Breast positioning system for full field digital mammography and digital breast tomosynthesis system

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ABSTRACT

This paper will present a new breast positioning system for amorphous selenium (\textit{a-Se}) based full field digital mammography (FFDM) system, which is also a platform of tomosynthesis prototype. Clinical images demonstrate that this method is capable extending the breast away from the chest wall, and maximizing the breast volume. Breast positioning system consists of two transparent moving sheets that apply traction of the breast controlled by motor. Sheets are under and above the compressed breast. Breast positioning sheets pull the breast into the imaging area during the compression. Digital mammography system is based on amorphous selenium flat panel detector (FPD) technology where the overall thickness of the selenium structure is 200 \(\mu\text{m}\), and the pixel size on this detector is 85 \(\mu\text{m}\). Preliminary results will be presented. Clinical study showed increment of the breast volume imaged, and it brought up to 1.0 cm - 2.0 cm more breast tissue. New breast position system also holds a promise of slight decrement of compression force used in the examination.

Maximizing the exposed breast tissue is complicated, but important aspect in the breast cancer detection and diagnosis. Increasing the field of view with an additional volume of breast tissue imaged is a key point in digital mammography and digital breast tomosynthesis (DBT).

Keywords: Imaging of the breast, Breast positioning, Full field digital mammography (FFDM), Digital breast tomosynthesis (DBT).

1. INTRODUCTION

Maximizing the exposed breast tissue is an important aspect in the breast cancer detection and diagnosis. If the breast is not properly positioned, all of the breast tissue may not be imaged. Imaging the anterior breast tissues is simple, but imaging the breast tissue adjacent to the chest wall is difficult. Given that the volume of the breast increases toward the chest wall, failure to image these tissues could exclude large areas where cancer might develop. High-quality imaging requires highly motivated technologists\textsuperscript{1} and high ergonomic of the mammography system, which has advanced compression device and does not have any breast positioning limitations. Compression of the breast needs to be also adequate and optimized.

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Experienced physicians are in agreement about the technical complexity of good mammography and the need for skilled technical support\(^2\).

In general two-view mammography (craniocaudal (CC) and mediolateral oblique (MLO)) is performed in screening mammography. Ideal MLO positioning should permit the breast to be imaged from high in the axilla down to and including inframammary fold, and CC positioning is achieved by having the technologist elevate the breast by gathering the tissues from below and pulling the breast up and away from the chest wall. As with the MLO, the opposite breast should be positioned symmetrically in the CC projection so that the mammograms can be viewed as mirror images. The properly positioned CC view should complement the MLO\(^1\).

Figure 1. shows an example of well-positioned screening examination. Properly positioned breast is one of the factors in early breast cancer detection, which is critical to successful treatment and the quality of patient’s life.

Figure 1. This is an example of well-positioned digital screening mammograms, craniocaudal (CC) and mediolateral oblique (MLO) views acquired by Planmed Nuance (Planmed Oy, Helsinki, Finland) FFDM system. The properly positioned MLO includes as much breast tissue as possible. The image includes the free margin of the pectoralis major muscle, visible down to the axis of the nipple on the MLO view. The CC view includes as much breast tissue as possible although the geometry of the breast and chest wall frequently means that less tissue is imagined than on the MLO.

It has been estimated that the pectoral major muscle should be visible on approximately 30% of CC views\(^1\). If pectoral muscle is not seen, look for cleavage. This ensures that at least medially, no tissue has been excluded\(^1\).
2. MATERIALS AND METHODS

2.1. Full field digital mammography (FFDM)

Full field digital mammography (FFDM) system, Planned Nuance (figure 2.), which is also a platform of tomosynthesis prototype, incorporates amorphous selenium (a-Se) flat panel detector (FPD). The effective flat panel detector area consists of 2816 x 2016 pixel matrix having a pixel pitch of 85 µm. This yields to a theoretical maximum spatial frequency of 5.9 lines per mm. The biasing voltage of 2 kV is applied over 200 µm thick a-Se layer. Flat field correction is applied on 13 bit raw images to eliminate the differences in pixel responses and to correct possible defects. FFDM system incorporates x-ray tube target from molybdenum with either 25 µm rhodium or 30 µm molybdenum filter. X-ray generator is high frequency having anode voltage range between 20 kV and 35 kV. The automatic exposure control (AEC) operation is based on a principle where the imaging chain components are all modeled into the system software. Once the imaging parameters are all known it enables the system to exactly define the tissue composition imaged and utilize exposure parameters optimal for it. Based on the detected object composition together with the other imaging parameters the amount of signal produced by the amorphous selenium flat panel is exactly calculated and the desired dose of the exposure on the detector is thereby reached accurately. The AEC consists of 48 individual detection areas that cover a selenium flat panel area of 100 cm². It is therefore able to measure a well representative sample of the tissue to be exposed and adjust the exposure parameters optimal for the breast tissue composition. This preliminary study concentrates digital screening studies. In future we will continue breast positioning system method evaluation also with breast tomosynthesis. Breast tomosynthesis has the potential to detect breast cancers earlier and the ability to discover very small cancers in very dense tissue.

Figure 2. Amorphous selenium (a-Se) based full field digital mammography system, which is also a platform of tomosynthesis prototype system. The overall thickness of the selenium structure is 200 µm, and the pixel size on this detector is 85 µm. For tomosynthesis acquisition the total arc is 60°, and the number of projection images is 15 exposures.
2.2. Breast positioning system

Sometimes it is difficult to maximize the field of view with standard compression systems. The dorsal part of the breast is often excluded from the imaging field. Maximizing the amount of breast tissue imaged is complicated, especially with small and dense breast, because the breast may slip out easily of the field of view as the compression paddle moves downward. To be able to optimize the volume of the breast imaged, a special breast positioning system, MaxView (Planmed, Helsinki, Finland), has been developed.

Breast positioning system consists of two transparent moving sheets, which are hygienic and radiolucent (figure 3a.), that apply traction of the breast controlled by motor. System has two traction modules (figure 3b.), upper and lower. The lower module is integrated to the FFDM unit and the upper module is integrated close to the compression paddle\(^6,7\).

Sheets are under and above the compressed breast. Breast positioning sheets pull the breast into the imaging area during the compression (figure 4.). User is able to control either upper or lower sheet, or both sheets at the same time\(^7\).

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Figure 3a. Breast positioning system’s hygienic radiolucent sheets (upper and lower sheet). Sheets can be moved together or separately\(^7\).

Figure 3b. Breast positioning system has two traction modules, upper and lower. The upper module is fitted with a compression paddle and the lower module is integrated to the FFDM system\(^7\).

Figure 4. Breast positioning system consists of two transparent moving sheets that apply traction of the breast controlled by motor. Sheets are under and above the compressed breast. Breast positioning sheets pull the breast into the imaging area during the compression\(^6,7\).
2.3. Screening material

We performed preliminary breast positioning study by using Planmed Nuance direct digital mammography unit, which was described in 2.1. The screening data is comprised of 50 screening cases, and for 16% of the cases the special breast positioning system was used. The screening examination includes right and left craniocaudal (CC) and mediolateral oblique (MLO) views, and age of the screening cases were between 50-69 years old. Special breast positioning system was used for right breast and standard breast compression system was used for left breast. Reason for this protocol was to be able to find out if this special positioning method will include more breast tissue in the image. Technologist also evaluated the ergonomic and easy-to-use features of the system.

The potential value of breast positioning system was investigated by testing its ability to include larger volume of the breast in the final image for the women who either have dense, small or dense and small breasts.

3. RESULTS

Figures 5, 6, and 7 describe the main advantages of the special breast positioning system, which are: if the pectoral major muscle is not visible in CC view, dedicated breast positioning system brings it in the field of view (figures 5, 6, and 7) and larger volume of the breast is imaged by using the breast positioning system (figures 5, 6, and 7).

Ergonomic benefits of the special breast positioning system are: when imaging small and dense breast, the breast do not slip out of the field of view as the compression paddle moves downward. Small and dense breast is easier to position and this way the screening procedure is more comfortable for the women. Method is especially more comfortable because of using the special compression system there is less need to re-position the breast.

Technologists reported that screening examination is easier and faster to perform for the ladies with small or dense breasts when the special breast positioning system is used. The main reason for this is that the breast do not slip out of the field of view as the compression paddle moves downward and slight breast position corrections would be possible to perform with a help of positioning system’s sheets.

<table>
<thead>
<tr>
<th>Indication for special breast positioning system (MaxView) clinical benefits</th>
<th>Number of the percentage where MaxView is better</th>
</tr>
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<tbody>
<tr>
<td>The pectoral muscle is only visible in the image taken with special breast positioning system</td>
<td>75%</td>
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<tr>
<td>Larger volume of the breast tissue was imaged by using special breast positioning system</td>
<td>100%</td>
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<tr>
<td>Special breast positioning system brought more than 1 cm – 2 cm breast tissue into the field of view</td>
<td>37,5%</td>
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<tr>
<td>Special breast positioning system brought more 0.5 cm – 1 cm breast tissue into the field of view</td>
<td>62,5%</td>
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Table 1. Results of the special breast positioning system used among the women who have dense or small breasts. Special breast positioning system was used for right breast and standard breast compression system was used for left breast. Reason for this protocol was to be able to find out if this special positioning method will include more breast tissue in the image and this way has clinical benefits.

<table>
<thead>
<tr>
<th>Indication for special breast positioning system (MaxView) ergonomic benefits</th>
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<tbody>
<tr>
<td>Small and dense breast is easier and faster to position.</td>
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<tr>
<td>Screening examination is more comfortable for the ladies.</td>
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<tr>
<td>The breast does not slip out of the field of view as the compression paddle moves downward.</td>
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<tr>
<td>Less re-positioning is needed.</td>
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<tr>
<td>Slight breast position correction is possible to perform with a help of positioning system.</td>
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</table>

Table 2. Results of the better ergonomic features of the special breast positioning system used among the women who have small or dense breasts.
Figure 5. Right and left CC digital mammograms of 56 years old woman. Right breast is compressed with special breast positioning system described in 2.2. and left breast is compressed with standard compression system. The pectoral major muscle is not visible in left CC view, but dedicated breast positioning system brings it in the field of view in right CC view, and overall larger volume of the breast is imaged with special breast positioning system.

Figure 6. Right and left CC digital mammograms of 68 years old woman. Right breast is compressed with special breast positioning system described in 2.2. and left breast is compressed with standard compression system. The pectoral major muscle is slightly visible in left CC view, but dedicated breast positioning system brings it much more visible in right CC view, and overall larger volume of the breast is imaged with special breast positioning system.
Figure 7. Right and left CC and MLO digital mammograms of 68 years old woman. Right breast is compressed with special breast positioning system described in 2.2. and left breast is compressed with standard compression system. The pectoral major muscle is not visible in left CC view, but dedicated breast positioning system brings it in the field of view in right CC view. Overall larger volume of the breast is imaged in right breast even it is slightly smaller than left breast.

4. DISCUSSIONS AND CONCLUSION

Optimum positioning for standard screening views is important, because compression is less painful with good positioning, and good positioning will visualize considerable more tissue adjacent to the chest wall. Experienced staff can achieve very good positioning in as many as 90% of all cases. Especially small and dense breasts are a challenge to position as well as needed for diagnostic image quality. This is a reason why advanced breast positioning system has been developed. It is important to remember that the main idea is not to correct the positioning mistakes, on the contrary the key idea is to be able to include necessary amount of breast tissue, which is required that radiologists are able to do the correct diagnosis in confident, and to help technologists to position these challenging breast types.

Two-dimensional (2D) mammography plays a most important role in all aspects of breast cancer detection, diagnosis and treatment. Although it is well known that 2D mammography has limitations and it is not capable of detecting all breast cancers, there is no question that mammography is an important imaging technique for detecting and diagnosing breast cancer. Challenges of 2D mammography are structured noise, which is created by the overlap of normal dense tissue structures within the breast. This may obscure the findings causing lesions to be missed (reduction of diagnostic sensitivity). Breast tissue may also simulate the presence of a cancer that does not actually exist. This causes a loss of diagnostic specificity.

Breast tomosynthesis acquires multiple images as the x-ray source moves through an arc above the stationary compressed breast and digital imaging detector. As the acquisition begins, the beam moves through a series of positions in different degrees. Once the projections of the breast are obtained during a tomosynthesis sequence, they can be reconstructed into a data set of slices through the breast in planes parallel to the detector and displayed in a manner suitable for review by a radiologist. In this way all slices through the breast can be obtained from a limited number of exposures and each exposure need only be a fraction of a full mammographic exposure so that the total dose can be within that used for standard 2D mammography screening. With stereotactic tubehead movement, the digital mammography system acquires a number of projection images with different angles, shown in figure 2. The total arc is 60°. There is much interest and excitement in the medical community regarding this new technology. Breast tomosynthesis holds a promise of better diagnostic capabilities and cancer detection, especially increasing the specificity of breast cancer detection. Some research groups have begun to evaluate tomosynthesis in diagnostic mammography while others use tomosynthesis as a part of mammography screening.

Increasing the field of view with an additional volume of breast tissue imaged is a key point also in digital breast tomosynthesis. There has been a study, which indicates that performing breast tomosynthesis imaging in both the MLO and CC views are desirable to optimally visualize the lesions or abnormalities. Our future research and clinical
evaluation will try to find out: While using a special breast positioning system and breast tomosynthesis, would only one view work?

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REFERENCES