Master of Science dissertation:

An investigation on the effect of slabbing and slice thickness on image reading time and microcalcification visibility in breast tomosynthesis

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Abstract

Breast tomosynthesis (BT) is a new X-ray modality that reconstructs the breast volume in many slices instead of, as in mammography, showing a single 2D projection of the breast. The slice thickness is typically 1 mm for clinically used BT-units. In screening the review of breast images with BT takes two to four times longer than the review of mammography images. In an effort to reduce the review time for BT, slabbing (a post-processing technique to make thicker slices) or reconstruction of thicker slices is investigated in this work. This work also includes an initial study on whether slabbing can make it easier to detect microcalcification.

This study was divided into three parts, investigating if it is possible to reduce BT reviewing time. In the first part many different slabbing methods were tested together with different reconstructed slice thicknesses on 16 hybrid images and the best three conditions with respect to image quality were further investigated in the second part. The second part was a visual grading analysis task to compare how the image quality of the three selected methods differs from that of the regular sets of images that are used today. One radiologist and three medical physicists participated in the study which was based on 27 pathological images. The final part was a free-response detection study where two radiologists reviewed 30 normal and 5 abnormal images, on two different occasions. The review times of the method which scored highest in the second part and the image presentation mode used in clinical routine work were measured and compered. This work also includes an initial study investigating if slabbed images can make it easier to detect microcalcification cluster.

The results of the final part showed that one radiologist had a significant reduced review time when slices were combined to slabs for the regular images while the other radiologist did not show any significant time difference between the two sets of images. When the two results were combined no significant difference could be seen between the two sets of images. The results of the study on improving microcalcification detection suggested that using images with slabbing instead of regular ones is not helpful to improve the detection.

The study was inconclusive, suggesting that more radiologists have to be included to predict if slabbing can reduce reading time. The results of the reading times of the two radiologists were too divergent to be generalized. The results from the microcalcification study showed that other methods must be investigated in preference to slabbing.

Contents

1. Introduction

The most common form of female cancer in Sweden is breast cancer, with 7 049 diagnosed cases in 2007. This corresponds to almost 30 % of all the female cancer cases and therefore every Swedish female between 40-75 years is offered a biennial mammography as a part of the Swedish breast screening program [1].

Before direct digital detectors could offer a clinically acceptable image, screen-film detectors were used in mammography. The screen-film detector had a reported sensitivity of 80-90 % in normal breasts, but in dense breasts the sensitivity could be as low as 48% [2]. After the implementation of digital mammography (DM) in the screening program, there have not been any reported changes in sensitivity relative to screen-film mammography (SFM) [3].

Both DM and SFM are modalities that show a two dimensional (2D) projection of a three dimensional (3D) breast volume. This means that all the information along an X-ray trajectory is superpositioned into pixels that build up the 2D-image. It has been shown that failure to detect cancer is mainly caused by anatomical structures, which is all the surrounding breast tissue except the lesion in the breast [3]. This could mean that detector improvement is not the most important goal in improving cancer detection. Instead it could be improved if a 3D imaging technique was used. One solution to this problem is breast tomosynthesis (BT), a modality that makes a three dimensional representation of the breast, and separates the overlapping information into many slices.

Slabbing is a post-processing technique to combine thin slice images into thicker slices. More microcalcifications of a cluster will be present in each slice constructed by slabbing and also each individual microcalcification will contribute to more than one slabbed slice. This is because slabbing uses several slices to make a resulting slice and to do this the same slice is used several times. Another way of using slabbing is to use the original slices just one time. This will lead to a reduction of the amount of resulting slices and possibly shorten the review time for the radiologist. Today review of BT images takes two to four times longer than DM images [4].

The aim of this master thesis is to study the effects of slabbing on image reading time in tomosynthesis, and also if slabbing can improve the visibility of microcalcifications.

2. Theory

2.1 Tomosynthesis

Breast tomosynthesis images are generated through a reconstruction algorithm that uses multiple projections, taken over a limited spatial angle, to build up a 3D-volume consisting of several slices. The detector is placed in a fixed position and the tube moves in an arc with a constant distance relative to a point above the detector elements (Figure 1) [5]. The limited tube angle distribution gives rise to an undersampling of the object of interest, which decreases the spatial resolution in the direction perpendicular to the detector. The undersampling will also generate artifacts during reconstruction of the multiple projections [6]. For BT the spatial resolution is almost equivalent to DM in the plane that is parallel to the detector. The breast is mechanically compressed during the image acquisition. This minimizes the scatter distribution to the detector, fixates the breast during the procedure and reduces the radiation dose to the breast.

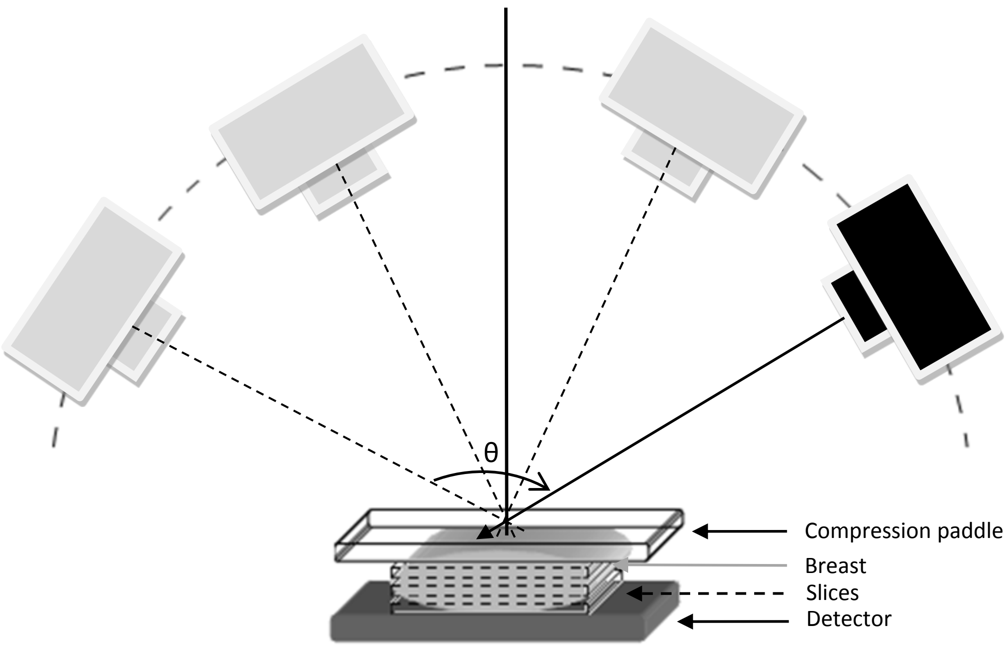

Figure 1: A schematic view over the tomosynthesis, where θ is the sweep angle, which is the total arc movement from the first to the last projection.

Image acquisition with BT and DM generally use the same detector but in DM there is a grid in front of the detector, to minimize the amount of scattered radiation reaching the detector. The main reason why an antiscatter grid is not used in BT is that the average glandular dose for each projection is much lower than in DM and at a tomosynthesis projection angle of 10° approximately 88% of the primary x-rays are cut off by the grid [7] [8].

2.2 Reconstruction

To generate the 3D-volume from the projection images different reconstruction algorithms are possible. Filtered back projection (FBP) and iterative reconstruction are two frequently used algorithms, where FBP is better on enhancing microcalcification and iterative reconstruction is better in reconstructing low-contrast soft tissues [9].

Förnvik et al. [10] showed that filtered back projection is still superior to iterative reconstructions, although the result could be biased by subjectivity of the readers. FBP will be the reconstruction algorithm used throughout this work to make different slice thicknesses.

2.2.1 Filtered backprojection

When 2D-projections are reconstructed to a 3D-volume, a Feldkamp reconstruction algorithm specifically developed for breast tomosynthesis is used. This algorithm was originally derived for 3D reconstructions with C-arms [11] [12].

Filtered backprojection uses a shift-and-add method with additional filter corrections to generate the 3D-volume. The principle of shift-and-add is the same as simple back-projection, and uses the same assumptions, such as the approximations of a parallel beam and monochromatic energy [13]. Reconstruction projections are modified by a geometric transformation from the detector geometry to a simulated parallel path geometry [14]. This simulated parallel path makes it possible to use the central slice theorem, similar to a method in computed tomography, to reconstruct projections [5].

There are three main filters used in FBP to correct for artifacts and blurring, all of which are included in the cascaded linear model [15]. This model describes how the signal propagates from the detector to the reconstructed images.

The invers filter is the first filter applied on the projections, which inverts the modulation transfer function during the backprojection process. It is proportional to a ramp-filter and is a noise emphasizing filter [16]. To reduce noise enhancement a spectrum apodization filter is adopted in the scanning direction of the tube. The spectrum filter is a Hanning window that limits the bandwidth and reduce noise and aliasing [5]. The last filter, a slice thickness filter, is also a Hanning window that is applied in a plane perpendicular to the detector in order to suppress out-of-plane artifacts and reduce noise components in the reconstructed image [14].

With FBP the reconstruction can be made with an arbitrary slice thickness. For a 1 mm slice thickness, which is the standard slice thickness used clinically in the BT-system used for this work, filter parameters have been optimized by Mertelmeier et al. [16]. When changing the slice thickness while keeping Mertelmeier's parameters for the slice thickness filter, image quality would no longer be kept optimized. The slice thickness filter (H_{ST}) with relative window width B is given by a Hanning window function,

$$H_{ST}(f_z) = \begin{Bmatrix} 0.5\left(1+\cos\left(\frac{\pi f_z}{B f_{z-NY}}\right)\right) & for\ \ |f_z| \le B f_{r-NY}\ \ and\ |f_z| \le \tan(\theta)\, f_{r-NY} \\ 0 & elsewhere \end{Bmatrix} \qquad (1)$$

where f_z is the frequency perpendicular to the detector, f_{z-NY} is the Nyquist frequency in the simulated plane with an angle θ to the detector and f_{r-NY} is the polar coordinate frequency of the Cartesian frequency coordinates perpendicular to the detector and parallel to the detector at the Nyquist frequency .

When choosing an arbitrary slice thickness q the Nyquist frequency [15] would be

$$f_{z-NY} = (1/2q) \qquad (2)$$

This means that when using larger slice thickness, aliasing would be more significant without changing parameter B in the slice thickness filter[5]. Keeping the slice thickness filter boundary value at the Nyquist frequency by adjusting B is one way to keep the optimization suggested by Mertelmeier et al. to suppress aliasing. Because slice thickness follows the sampling theorem, larger slice reconstruction would show less noise and contrast in the reconstructed image.

2.3 Slabbing

One way to make thicker slices instead of reconstructing thicker slices is to use slabs. Slabbing is a post-processing technique where two or more slices are combined to generate one new thicker slice (Figure 2). Slabbing is made pixel-wise and often either by using the maximum pixel value (MAX) or the arithmetic mean (AVE) of the pixels of interest. Diekmann et al. [17] studied contrast differences between MAX and AVE for slabs consisting of ten 1 mm slices in phantom measurements. They found that post-processing with MAX gives enhanced detection of microcalcification than AVE but it also increases the noise level in the resulting image. Post-processing of AVE gives a lower noise level and improved detection of low density objects like masses than MAX for ten 1 mm thick slices.

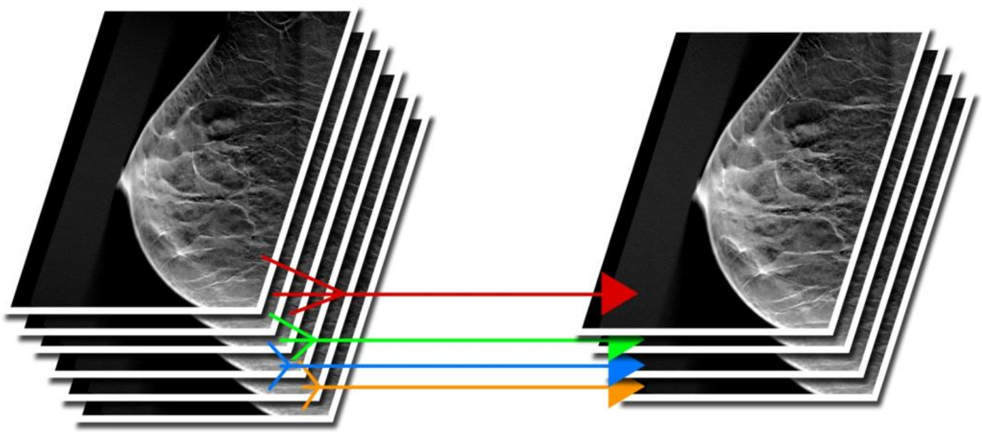

Figure 2: Four slabs consisting of three slices combined with maximum pixel value.

In slabbing the resulting image stack can either keep the same amount of slices as the original stack, meaning that each individual slice can contribute to many different slices. Alternatively the amount of slices in the stack can be reduced, where one slice only contributes to one of the resulting slices. When performing slabbing on a stack of images, slices in the beginning and the end of the stack do not contribute as much as those in the middle in the stack. This edge problem can be compensated for, e.g. doubling those slices, and the effect depends on how many slices that are combined in the slabbing process.

2.4 Evaluation

Physical measurements in medical imaging, like signal-to-noise ratio or detective quantum efficiency, mostly describe the quality of the equipment and do not necessarily represent the clinical image quality. To evaluate different modalities or techniques in a clinical situation a problem solving approach is preferred. In a problem solving approach observers perform a task, such as estimating the visibility of pre-defined anatomical or defining pathological landmark and rating those using different criteria.

2.4.1 Visual grading analysis

Visual grading characteristic (VGC) analysis is a non-parametric rank-invariant statistical analysis where an observer grades the fulfillment of criteria in the task they perform [18]. VGC analysis is a method that can analyze data collected from a Visual grading analysis (VGA) study [18]. There are two ways to perform a VGA study, either with absolute rating, where ratings are based on absolute values which often reflect the diagnostic requirements of the image, or in a relative rating where two or more images of the same object is compared with each other. In relative VGA the reference image are the prior image standard which the new modality or technique is compared with.

In both absolute VGA and relative VGA, gradings are converted to an arbitrary numeric scale of 3-, 5- or 7-steps, were a grading of *much worse* for relative or *poor image quality* for absolute corresponds to the lowest value and a grading of *much better* or *excellent image quality* corresponds to the highest numerical value for relative respective absolute scores [19].

After a VGA study is performed the result for each system can be summarized in a VGA Score (VGAS),

$$\mathrm{VGAS} = \frac{\sum_{\mathrm{O,I}} \mathrm{S_C}}{\mathrm{N_i N_o}} \qquad (3)$$

where $\mathrm{S_C}$ is the individual score for observer O and image I, $\mathrm{N_i}$ is the number of images in the study and $\mathrm{N_o}$ is the number of participating observers [19]. A statistical analysis with the Friedman test is performed to determine whether, there is a significant difference between groups.

Disadvantages with VGA studies are that gradings are converted to an ordinal scale and the interval between different gradings cannot be assumed to be linear. Because it is observer dependent it is also sensitive to bias and this should be taken into consideration during the development of a study [20].

3. Materials & Methods

The study was divided into three different steps. The first step consisted of two parts. The first part investigated various slabbed slice thicknesses when the amount of resulting images was kept constant. In the second part the number of resulting images was reduced and the slice thickness varied. The second step was a statistical evaluation of the image quality of the initial study and the final step investigated image reading time of breast volumes from slabbed images compared to breast volumes of regular slice thickness.

Images used in this work have been acquired with a Mammomat Novation^{TOMO} and with Mammomat Inspiration^{TOMO} (Siemens Medical Solutions, Erlangen, Germany). With the two machines, twenty-five projection images with equal tube loading is taken over a sweep angle of 40°. The machines use a direct digital amorphous selenium detector, with a pixel pitch of 85 µm [21]. Beam quality has been determined by automatic exposure control with an average glandular dose of approximately 2 mGy for a 50 mm standard breast, which was about twice the dose compared to DM images, and a tungsten/rhodium anode/filter was used [22]. Siemens' proprietary filtered backprojection based reconstruction algorithm, TomoEngine 9.02 was used to reconstruct images. To generate slabs a plugin program for ImageJ (United States National Institute of Health, Bethesda, USA) called Grouped ZProjector was employed. An evaluation of images was made on two DICOM calibrated EIZO SMD21510D monitors with the software program ViewDEX 2.39_SE (Viewer for Digital Evaluation of X-ray images) [23]. The statistical analysis was done with MATLAB (MathWorks, Natick, Massachusetts, U.S.A) except the normal distribution test that was done with MedCalc (MedCalc Software bvba, Mariakerke, Belgium)

3.1 Initial study

3.1.1 Slabbing and maintaining the number of slice images

The first step of evaluating slabbing was performed using sixteen hybrid images, i.e. normal BT images with artificial masses or microcalcification cluster added to them. Six of the hybrid images had masses added to them and ten had microcalcifications added. These hybrid images have been used in previous studies and have been verified to accurately simulate real lesions [24]. The reason for using this kind of images was to know the correct location and structure of the lesions in the images. Both AVE and MAX were performed to create slabs. Slabs of AVE showed a decrease in visibility of micro-calcification. For MAX images, with five or more slices contributing to the resulting slabbed slice, many bright structures were maintained in all the slabs they were contributing to (Figure 3).

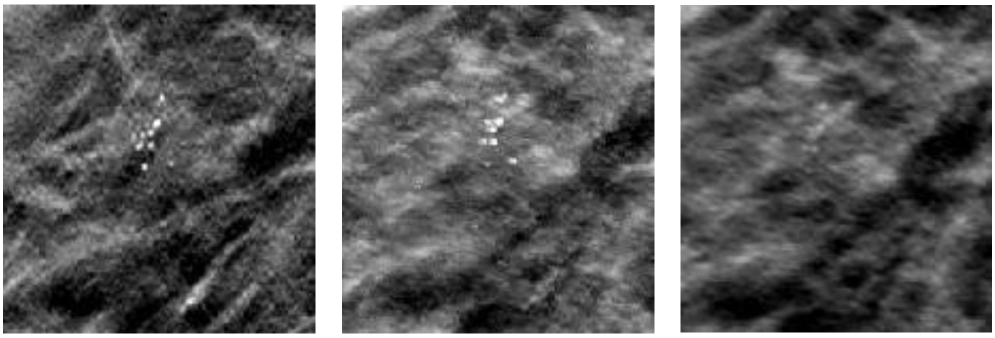

Figure 3: To the left is a hybrid slice image with an artificial cluster of microcalcification. In the middle is a slabbed slice consisting of 5 slices combined with MAX and to the right is a slabbed slice consisting of 5 slices combined with AVE.

3.1.2 Slabbing with reduced number of slices

Investigation of slabs with a reduced number of slices was made with the same sixteen hybrid images as above. Reconstructed slices with thicknesses of 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 mm, were used. The reconstructed slices were slabbed with MAX slabbing where the resulting slices were built up of 1 to 5 slices. The evaluation of the images was made by using standard slice image, (reconstructed to 1 mm thick slices) as reference and relative to this the new images were evaluated based on five criteria:

- Preservation of volume information
- In-plane information
- Amount of reduced slices
- Contrast
- Noise

Preservation of the volume information is how well a slice corresponds to the next and the previous slice, as opposed to a stack of slices that represents a set of independent slices. In-plane information is the visibility of the artificial object of interest in the slide that shows the structure best. The amount of reduced slices is the number of slices saved in relation to having the standard one slice per mm. The parameter contrast is in this case an overall grading of the visibility of the object. The last criterion is an overall noise reduction in the entire image stack relative to the reference image.

After reviewing every combination of slice thickness and the amount of slabs for all sixteen images, the three that fulfilled the five criteria best were used in the further investigations. The final selection was made in collaboration with an experienced radiologist. From the initial study the three that were selected were slices post-processed with 1 mm reconstruction thickness with slabs consisting of 2 slices, 1 mm reconstruction thickness with slabs consisting of 4 slices but with a step length of 2 slices to conduct the next slabbing and the last was generated by a 2 mm reconstruction thickness without any slabbing (Figure 4). All the three that were selected have a reduction factor of two in number of slices.

3.2 Image quality of slabbed images

To determine the image quality of images resulting from the four different postprocessing procedures an observer performing test of structure visibility was made. From the initial study the three post-processing procedures that best fulfilled the criteria were chosen along with a fourth image set consisting of the standard 1 mm images. The observer performanc test was carried out using twenty-seven pathological structures from clinical images, consisting of thirteen lesions and fourteen microcalcification clusters. Window width and window level for all images were automatically optimized, to minimize differences in image appearance. This was performed in *ImageJ* with a built-in automatic optimization tool. The breast contour was outlined in the slice that showed the structure the clearest. Three experienced physicists and one experienced radiologist took part in the study. The image quality analysis consisted of two parts: The first part was a rank test, where the observer looked at the four images at the same time and graded them from 1 to 4 relative to each other, were the best image was graded 1 and the worst 4. The second part was a relative VGA study where every image was compared to the prior standard.

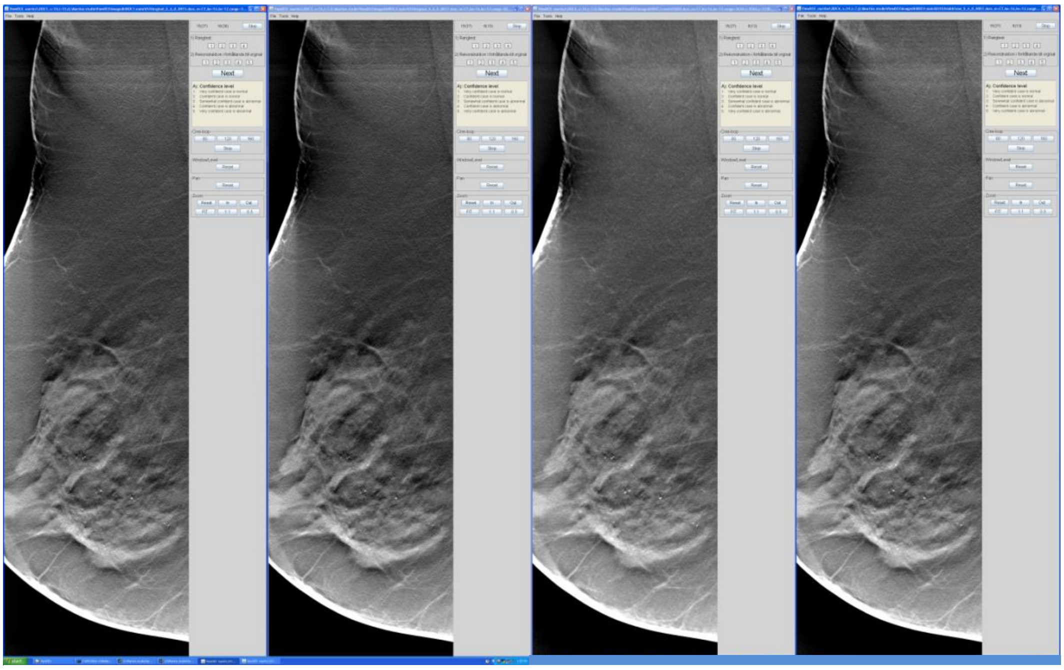

Figure 4: Four sets of images displayed in ViewDEX where the observer graded them first in a rank test and second in a relative VGA study where, in this case, the left image is the reference image.

In the rank test all four images of the same pathological structure (Figure 4) was shown simultaneously to the observer. The positions of the images were randomly selected and the structure of interest was presented to the observer in a randomly selected image. When the observers had graded the images they were told at which position the regular set of image was placed. Then the three sets of images from the *initial study* were individually graded from 1 to 5 relative to the reference image in a relative VGA study where a grading of 3 represents equal image quality, a higher grading represent a better and a lower grade represent a poorer image quality.

3.3 Reducing review time with slabbing

A free-response study (FROC) [25] was made to evaluate if slabbing can reduce review time for the radiologist. The best slabbing technique from the *Image quality of slabbed images*, in part 3.2, was compared with regular breast tomosynthesis images. To investigate a difference in review time a simulated screening situation was performed, where two experienced radiologists reviewed 35 cases, 30 normal and 5 cancer cases, on two different occasions. In the first session the cases were randomly ordered, consisting of 16 cases of regular sets of images and 19 cases of images generated by slabbing. In the second session, three weeks after the first one, a new randomization was made and the images previously showed as regular sets of images were changed to slabbed images and vice versa. All sets of images had the same window settings, which were automatically optimized for each case. This was performed in *ImageJ* as described in section 3.2. The abnormal cases had been verified in advanced by an additional radiologist and the normal cases were from patients who had minimal abnormal findings on DM and were cleared on additional imaging including ultra-sound and also declared normal on the subsequent one-year follow up.

Both trials started with two demonstration cases where the radiologists learned how to operate the ViewDEX software. Before each session, the radiologists were informed that despite the lack of patient anamnesis and complementary images, to behave as in a regular screening situation where findings are marked and classified according to the BI-RADS system[26]. The time for reviewing each case was measured. The reviewing of each case started when the case was completely loaded into ViewDEX and radiologist were able to zoom and change window level in the images. It was not possible for them to use *cine-loop*, instead they could only free scroll though slices using the mouse. Review time for every case was recorded manually and begun when the radiologist started reviewing images until they pressed a button to load the next case.

4. Results

4.1 Results of the initial study

The evaluation from the first initial study, where slabbing and maintaining the number of slice images, was made together with an experienced radiologist. The results were that detecting objects in more slices were found not to outweigh the overall reduction in image quality, if the regular slices of 1 mm set where replaced by slabbing. Images slabbed with MAX had an overall better image quality than images slabbed with AVE.

From the second initial study, where slabbing led to a reduction of the amount of slices, three different sets of conditions were selected to take part in the statistical analysis (Figure5).

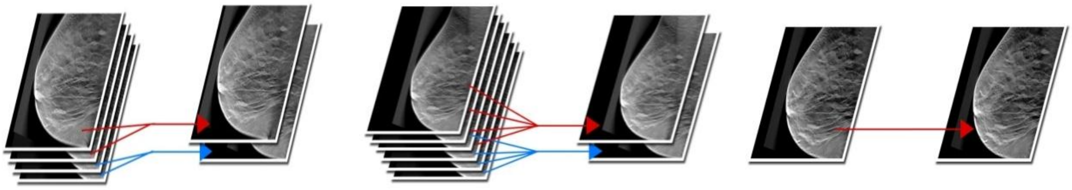

Figure 5: The three postprocessing steps that were shown to fulfill the criteria best. The left and middle are both reconstructed with 1 mm slices, but the left has slabs consisting of 2 slices and the middle has slabs consisting of 4 slices and a step length of two slices between slabs. The right is a 2 mm reconstruction without any slabbing.

4.2 Results of image quality of slabbed images

The results from both the rank test (figure 6) and the relative VGA study (figure 7-9) was that the regular set of images got the best VGA-score. A statistical test of the VGA-score, using a non-parametric Friedman test for repeated measurements, showed that the 1 mm reconstruction thickness with slabs consisting of 2 slices was the only one that did not significantly differ from the regular set of images.

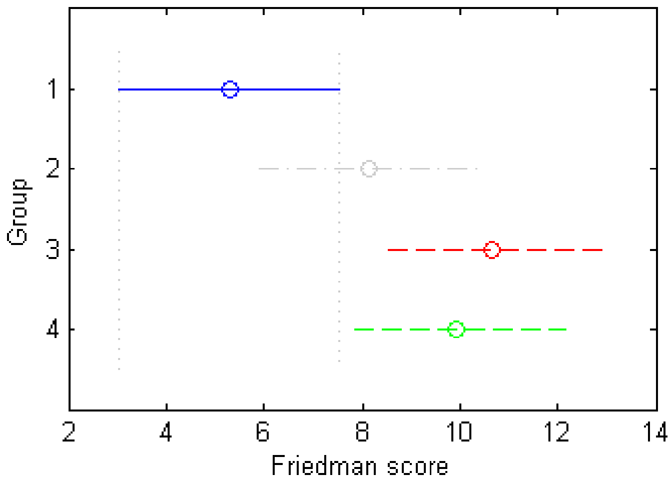

Figure 6: Results of the rank test, with a Friedman test for multiple readers, where a lower score represents a better image quality. Group 1 (blue) is the regular set of images, group 2 (black) is a 1 mm reconstruction thickness with slabs consisting of 2 slices, group 3 (red) is a 1 mm reconstruction thickness with slabs consisting of 4 slices and group 4 (red) is a 2 mm reconstruction thickness with no slabbing.

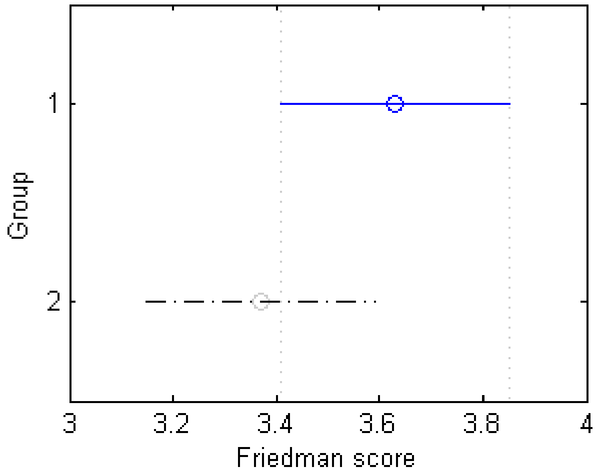

Figure 7: Result of the relative test, with a Friedman test for multiple readers, where the regular set of images (group 1) did not indicate any significant difference compared to 1 mm reconstruction thickness with slabs consisting of 2 slices (group 2).

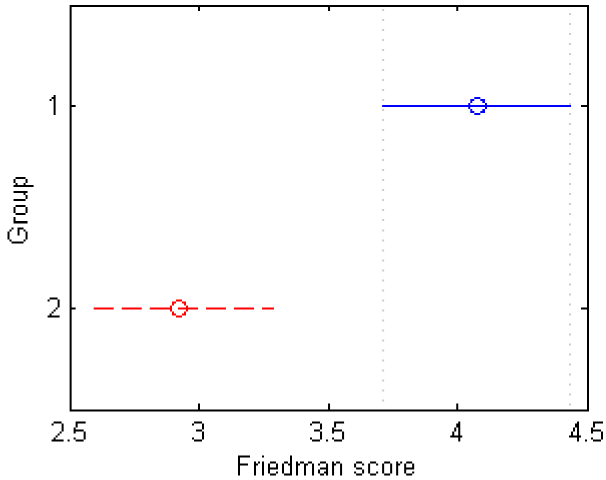

Figure 8: Result of the relative test, with a Friedman test for multiple readers, where the regular set of images (group 1) indicated a significantly better image quality than 1 mm reconstruction thickness with slabs consisting of 4 slices (group 2).

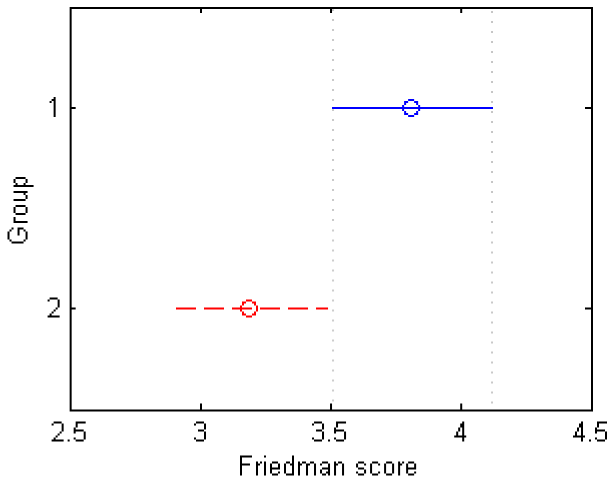

Figure 9: Result of the relative test, with a Friedman test for multiple readers, where the regular set of images (group 1) indicated a significantly better image quality than 2 mm reconstruction thickness with no slabbing (group 2).

4.2 Results of reducing review time with slabbing

A D'Agostino-Pearson test for Normal distribution accepted the results as a normal distribution for radiologist A (P=0.783) and Radiologist B (P=0.234). The time difference distribution was defined as the time difference between slabbed images and regular images, where a negative time represented that slabbed images were reviewed faster and a positive time that the regular images were reviewed slower (Figure 10-11). The individual results where that radiologist A had a significantly faster review time for slabbed images than regular ones (P=0.039) while the other radiologist B did not have any significant difference the two images (P=0.906). For radiologist A and radiologist B the arithmetic mean difference was -14.2 respectively -1.2 seconds in favor to slabbed images. When the two radiologist's results were combined, with an ANOVA for multiple readers with pairwise data, there was no significant difference between the two image distributions (P=0.133).

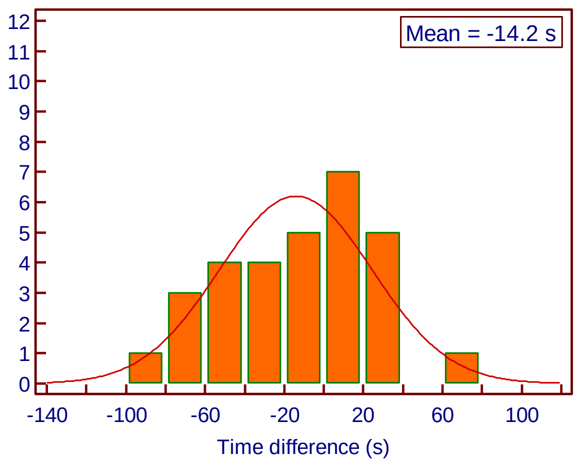

Figure 10: The distrubution of image reading time for radiologist A. Negative scores corresponds to that slabbed images were read faster and positive scores corresponds to that regular images were read faster.

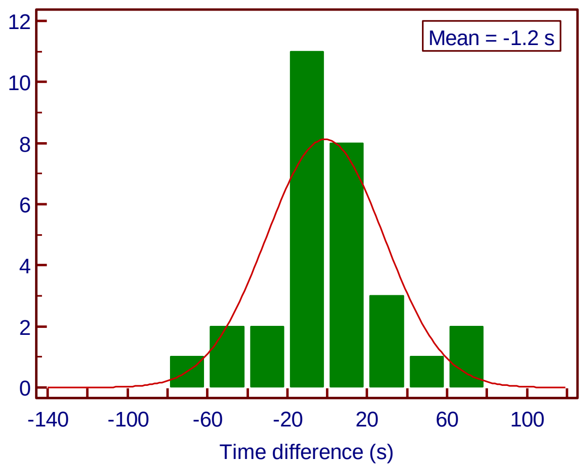

Figure 11: The distrubution of image reading time for radiologist B. Negative scores corresponds to that slabbed imeges were read faster and positive score corresponds to that regular images were read faster.

5. Discussion

The goal of this project was to find a slabbing method that shortens the radiologists reading time. To achieve this goal the project were divided into three steps.

In the first initial study (on microcalcification detection), slabs were combined with both MAX and AVE slices. In the study, of reduced review time, only slabs consisting of MAX slices were used. The reason for this was that in the first study MAX images showed a more promising result than AVE images.

Figure 6 demonstrates that it is better to slab slices than to use thicker reconstructed slices. To determine how large this difference is or if this difference is not of clinical importance further research need to be done. Between regular sets of imaging and slabbing two 1 mm slice has no significantly reduction in visibility of the investigated structures.

Then combining the two 1 mm slice to one slice was made pixel-wise with MAX. If it instead had been combined pixel-wise with AVE the result would probably not have been much different. This is because the difference between the two combining tools are not that effected then only two slices are combined.

The advantage of making slabs is that it can act as a complement to the regular set of images, and thus no new reconstruction has to be made.

In the final study radiologists were only allowed to use free scroll and not the *cine-loop*. Under real circumstances they use both to make a diagnosis. The reason to perform the test with this limitation was to give the radiologist the opportunity to decide a suitable frame rate and not add another parameter that is difficult to predetermine and whose effect on the result is problematic to evaluate.

The result was that one radiologist did not show any significant difference in reading time while the other had a significantly lower review time for slabbed images. To determine the true effects of slabbing more radiologists has to be included into the study. One reason the lack of difference in time could be that each slabbed image contains more information than regular images which could make the investigation of each slice more time consuming for the radiologist.

To find an optimum image presentation mode, two slabbing techniques and one reconstruction of thicker slices were selected from predefined criteria. The outcome was probably affected by the selection of hybrid images and image criteria, because the differences between some of the postprocessing alternatives are small.

Diekmann et al. [17] measured contrast levels for AVE and MAX, when ten slices were slabbed into one slice using a phantom setup. This study used real and hybrid cases and multiple slabbing configurations for observers to classify the changes in visibility of the structures. This study also includes different reconstruction thicknesses.

In the free response study observers performed a task to determine a difference, in this case reviewing time, where the task was to categorize the breast images after the BI-RADS classification. In this work only the data about time spent at every case was extracted but it was possible to calculate the specificity and sensitivity and from that calculate a figure of merit. In order to make a correct calculation of specificity and sensitivity the study has to contain a substantially more cases, which was not possible due to limited radiologist time. Instead the *image quality study* showed that the pathological image quality was equal between the two methods. But in a future work, if slabbing will be determined advantageous, it could be of interest to study specificity and sensitivity.

A clinically produced breast tomosynthesis stack typically consists of 50 to 70 slices depending on the breast thickness, requiring a total memory slot of around 1 GB (gigabyte). The images are currently uploaded directly from the picture and archiving system (PACS) whenever the radiologists review images and the transfer of this amount of data to the workstation is time consuming. This is a problem that will probably be solved in the future, with faster networks and computers, and the benefits of less data have not been investigated in this work. A reduction of the amount of data will surely lead to shorter loading times.

6. Conclusions

The results of this study indicated that slabbing gives a better image quality than reconstructing thicker slices.

It was also showed that slabbing two 1 mm slice into a thicker slice instead of using the regular 1 mm slice had no significant effect on the image quality.

The study could not determine that slabbing would result in a shorter image reading time compared to reading images reconstructed with conventional methods.

7. Acknowledgments

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