Verification of Microstructure Qualities of ACR-Approved Mammography Phantoms by Refraction-Enhanced Synchrotron Radiation Imaging

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ABSTRACT

Images of microcalcification specks showed large variation in conventional radiographs of phantoms which are approved for mammography image quality standard by the American College of Radiology (ACR). This kind of variation is not appropriate for image quality standards because the number of specks are visually counted in images and that number is important in image quality evaluation. Our study using synchrotron radiation (SR) imaging revealed the overlapping of micro-sized air bubble(s) to some specks, and also the structural deformation or crackings. Eight phantoms approved by ACR from two different makers and an air-bubble phantom were examined. SR imaging was performed at a synchrotron radiation facility, SPring-8, in Japan. The image-detector was a fluorescent-screen optical-lens coupling system using a CCD camera with a spatial resolution of 6 □m. Objects when imaged with longer sample-to-detector distance show edge enhancement due to a difference in refraction indices, that is refraction enhancement. Refraction-enhanced SR images revealed that some of specks carried foreign objects, which were proven to be air. In phantoms provided by one maker, attaching/overlapping airs were observed for 62 out of 150 specks (41 %) , with a higher incidence for the smallest specks. A speck becomes hardly visible in a conventional radiograph when air(s) overlaps the majority part of a speck, though depending on the size of the air-inclusion and on its configuration. Those airs might have been adsorbed on a speck surface before being embedded and then introduced into the matrix together with specks. Our study using SR imaging has clearly shown the nature of defects in some mammography phantoms which seriously degrade the quality as an image standard.

Keywords: synchrotron radiation imaging, mammography, phantom, microcalcification, microstructure

INTRODUCTION

In a mammography quality assurance program, a phantom is radiographed to evaluate total system performance including film development procedures. The test objects in those phantoms, therefore, should be strictly qualified regarding their size and density. It has, however, been recognized by visual inspection that microcalcification specks are lacking in uniformity in phantoms approved by ACR [1, 2, 3)]. Variation was still demonstrated in 14 phantoms of a single new version by quantitative measurement of signal intensity of specks on radiographs [4, 5)].

Synchrotron radiation (SR) imaging of phantoms was performed, and it revealed defects which could not be detected by conventional radiography, and which could probably explain the apparent non-uniformity of specks.

MATERIALS AND METHODS

Eight phantoms from two makers were studied. They are the model approved by American College of Radiology (ACR) [3)] . SR imaging was performed at a synchrotron radiation facility, SPring-8, in Japan. The energy of monochromatic X-ray was adjusted to 20 keV, and radiation field-of-view was 24 X 24 mm. Phantoms were imaged with the same projection as imaged by conventional mammography. The image-detector was a fluorescent-screen optical-lens coupling system using a CCD camera with a spatial resolution of 6 μm. SR images were obtained for 40 groups of specks in total, each group containing 6 specks.

Images were obtained with various sample-to-detector distances, and objects, when imaged with longer distance, show edge enhancement due to a difference in refraction indices, named refraction-enhanced images [6].

RESULTS

An exposure time was approximately 30 to 60 sec. On refraction-enhanced image of a hand-made phantom including air bubbles, bubbles were shown as a white region, indicating higher transmitted X-ray intensity, with black margin [7]. As shown in Fig. 1, refraction-enhanced images showed air bubble(s) attaching or overlapping some of the specks. In phantoms of one maker, the incidence of specks carrying airs was 41 % in total and 83 % for the smallest specks. If an air bubble overlapped whole of a speck, that speck could hardly been recognized in absorption SR images as well as in conventional radiographs.

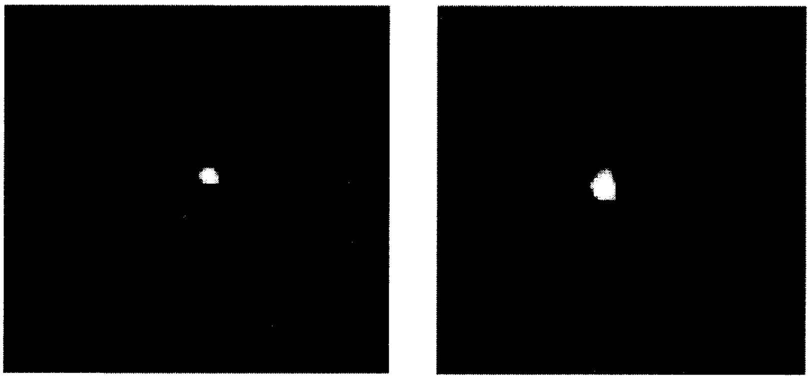

Figure 1. Refraction-enhanced synchrotron radiation image of microcalcification specks with a nominal size of 160 μm. Specks are imaged as a black region with white margin and objects with opposite contrast are air bubbles. Left: relatively small air can be seen attaching specks, but not overlapping. Right: air completely overlaps a speck, and the speck , therefore, could not be visualized in an absorption-contrast SR image, but rather depicted as a vague white region on the contrary to a "pure" speck.

Besides air bubbles, other kinds of structural deformation like crackings were visualized by refraction -enhanced SR imaging (Fig. 2, left), which were visible neither in absorption SR images nor in conventional radiographs.

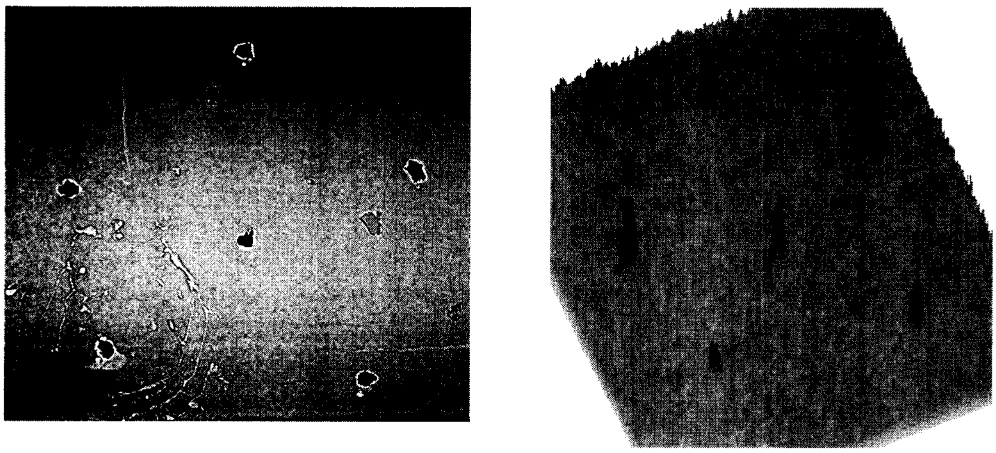

Figure 2. Images of 6 microcalcification specks with a nominal size of 540 μm; refraction-enhanced synchrotron image on the left [8] and conventional radiograph shown as a surface plot on the right (contrast is inverted to make comparison with the left image easy). A circular, structural deformation can be seen running around a speck located at the lower left position (left). In a conventional radiograph, the contrast of that speck, as a consequence, is degraded and poorer than other 5, but deformation is not visualized and matrix looks pretty uniform (right).

DISCUSSION AND CONCLUSIONS

Air bubbles are imaged as white in the central area with a clear black margin in refraction-enhanced images as expected from its lower X-ray attenuation and lower refractive index than matrix material [7, 8]. The content of the circular structures shown in Fig. 2 might presumably be air or simple void because the running structure has black margins. A part of the deformation extends as an area and surrounds a speck, located lower left, and the X-ray absorption contrast of the speck was reduced probably by the deformation, and its visibility is vague comparing to the rest 5 specks (Fig. 2, right).

The degradation of the appearance of specks in projection images can be attributed to air or void which are attaching specks [7]. It was estimated that X-ray absorption by a speck will be compensated when the air bubble has the diameter twice as much as the speck, if air or void were located along the same X-ray projection path. It can be speculated as an origin if air bubbles attaching specks that specks adsorb airs on their surfaces and carried them when being embedded into the matrix.

As those kinds of defect, like air inclusions and crackings, cannot be detected by conventional radiography, a facility, if inadvertently purchased defective phantoms, could not realize that and might use it for quality assurance without notice.

As conclusions,

Microcalcification specks in ACR-approved phantoms have variation in conventional radiographs.

Synchrotron radiation (SR) imaging visualized air bubbles or crackings in phantoms.

They were found to seriously degrade the contrast of specks.

This defect in quality control phantoms may cause difficulty in quality assurance specifications.

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