Determination of adequate breast tissue visualization using an automated posterior nipple line measure

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Aims and objectives

Optimal patient positioning allows for the maximal inclusion of breast tissue seen on a mammogram and even marginal exclusion of tissue can impact the clinical effectiveness of screening mammography (1,2). Because this variability in patient positioning can affect the quality of the mammogram, it is important that images are reviewed for the organisation and for the technologist to track compliance and identify areas of improvement. However, current review of image adequacy relies on manual assessment by technologists and radiologists which is labour-intensive and subjective. An automated tool would enable objective review of patient positioning and allow for real-time assessment and system-wide review.

Previous work by Volpara has demonstrated automation of key positioning landmarks, including nipple location, nipple profile detection, nipple angle on the cranio-caudal (CC) view and inframammary fold, can be achieved in a robust fashion and used to monitor patient positioning (3). Another key landmark that is measured to determine optimal patient positioning is the posterior nipple line (PNL) on the mediolateral oblique (MLO) and CC view. The PNL on the MLO should not exceed that on the CC view by more than 10 mm, indicating that maximal posterior tissue has been included. This is an important measure as it is estimated that 6-10% of missed cancers are due to the chest wall tissue not being included on the image (4). However, measurement of this metric is very time intensive as visual assessment is not possible and the distances need to be computed and compared between views.

Therefore, we wanted to evaluate the performance of an automated algorithm to measure the PNL on CC and MLO views.
Methods and materials

Evaluation of the automated PNL measure utilized 108 "For Processing" digital mammographic images, 54 CC and MLO raw mammogram pairs from a mix of different systems. The images were processed using VolparaDensity (Volpara Solutions, Wellington, NZ) to obtain normalized Volpara Density Maps. Nipple location was automatically determined on both views and the pectoral muscle was segmented on the MLO as described previously (3). The PNL was then determined on both views; on the CC view the measurement was taken from the nipple/skin line to the posterior image edge (Figure 1A). On the MLO view, the PNL is measured from the nipple/skin line to either the anterior pectoral edge or to the image edge when the pectoral muscle is not adequately extended (Figure 1B & Figure 1C). The performance of the automated algorithm was compared to a single reader's manual measurement following the same guidelines.
Fig. 1: Figure 1 - Measurement of the posterior nipple line (PNL) on the CC (A) and MLO (B) view. When the pectoral muscle is not adequately extended (C), the PNL will report the distance from the nipple to the posterior image edge along a line perpendicular to a straight-line estimate of the pectoral muscle.

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## Results

The median PNL difference between the algorithm and manual measurement for both CC and MLO views was 4.55 mm (IQR 2.6 - 6.2, Figure 2) which was not statistically significant (P = 0.11).

The difference between the manual and algorithm PNL measure was higher on the MLO view (Figure 3, 5.3 mm IQR 2.9 - 7.2) compared to the CC view (Figure 4, 4.4 mm IQR 2.6 - 6.1) but this difference was not statistically significant.

MLO PNL measurement outliers were due to incorrect pectoral segmentation by the algorithm. An example of this is a case where the measurement difference between the algorithm and manual measure was 19.5 mm (Figure 5). This difference was due to an incorrect pectoral segmentation, which was caused by the skin fold at the inframammary fold region, causing the PNL measure from the algorithm to be underestimated.

The median absolute MLO-CC paired difference was 6.1 mm (IQR 2.3 - 10.9) and 7.1 mm (IQR 2.6 - 11.5), for the algorithm and manual measures. 15 pairs had a MLO-CC difference where the CC PNL was > 10 mm shorter than the MLO PNL, with 89% agreement between the algorithm and manual measurement (# 0.679). 9 of these were identified by both methods, 2 by the algorithm alone and 4 by manual alone (Table 1).

<table>
<thead>
<tr>
<th>Automated Algorithm</th>
<th>Sufficient PNL</th>
<th>MLO - CC &gt; 10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Measure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sufficient PNL</td>
<td>39 (72%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>MLO - CC &gt; 10 mm</td>
<td>9 (17%)</td>
<td>13 (24%)</td>
</tr>
<tr>
<td></td>
<td>43 (80%)</td>
<td>11 (20%)</td>
</tr>
<tr>
<td></td>
<td>54 (100%)</td>
<td></td>
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</table>
**Fig. 2:** Distribution of PNL absolute difference (mm) between manual measurement and the automated algorithm on all images

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Fig. 3: Distribution of PNL absolute difference (mm) between manual measurement and the automated algorithm on MLO images

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Fig. 4: Distribution of PNL absolute difference (mm) between manual measurement and the automated algorithm on CC images

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Fig. 5: Example case where there was high error between the manual measurement (A) and algorithm result (B) for the PNL on the MLO due to incorrect pectoral muscle segmentation.

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Conclusion

Compared to manual measurement, the automated algorithm has good concordance and is robust at determining the PNL length on mammograms. We propose that this automated technique can be used to determine adequate posterior breast tissue visualization in an efficient and objective manner.

Previous studies have found MLO PNL measures are on average 6.2 mm longer than CC views (5). This is in line with the average difference we saw in our cohort. We found 27% of cases did not have sufficient PNL on the CC view, determined by the algorithm or manual measurement. Other studies have reported up to 69% of cases fail this rule (4). The algorithm and manual measure identified the same case as not meeting the 10 mm threshold 89% of the time. The cases where the two measures did not give the same result were often due to underestimation of the MLO PNL by the algorithm caused by inaccurate pectoral segmentation. Further work is underway to improve the segmentation and resolve these outliers.

This work combined with our previous studies to automate breast positioning metrics has led to the development of an automated positioning scoring for a standard 4-view mammographic study. The following case is an example of a 'Perfect' case as determined by the algorithm (Figure 6). The MLO images met the criteria of; Nipple in profile (A), inframammary fold is visible (B), the pectoral muscle extends past the level of the PNL (C) and the pectoral muscles are convex (D). The CC images met the criteria of; Nipple in profile (A), the CC PNL length is \# 10 mm compared to the MLO PNL of the same side (E) the nipple is in the midline of the breast (<2° from midline, (F)) and the lateral and medial tissue is not cut off.

Both the combined positioning score and the individual metrics will allow comprehensive review of patient positioning for organizations and operators. Having the ability to access automated, objective positioning results may help improve training of technologists and performance throughout their career. A recent study by Miglioretti et al., among CT technologists determined that providing them with audit feedback on patient radiation dose in CT imaging could lower patient dose [6]. Although this is a different radiologic examination, their study shows that personalised feedback on performance can change the technologists’ attitudes and behaviour. A recent Cochrane Collaboration review [7] found that audits on professional performance are most effective when the professionals are not performing well.

Our automated algorithm for breast positioning is highly robust and has the potential to improve the efficiency of assessing mammographic breast positioning.
Fig. 6: Example of a "perfect" positioned mammogram as determined by the automated algorithm Nipple in profile (A), Inframammary Fold is visible (B), the pectoral muscle extends past the level of the PNL (C) and the pectoral muscles are convex (D). The CC PNL length is # 10 mm compared to the MLO PNL of the same side (E) the nipple is in the midline of the breast (<2° from midline, (F))

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