PSUMJ
PSU MEDICAL JOURNAL

Original Article

Development of a Micro Computed Tomography Scanner for Localization of Lesions and Assessment of the Margin Width of Resected Breast Specimens in the Operating Room

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ABSTRACT

Objective: The objective of this study was to develop a micro-computed tomography (micro-CT) scanner machine and software dedicated to the localization of calcification in resected breast tissue specimens in a 3-dimensional image. The micro-CT scanner was designed to be used as a mobile machine, particularly for use in the operating room.

Material and Methods: The system was designed to perform a 360-degree scan on a rotating table between the x-ray source and the detector sensor using a cone beam x-ray. The prototype was developed collaboratively between Prince of Songkla University (PSU) and the National Science and Technology Development Agency, Thailand (NSTDA). This was the first prototype for scanning specimens. The overall scan time and the image reconstruction was 5-10 minutes. The machine was tested for safety by PTEC (Electrical and Electronic Product Testing Center of NSTDA).

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doi: 10.31584/psumj.2022247034
https://he01.tci-thaijo.org/index.php/PSUMJ/

PSU Med J 2022;2(1):9-14
Receive 21 January 2021
Revised 7 September 2021
Accepted 14 September 2021
Published online 26 January 2022

Results: The specification of MiniiScan® and preliminary results of 3D image reconstruction of the resected breast tissue specimen by using the MiniiScan® are present in this report. The study evaluated specimens form 31 patients obtained from June 2016 through January 2018. The average scan time was 10.4 minutes. The turnaround time of the conventional technique was 27.9 minutes. The quality of the 3D images as evaluated by PSU staffs was superior to the conventional x-ray images done with the standard mammogram. The 3D images can display the correct position of calcification and a width between calcification to margins in all directional plane.

Conclusion: The 3D images of the prototype intraoperative MiniiScan® scan were superior in quality to the standard mammogram, and had a quicker turnaround time for intraoperative application. Surgeons can use this machine in the operating room instead of relying on the conventional x-rays with a mammogram machine outside the operating theater.

Keywords: Abnormal calcification; Intraoperative 3D images of breast tissue specimen; Specimen radiography

INTRODUCTION

The incidence of breast cancer is becoming more prevalent world wide.[1,2] The incidence is about 100:100,000 per year in Europe and the United States of America (USA). Currently, breast cancer is the most common female cancer in Thailand.[3] The screening mammogram is used for detection of early breast cancer. A cluster of pleomorphic microcalcifications on a mammogram is an indication for tissue biopsy. The wide excision is used to approach the not-palpable microcalcification after x-ray localization and guided with wire **(Figure 1 A-B)**. Confirmation is needed to ensure that the resected breast tissue included the abnormal lesion. An x-ray of the specimen can also be used for detection of the microcalcification at the margin of the specimen. The limitation of the conventional x-ray technique is the long turnaround time for the x-ray result.[4-5] Also, the specimen must be examined on the mammogram machine outside the operating room. The image acquired from the conventional x-ray technique is a 2D image which may lead to misinterpretation, as a calcified lesion may be located in different positions depending on specimen rotation during the x-ray.[6-8] The machine that is specifically desired for the x-ray specimen in the operation room is rarely available. Microcalcifications located close to the margin of the specimen are an indication that a re-excision of the margin of the specimen (surgical caving margin) may be needed.[9-12] Intraoperative 3D images will minimize these errors and reduce the turnaround time. A commercial micro-CT scan for animal laboratories can be used for this type of specimen scan but it is not cost effective and the imaging scan requires more than half an hour for turnaround time.

Objective the project to develop a micro-CT scanner machine for detection calcification in a resected breast specimen, and also for application in further investigation of the soft tissue specimens in the: pancreas, liver, brain, etc.[13-15]

MATERIAL AND METHODS

The ability to portray a resected specimen on a rotating table between a cone beam x-ray source and a high-definition detector was the desired principle system of the MiniiScan® prototype. The MiniiScan® was planned for use intraoperatively with no radiation hazard for the operator. The hardware was designed by the National Metal and Materials Technology Center (MTEC), NSTDA and the software developed by the National Electronics and Computer Technology Center (NECTEC), NSTDA. The basket specimen reservoir for prevention of specimen movement during the scan process was developed by Prince of Songkla University staffs.

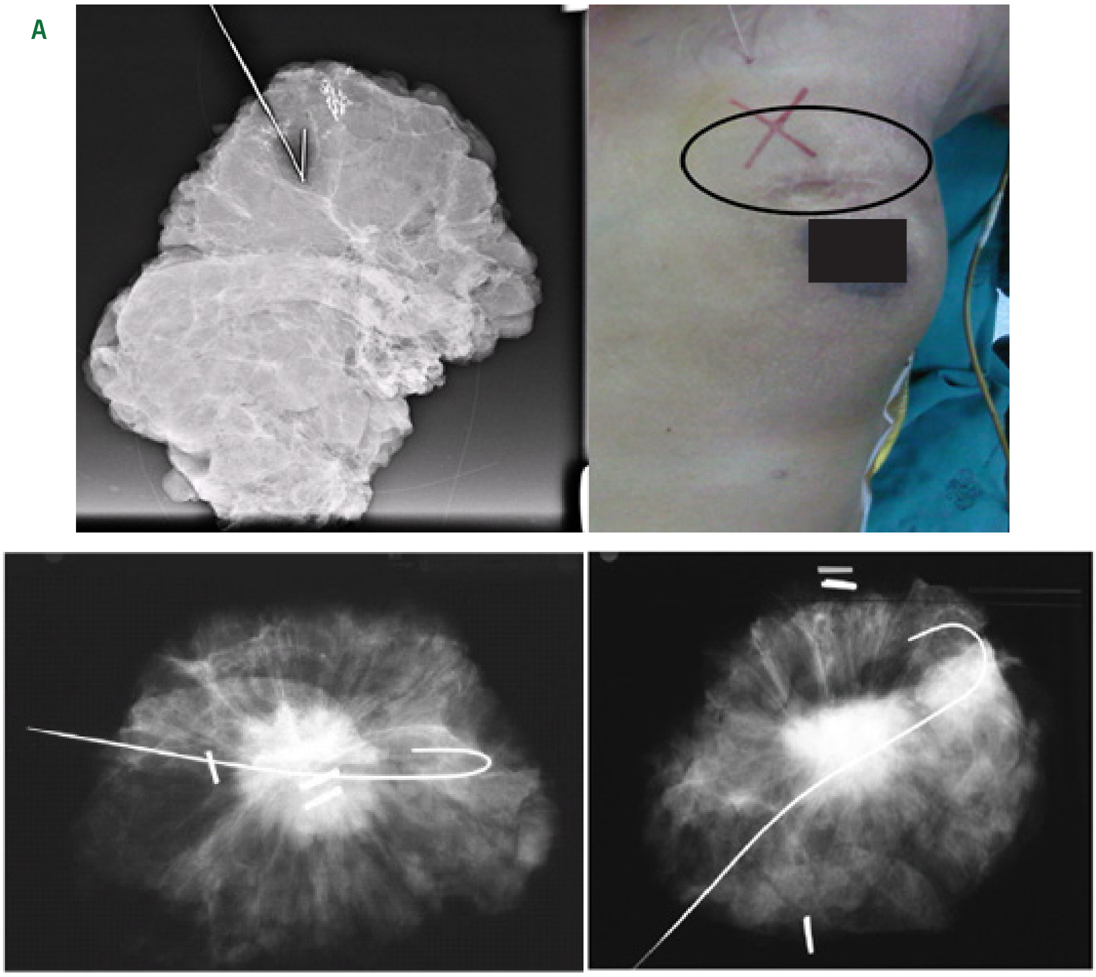


Figure 1 A: The left side picture shows the area where a calcified lesion in a breast was localized at the tip of a wire beneath the skin marker. The right-side picture shows an x-ray of the specimen report indicating that there was calcification in the specimen but closer to the upper margin.

B: These pictures show the position of a lesion in different positions depending on specimen rotation, with the 2 clips fixed at breast specimen margins. In the left-side specimen x-ray, the position of both clips (lesion) is at the center of the specimen, while in the right-side x-ray, with the specimen rotated 90 degrees, clips are at the margin.

The 360-degree specimen rotated on the table for about 5 minutes during the scan process. The FOV (field of view) covered all dimension in a 9 cm. area of scan image. A pulse x-ray source of 70 kVp was used for the x-ray tube and the detector type was an amorphous silicon flat panel. All of the images were reconstructed by the developed software. The scan time was depended on the image quality, the number of scan images and number of frames per second, (Figure 2; Table 1). The electronic safety was approved by PTEC and the radiation hazard was approved by the Department of Medical Science, Ministry of Public Health, (Figure 3A).

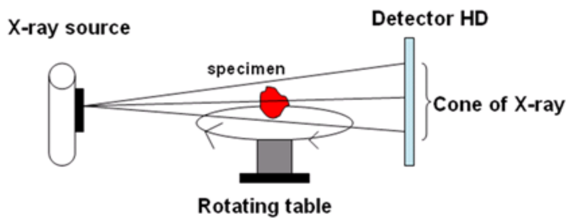


Figure 2 The diagram of the MiniiScan® x-ray andsystem

RESULTS

The MiniiScan® for detection of microcalcification of resected breast tissue specimens was completed in June 2016. The software developed for this machine could be set to 4 different image-qualities for difference size and shape of the microcalcification. The scan time was about 5 minutes and the image reconstruction process about another 5 minutes. The dimensions of the machine are 1.42m x 1.24m x 0.81m and its weight is 150 kg **(Figure 3B)**. The machine includes a CPU, monitor, keyboard and data storage device. An emergency stop button was included for prevention of errors during the scanning process **(Figure 3C)**.

An early prototype of the machine was tested for quality and safety in the lab. Then machine images were compared to conventional 2D x-ray images for improvement of the quality and to refine the user-friendly software. Scans of intraoperative specimen in 31 patients were evaluated from June 2016 to January 2018. The average turnaround time of 3D imaging was 10.4 minutes, while the average waiting time for the 2D x-rays of the mammogram machine, using the conventional technique outside the operating room, was 27.9 minutes. A preliminary report of the image quality of the new machine indicated the results were comparable to the conventional x-ray specimens done by a mammogram machine **(Figure 4)**. The advantage of a 3D images is it can be viewed in every direction of calcification related to the margin of specimen. The next step is to compare the new machine with conventional 2D images in a larger clinical trial.

CONCLUSION

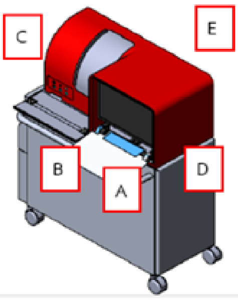
The MiniiScan® 3D scanner for resected breast tissue specimens for detection of microcalcification located inside the specimen was developed. The preliminary report of the image quality indicated the quality of the new images was comparable to conventional x-ray specimens on a normal x-ray mammogram machine. The new machine in terms of image quality, scan time and turnaround time was superior to the conventional x-ray machine.

Table 1 The scanning protocol of the MiniiScan®

No	Protocol	X-ray setting	Scan time(s)	FOV in D (cm) x H (cm)	Matric size (voxels)
1	0.2 mm, 9x9 FOV (Fast)	70 kV, 8 mA, 16 ms/proj	18	9 x 9	450 x 450 x 450
2	0.2 mm, 4x4 FOV (Fast)	70 kV, 8 mA, 16 ms/proj	18	4 x 4	200 x 200 x 200
3	0.125 mm, 7x7 FOV (Fast)	70 kV, 8 mA, 23 ms/proj	18	7 x 7	560 x 560 x 560
4	0.125 mm, 4x4 FOV (Fast)	70 kV, 8 mA, 23 ms/proj	18	4 x 4	320 x 320 x 320
5	0.2 mm, 9x9 FOV (Slow)	70 kV, 8 mA, 16 ms/proj	126	9 x 9	450 x 450 x 450
6	0.2 mm, 4x4 FOV (Slow)	70 kV, 8 mA, 16 ms/proj	90	4 x 4	200 x 200 x 200
7	0.125 mm, 7x7 FOV (Slow)	70 kV, 8 mA, 23 ms/proj	126	7 x 7	560 x 560 x 560
8	0.125 mm, 4x4 FOV (Slow)	70 kV, 8 mA, 23 ms/proj	90	4 x 4	320 x 320 x 320

A

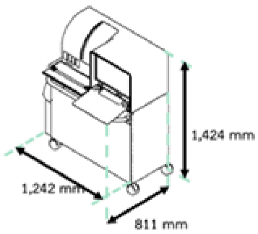
Test of radiation effect



Position	Distance from Machine	Dose Rate (µSv/hr)
A: Front (Control)	30 cm	3
B: Front (Door)	30 cm	13
C: Left	30 cm	1
D: Right	30 cm	2
E: Back	30 cm	1
A: Front (Control)	100 cm	2

B

Specifications



Detector type	Amorphous Silicon Flat Panel
Detector size	130 mm x 130 mm
X-ray source	Pulsed
Tube voltage	70 kVp
Tube current	8 mA
Focal spot	0.5 mm
Scan time	18-126 sec
Field of View (FOV)	Max: 90 mm(D) x 90 mm(D) Min: 40 mm(D) x 40 mm(D)
Voxel size	0.125, 0.2 mm
Machine size	811 mm x 1,242 mm x 1,424 mm
Machine weight	150 kg

C

Figure 3 A: Quantitative test results of the radiation hazard during the scan **B:** The prototype specifications of the MiniiScan® **C:** A picture of the MiniiScan®

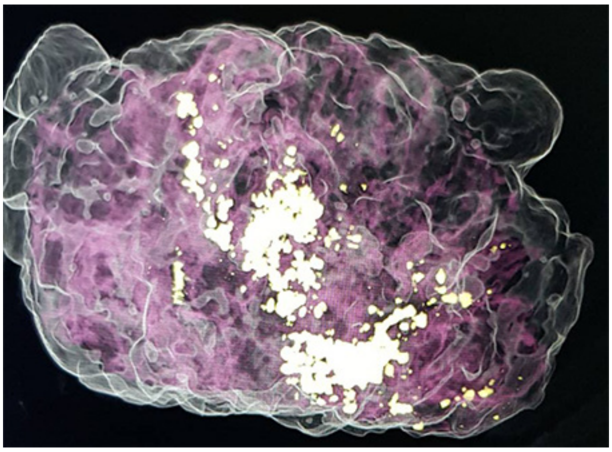


Figure 4 Example of 3D picture from the mini-CT scan machine

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