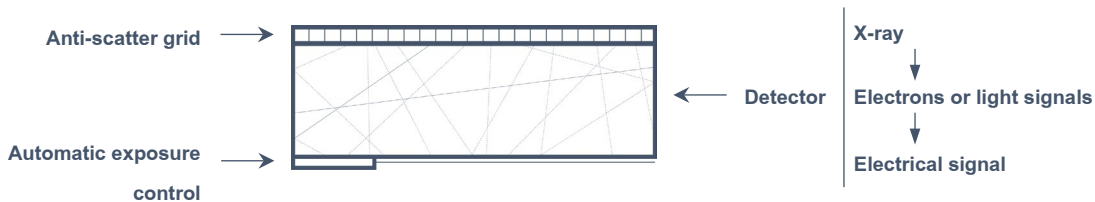
In digital mammography, incoming **X-ray photons** are collected by a detector and converted into an **electrical signal**. The magnitude of the electrical signal is directly proportional to the number of detected photons, with high sensitivity to small variations in X-ray intensity, leading to a broad range of signal values¹⁰.

Mammography detectors consist of closely spaced **detector pixels**. Small pixel sizes improve the ability to distinguish between closely adjacent structures. This high spatial resolution is essential in mammography, where very small lesions or subtle tissue changes must be detected. Mammography detectors therefore typically use pixel sizes between 0.05 and 0.1 mm¹⁰.

The electrical signals from the individual mini-detectors are converted into **digital values** by analogue-to-digital converters, resulting in one numerical pixel value per detector element. During image display, a computer assigns a specific **grey level** or brightness to each pixel value¹⁰. To minimise information loss, images are best reviewed at 100% resolution, ensuring a one-to-one correspondence between detector pixels and display pixels.

The wide range of pixel values in digital mammography allows contrast and brightness adjustment and image magnification, provided that the monitor has sufficient resolution (5–12 megapixels) and luminance (≥ 450 cd/m²)¹⁰.

A moving anti-scatter grid is often placed on top of the detector to remove X-rays that have been deflected from their original path as a result of interactions with tissue⁷³.



4. Manual adjustment of tube voltage (kV), tube loading (mAs), and anode/filter material

The kV and mAs settings, or the choice of anode and filter, are typically selected by the automatic exposure control (AEC) based on breast thickness and density. Just before the final exposure, a small preliminary exposure on the AEC assesses the density of the breast. The breast thickness corresponds to the distance between the compression paddle and the detector plate. In some breast-, skin-, or disease-related conditions, adequate compression cannot be achieved, making manual exposure settings necessary. Breast or other implants, scar tissue, or specific breast conditions may also hinder the proper functioning of the AEC⁶⁴. In more recent and more sophisticated AEC systems, manual exposure settings are rarely required.

Examples of manual mAs and kV settings according to breast thickness are provided below. These settings were determined using phantom imaging (Quality Control Centre, Ghent University, Campus Proeftuin).

GE Senographe Essential

Gecompr. borstdikte	Anode/filter	Buis-spanning	Buis-lading
(mm)		(kV)	(mAs)
15-30	Mo/Mo	26	25
30-40	Mo/Rh	26	40
40-50	Rh/Rh	29	45
50-60	Rh/Rh	29	63
60-70	Rh/Rh	29	80
70-85	Rh/Rh	30	100
85-100	Rh/Rh	31	140

Siemens Mammomat Inspiration

Gecompr. borstdikte	Anode/filter	Buis-spanning	Buis-lading
(mm)		(kV)	(mAs)
15-30	W/Rh	26	32
30-40	W/Rh	27	50
40-50	W/Rh	28	71
50-60	W/Rh	29	80
60-70	W/Rh	30	100
70-85	W/Rh	31	140
85-100	W/Rh	32	180

Fujifilm Amulet S

Gecompr. borstdikte	Anode/filter	Buis-spanning	Buis-lading
(mm)		(kV)	(mAs)
15-30	W/Rh	26	40
30-40	W/Rh	27	63
40-50	W/Rh	28	80
50-60	W/Rh	29	100
60-70	W/Rh	30	110
70-85	W/Rh	31	140
85-100	W/Rh	32	220

Giotto Class

Gecompr. borstdikte	Anode/filter	Buis-spanning	Buis-lading
(mm)		(kV)	(mAs)
15-30	W/Ag	25	40
30-40	W/Ag	27	45
40-50	W/Ag	28	63
50-60	W/Ag	30	63
60-70	W/Ag	31	71
70-85	W/Ag	32	110
85-100	W/Ag	35	125

GE Senographe Pristina

Gecompr. borstdikte	Anode/ filter	Buis- spanning	Buis- lading
(mm)		(kV)	(mAs)
15-30	Mo/Mo	26	16
30-40	Mo/Mo	26	40
40-50	Rh/Ag	34	25
50-60	Rh/Ag	34	30
60-70	Rh/Ag	34	36
70-85	Rh/Ag	34	50
85-100	Rh/Ag	34	80

Hologic Dimensions

Gecompr. borstdikte	Anode/ filter	Buis- spanning	Buis- lading
(mm)		(kV)	(mAs)
15-30	W/Rh	25	50
30-40	W/Rh	27	63
40-50	W/Rh	28	90
50-60	W/Rh	30	110
60-70	W/Rh	31	140
70-85	W/Ag	31	140
85-100	W/Ag	34	120

Compression, mAs, and kV settings are often available from previous images and may be reused when image quality is adequate, the same mammography system is used, and the woman has not changed significantly.

5. NRR-procedure

Image quality of 100% cannot be achieved in all women of screening age (frozen shoulder, back or neck problems, breast pathology, etc.), which is why the Flemish guidelines allow a certain margin of suboptimal quality. The percentage of women with a screening mammogram of good radiographic quality (submitted for second reading) must be $\geq 85\%$. Image sets concluded as “not good, but cannot be improved”, for example due to anatomical variation or pathology, are included in this category as images of suboptimal quality.

The number of technically uninterpretable images (technical recalls) or the percentage of women who are recalled for technical reasons to repeat the screening mammogram should be $\leq 3\%$ of screening mammograms (acceptable) and preferably $\leq 1\%$ of screening mammograms (desirable).

If these standards are not met, an NRR-procedure will be initiated. A Notice will be sent and, if quality problems remain, participation in a Remediation programme will be requested. If the quality problems persist after this, a licence Revocation procedure may be initiated¹⁹.

The NRR-procedure is described in more detail in the Flemish guidelines for population-based cancer screening and in the Flemish Codex containing the Decrees of the Flemish Government.

→ <https://borstkanker.bevolkingsonderzoek.be/nl/bk/draaiboek>

→ <https://codex.vlaanderen.be/Zoeken/Document.aspx?DID=1021797&param=inhoud>

All illustrations in this manual were created using Adobe Illustrator. For the translation and linguistic refinement of this work, the authors used DeepL Translator Pro and Microsoft Copilot to enhance clarity, readability, and linguistic accuracy.

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Assessing the quality of a mammogram is not easy. Nevertheless, it is important that this is done correctly and uniformly. Images of insufficient quality prevent early detection of cancer, increase the number of interval cancers or can cause false positive results. Unnecessary retakes increase radiation exposure, costs and discomfort. Furthermore, a radiographer can only improve if he or she can identify areas for possible improvement.

Forty-one experts, including mammography radiologists and radiographer instructors, have jointly established a consensus on which quality criteria are important in screening mammography and when an image is good, suboptimal or inadequate. This manual is the result of that consensus.

