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Concept for fast breast cancer ultrasound screening in addition to mammography – first clinical results

Madeleine Hertel
Siemens Healthcare GmbH
Otto-von-Guericke-Universität, Magdeburg
Forchheim, Germany
madeleine.hertel@siemens-healthineers.com

Michael Golatta
University Hospital Heidelberg
Department of Gynecology
Heidelberg, Germany
michael.golatta@med.uni-heidelberg.de

Marija Juskic
University Hospital Heidelberg
Department of Gynecology
Heidelberg, Germany
marija.juskic@med.uni-heidelberg.de

Steffen Kappler
Siemens Healthcare GmbH
Forchheim, Germany
steffen.kappler@siemens-healthineers.com

Ralf Nanke
Siemens Healthcare GmbH
Forchheim, Germany
ralf.nanke@siemens-healthineers.com

Thomas Mertelmeier
Siemens Healthcare GmbH
Forchheim, Germany
thomas.mertelmeier@siemens.com

Benedikt Schaefgen
University Hospital Heidelberg
Department of Gynecology
Heidelberg, Germany
benedikt.schaefgen@med.uni-heidelberg.de

Georg Rose
Otto-von-Guericke-University
Institute of Medical Technology
Magdeburg, Germany
georg.rose@ovgu.de

Marcus Radicke
Siemens Healthcare GmbH
Forchheim, Germany
marcus.radicke@siemens-healthineers.com

***Abstract*—In breast cancer screening, x-ray mammography is the standard imaging modality. For clarification of suspicious findings, handheld ultrasound (US) is used as an adjunct modality. It is so far not included in screening due to the lack of standardization, high costs and the risk of increased false positives within screening population. First attempts to standardize US with automated breast US are still not completely fulfilling clinical needs, e.g. workflow and reading are claimed not to be fast enough. Therefore, various groups introduced new concepts of fast US screening, providing standardized images in the same orientation as the mammography images, leading to a speed-up of reading and reporting.**

To acquire US images in an x-ray mammography environment, an automated breast US transducer was inserted into a modified compression paddle. After mammography or tomosynthesis, an automated breast US scan was performed. We investigated new concepts to optimize workflow speed and approaches to achieve nearly full US coverage of the breast in a clinical study.

We successfully integrated automated US scanning in a clinical workflow with less than one minute for the additional scan. Compared to the workflows of automated breast US and handheld US, the proposed scanning concept provides a high time and cost saving potential. Preliminary results indicate a high breast area coverage of the US scan. The first clinical results of our method demonstrated a proof of concept for a technical solution to include US screening into the standard breast cancer screening workflow. The standard workflow is changed minimally and the additional time investment is low since no patient repositioning or system adjustments are needed between both scanning modalities.

***Index Terms*—mammography, ultrasound, multimodal breast imaging**

I. Introduction

Mammography as the standard x-ray imaging method for breast cancer screening has led to a reduced breast cancer mortality [1], [2]. However, in dense breast tissue the performance of mammography is limited leading to a reduced sensitivity. Breast cancer can be obscured by overlying dense tissue and therefore impeding its detection.

Supplemental ultrasound (US) increases the detection of breast cancer in women with mammographically dense breast tissue [3] - [5]. One obstacle to include US into screening is the lack of standardization of US due to its operator dependency when performed handheld. In order to eliminate that dependency, automated breast US was introduced. Although the US images are now more generalized compared to handheld US, the acquisition time as well as the reading of the images, as there are usually multiple scans and not in the same orientation as the mammography images, still take too long for an integration into a screening workflow.

In recent years, concepts of integrating US into the mammography workflow providing standardized images in the same view as mammography, were introduced [6] - [9], but so far not included in a screening environment.

In this study, we investigated a concept for fast breast US screening and the performance of US in conjunction with mammography and tomosynthesis, using a standardized workflow to provide images from both modalities in the same orientation.

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II. Materials and Methods

A. X-ray and ultrasound prototype

The x-ray and ultrasound (XUS) prototype is based on the mammography unit MAMMOMAT Inspiration (Siemens Healthcare GmbH) and the US unit ACUSON S2000 with an automatic breast volume scanner ABVS (Siemens Healthcare GmbH). Fig. 1 illustrates the setup. The standard compression plate used in mammography is replaced by a prototype compression paddle. It allows the insertion of an US transducer to perform the automated breast US. Also, the bottom of the paddle is replaced by a gauze which is penetrable to US lotion and US waves, to create a contact area with the breast. The gauze is such tightened that compression forces of 100 N, required for mammography and tomosynthesis, can still be applied. After the standard mammography or tomosythesis scan and without patient respositioning, the breast remains compressed. US lotion is applied on the breast and a linear ultrasound transducer (Siemens 14L5BV) is inserted into the compression paddle to automatically acquire an automated breast US volume with 300 x 154 x 60 mm^3. The breast is scanned with both modalities in the exact same orientation.

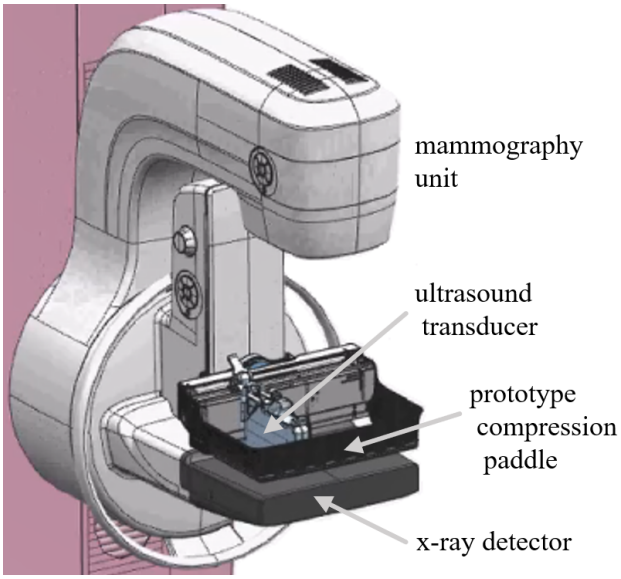

Fig. 1. XUS prototype - the standard compression plate is replaced by a prototype compression paddle where an ultrasound transducer can be inserted and the bottom is replaced by a gauze to achieve images from both modalities, x-ray and ultrasound, in the same orientation.

B. Study setup

The study at the University Hospital in Heidelberg started in March 2019 and is still continuing. Fig. 2 shows the prototype setup at the hospital. Patients were included if they referred for radiological examination of the breast with an indication for mammography or tomosynthesis. The patients received the standard diagnostic examination, mammography or tomosynthesis and the suspicious breast

Fig. 2. XUS prototype installation at the University Hospital, Heidelberg. On the left, the mammography unit MAMMOMAT Inspiration with the mounted prototype compression paddle, on the right the US unit ACUSON S2000.

was then compressed with the prototype compression paddle, as required, in either craniocaudal (CC), mediolateral-oblique (MLO) or mediolateral (ML), depending on the position of the indication. Directly after the x-ray scan, the US transducer was inserted into the compression paddle, US lotion was applied, the automated breast US performed and the patient released. The additional time for the US scan ranged from 40 to 60 s for the US scan itself and 30 s for the setup modification and cleaning. After examination, the US transducer was removed from the paddle and the gauze replaced. The adjusted US parameter have been predefined in a look-up table based on a performed pre-study in the University Hospital, Heidelberg, in September 2018.

III. Results

Only preliminary evaluations, especially for the medical indications and image quality, are available due to the study still ongoing. The additional US scan was included well into the mammography workflow. An average of 40 to 60 s per US scan was achieved and an US volume of 300 x 154 x 60 mm^3 could be acquired.

In general, the breast area coverage of the US scan was comparable to the mammography and tomosynthesis scans. Due to constructional reasons of the US transducer, illustrated in Fig. 3, all US images are about 10 mm smaller towards the thoracic wall, compared to the x-ray images. Due to an optimized compression workflow and paddle design, earlier problems of covering the anterior side of the breast improved significantly leading to images reaching up to full US coverage including the mamilla. An example-set of well-covered images is shown in Fig. 4.

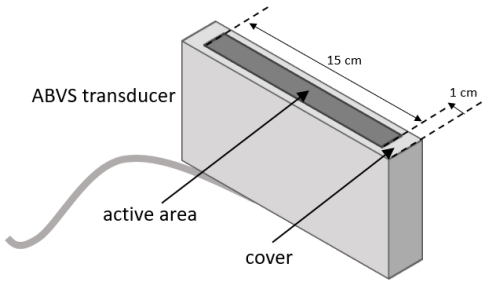

Fig. 3. Next to the active area of the ABVS transducer (14L5BV) the cover has a width of 1 cm, limiting the US image acquisition in our setup close to the thoracic wall.

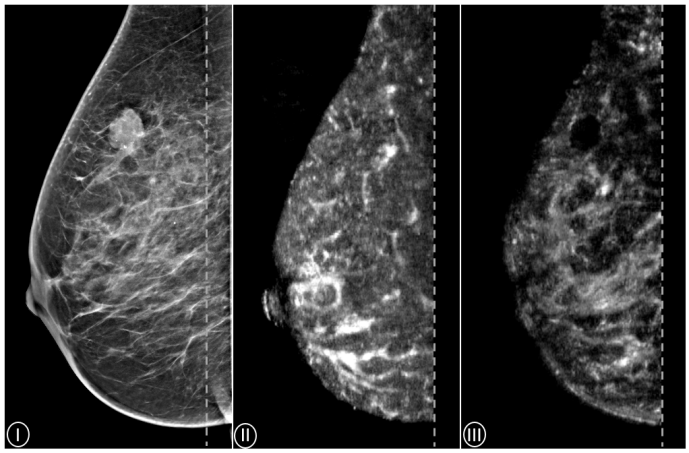

Fig. 4. Images acquired with the XUS prototype. I: 2-D x-ray projection of a right breast with a tumor in MLO view. The grey dashed line symbolizes the limitation of the US transducer towards the thoracic wall. II: One slice of the corresponding US volume showing a high coverage up to the mamilla. III: Different slice of the same US volume including the tumor.

IV. Discussion

The XUS prototype combines the advantages of mammography/tomosynthesis and automated breast US in one device, acquiring both imaging modalities in one procedure. The main advantages include a reduction of the time for an US examination and a precise correlation of potential findings in both imaging modalities. A time ranging from 40 to 60 s for an additional, automated breast US examination was achieved. Compared to the workflows of handheld US or automated breast US alone, which both take more than 10 minutes each, the time and therefore cost saving potential of performing the US scan in the presented approach is high.

The US coverage enhanced compared to prior studies, but still needs further improvement. Technical limitations like the scanning towards thoracic wall and depths larger than 6 cm need to be overcome. Furthermore, ideas how to create more contact area and increase the coverage especially up to the mamilla should be investigated, to reach image qualities comparable to standard automated breast US. The US parameters were adjusted depending on the breast thickness and according to a standardized look-up table, but also need more individualized improvement, e.g. taking breast tissue density into account.

Preliminary assessment of the US images indicates clinical acceptable image quality. Due to the ongoing study a detailed analysis of the image quality is still pending. In conclusion, we successfully tested a technical device for standardized breast US examination that could potentially be used in a future breast cancer screening setting.

Disclaimer

The presented method is part of a research project and not commercially available.

Conflicts of interest

The authors M. Hertel, S. Kappler, T. Mertelmeier, R. Nanke and M. Radicke are employees of the Siemens Healthcare GmbH. For all other authors there is no conflict of interest.

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