Volumetric breast density estimation on conventional mammography versus digital breast tomosynthesis

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Aims and objectives

Breast density reporting is a legal requirement in several US states, and clinical decisions are increasingly being made based upon these breast density results, in the US and elsewhere. The BI-RADS definition of the overall breast composition is "an assessment of the volume of attenuating tissues in the breast" [1]. Currently the radiologist assesses the volume of attenuating tissue in the breast by visually inspecting the craniocaudal (CC) and mediolateral oblique (MLO) mammograms and reporting the appropriate BI-RADS density category: 1) Almost entirely fatty; 2) Scattered fibroglandular densities; 3) Heterogeneously dense; and 4) Extremely dense.

There is high inter- and intra-reader variability in the assessment of breast density [2]. Recently, commercial systems have come to market (i.e. Volpara™ and Quantra™), which provide automated volumetric breast density assessments from 2D mammograms giving objective, consistent measurements [3-5]. These systems have been shown to be highly correlated with breast density measurements produced from MRI [6].

Digital breast tomosynthesis (DBT) is a promising new modality to improve screening for breast cancer. When DBT is used in "combo" mode, the conventional CC and MLO mammograms are taken at the same time as a series of low dose mammograms. These projection images are then used to reconstruct a pseudo-3D image of the breast. In this scenario, breast density can be assessed using the conventional CC and MLO mammograms. In the future, however, it appears highly likely that only the pseudo-3D images and synthetic 2D views may be available to the radiologist, in order to keep radiation dose to a minimum. Currently, there is no published data comparing radiologists' assessments of breast density from the 3D image or from the synthesized 2D views, with density assessed using the conventional CC and MLO mammograms.

In this study, we assess one of the commercial systems measurements of volumetric breast density (Volpara™) of conventional 2D mammograms and compare this to assessment of DBT volumetric density.
Methods and materials

Digital breast tomosynthesis (DBT) uses a series of low-dose x-ray projections at various angles, to reconstruct a pseudo-3D image of the breast. There are several DBT systems available on the global market, but only one with FDA approval (at time of writing): Hologic's Selenia Dimensions 3D. Initial FDA approval of the Dimensions System, for screening, required it to function in "combo" mode, where conventional 2D mammograms are performed at the same time as the series of low-dose x-ray projections. FDA approval has now been granted to allow the use of synthesized or "C-View" images rather than the conventional 2D mammograms.

In this study, raw images (all anonymized) from 20 women imaged in combo-mode on a Hologic DBT unit were selected, which represent a range of BIRADS density categories as visually assessed on the conventional images. All images were acquired in combo-mode, so that the 2D and 3D images were acquired under the same breast compression and at (approximately) the same time. Volpara™ was used to automatically estimate breast volume, volumetric breast density (VBD) and BIRADS density category from the raw conventional mammograms and from the raw DBT projections.

As noted, DBT is simply a series of low-dose x-ray projections and those low-dose projections can be exported from a DBT system in "raw" format which means that the manufacturer has not overly manipulated the data for visualization purposes. To run Volpara over DBT images, software was written to simply extract a raw projection image and populate it with the appropriate DICOM tags before running Volpara.

To compare the density results from the 2D and 3D images, Pearson Correlation Coefficients (PCCs) for breast volume (BV), fibroglandular volume (FGV) and VBD were calculated. Volumetric parameters were calculated as the mean across a typical four-view study. Student's t-test was used to compare whether there were any significant differences between measuring VBD from conventional mammograms or DBT projections. A confusion matrix showing the agreement between BI-RADS categories as determined from the conventional mammograms versus the DBT images, was also generated.
Results

Examples of some of the different image types that could potentially be used by radiologists to visually assess breast density are given in Figure 1 (note: as the C-View module is optional, synthetic CC and MLO views were not available for the current study).

A comparison of the means for the various Volpara parameters, indicate that there was no significant difference between VBD, BV and FGV estimates from conventional mammograms or the DBT projections (Figure 2). The overall mean VBD as assessed from the DBT images was lower than the VBD from the conventional mammograms, but this change was not statistically significant. The breast volumes as estimated from the conventional mammograms and the raw DBT projections were near identical, with a PCC of 0.998. As seen in Figure 3, variation was highest for the largest breast volumes. The VBD and FGV estimates were also highly correlated between the 2D images and DBT projections, with PCCs of 0.903 and 0.919, respectively (see Figures 4 and 5).

The Volpara generated BI-RADS density scores matched for 19 out of 20 cases, with a weighted kappa score of $\kappa = 0.953$, indicating that there was very good agreement between density assessed from the DBT projections and the conventional mammograms (Figure 6). It was noted, however, that Volpara outputs for very dense breasts appeared to be lower on the DBT projections compared to the conventional mammograms, and reasons for this are currently under investigation.
Images for this section:

**Fig. 1:** For clinics implementing Hologic’s Selenia Dimensions 3D x-ray system, several image format options are available to radiologists for making visual assessments of mammographic breast density. Currently, conventional 2D mammographic images (“For Presentation/Display”) are the most widely used (left panel). However, radiologists could potentially also use the tomosynthesis reconstructions (right panel; only a single slice shown) or the synthesized mammographic "C-views" (not shown) to visually assess breast density.

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Table 1: Table comparing the mean values for volumetric breast density (VBD), breast volume (BV), and fibroglandular volume (FGV), as assessed by Volpara from the conventional mammographic images (2D) or the DBT projections (DBT).

<table>
<thead>
<tr>
<th></th>
<th>Mean (95% CI)</th>
<th>Abs difference in means</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBD (%)</td>
<td>18.4 (13.5-23.3)</td>
<td>15.7 (12.1-19.4)</td>
<td>2.7</td>
</tr>
<tr>
<td>BV (cm³)</td>
<td>860.5 (583.7-1137.3)</td>
<td>908.8 (627.4-1190.1)</td>
<td>48.3</td>
</tr>
<tr>
<td>FGV (cm³)</td>
<td>118.1 (82.8-153.3)</td>
<td>106.9 (79.4-134.4)</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Fig. 2: Graph showing the correlation between Volpara estimates for breast volume, as assessed from the conventional mammograms and the DBT projections.

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**Fig. 3:** Graph showing the correlation between Volpara estimates for volumetric breast density (VBD), as assessed from the conventional mammograms and the DBT projections.

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**Fig. 4:** Graph showing the correlation between Volpara estimates for fibroglandular volume (FGV), as assessed from the conventional mammograms and the DBT projections.

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**Fig. 5:** Confusion matrix showing the agreement between BI-RADS scores automatically generated by Volpara, from the conventional mammograms and DBT projections.

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Conclusion

Despite the significant implications of breast density in breast cancer screening, few studies have investigated breast density assessments derived specifically from DBT images. Tagliafico et al. have compared several area-based density assessment methods for 2D mammograms and DBT projections. Using a maximum entropy thresholding method, the mean breast density was 11.4% higher on conventional mammography compared to the breast density obtained from the average density of the DBT projections [7]. Subsequent studies, using semi-automated or fully-automated software, demonstrated highly significant differences between the breast density measured on conventional mammograms and DBT, with density measures on DBT tending to be lower than for the 2D images [8, 9].

In the present study, automated volumetric breast density estimations showed very good correlations between the 2D and 3D mammograms. This is especially important for sites that are transitioning to DBT, and whose patients may only have prior 2D mammograms. These results also have additional implications for those wanting to monitor longitudinal changes in breast density (e.g. in response to pharmacological agents, such as tamoxifen) or for studies looking at breast density as a breast cancer risk factor. Additionally, for sites wanting to implement the C-View module, to replace conventional mammography, automated volumetric methods can ensure consistency in breast density measures. Automated volumetric breast density methods are a promising alternative to visually assessed breast density assessments, and produce reliable and objective breast density estimations from both raw conventional mammograms and raw DBT projections.
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References


