



## Lesion Size Inaccuracies in Digital Mammography

Jean R. Paquelet<sup>1</sup>  
R. Edward Hendrick<sup>2</sup>

**OBJECTIVE.** We show with both a clinical case and measurements using the American College of Radiology mammography phantom that some digital mammography acquisition and image display combinations lead to both marked over- and underestimation of lesion sizes on geometrically magnified images.

**CONCLUSION.** The results of this study indicate that the accuracy of lesion size measurements in all magnification modes should be a routine quality control acceptance test with each acquisition–display system combination in digital mammography.

To date, the U.S. Food and Drug Administration (FDA) has approved eight digital mammography acquisition systems from five different manufacturers. Each manufacturer provides one or more choices of radiologist review workstation, and the FDA has approved at least six additional third-party review workstations for interpretation of digital mammograms. One might assume, as we did, that because these acquisition and display systems are DICOM compliant and FDA approved, lesion size measurements would be accurate and consistent regardless of the acquisition–display combination [1]. Through first-hand experience, we have learned that this is not always the case. Available documents on digital mammography image quality [2, 3], quality control (QC) recommendations [4, 5], and manufacturer-provided QC manuals have not addressed the issue of measurement accuracy in any acquisition mode. (See, for example, Fischer SenoScan System Operator Manual, Fujifilm FCR<sub>m</sub> Fuji CR for Mammography Quality Control Manual, GE Healthcare Senographe Essential Acquisition System Quality Control Manual, Lorad Selenia Quality Control Manual, and Siemens MAMMOMAT Novation Quality Control Manual.)

We became aware of the problem of inaccurate lesion size measurements when we imaged a 40-year-old woman using a GE mammography unit (Instrumentarium Performance, GE Healthcare) with a Fuji image receptor (CR, Fujifilm USA) and a Fuji proces-

sor (Clearview, Fujifilm USA) and displayed the images using a Fuji PACS (Synapse [software version 3.2.1]). We refer to this acquisition–display combination as “system X.” The woman’s baseline screening mammogram showed microcalcifications in the lower inner quadrant of the left breast. Spot compression images (magnification, 1.6×) revealed an underlying mass not visible on screening images. Electronic calipers on the PACS review workstation applied to these magnification images showed the mass to be approximately 1.9 cm in largest dimension (Fig. 1A). Ultrasound imaging (Fig. 1B) and breast MRI (Fig. 1C) were subsequently performed, and the same mass measured 1.0 and 0.9 cm in largest dimension, respectively. Ultrasound-guided biopsy revealed invasive ductal cancer. Lumpectomy was performed after ultrasound-guided needle localization. Pathologic evaluation revealed a 0.9-cm invasive ductal cancer. The discrepancy between mammographically determined cancer size and the cancer size measured on ultrasound, MRI, and the lumpectomy specimen shown at tumor board caused confusion concerning cancer staging and treatment planning.

### Materials and Methods

To investigate the accuracy of lesion size measurement, we used the American College of Radiology (ACR) Mammography Accreditation Program phantom with a 1-cm diameter acrylic disk placed on its upper surface, 4.5 cm above the breast support surface. We acquired digital mammograms of this phantom in contact (nonmagnification) mode

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R. E. Hendrick is a consultant to GE Healthcare on digital breast tomosynthesis.

<sup>1</sup>Advanced Medical Imaging Associates, Fort Collins, CO 80525

<sup>2</sup>University of Colorado—Denver, School of Medicine, Department of Radiology, 12700 E 19th Ave., Mail Stop C-278, Aurora, CO 80045. Address correspondence to R. E. Hendrick (edward.hendrick@gmail.com).

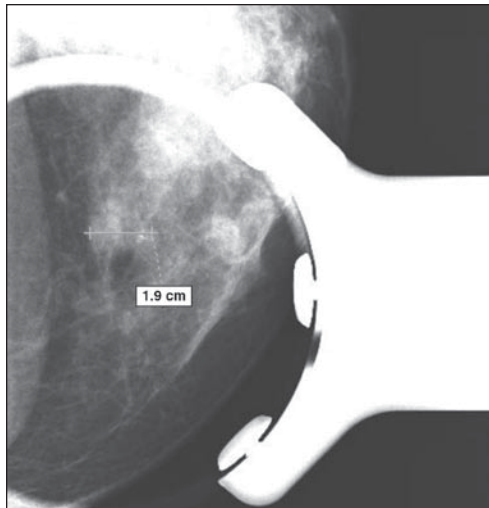
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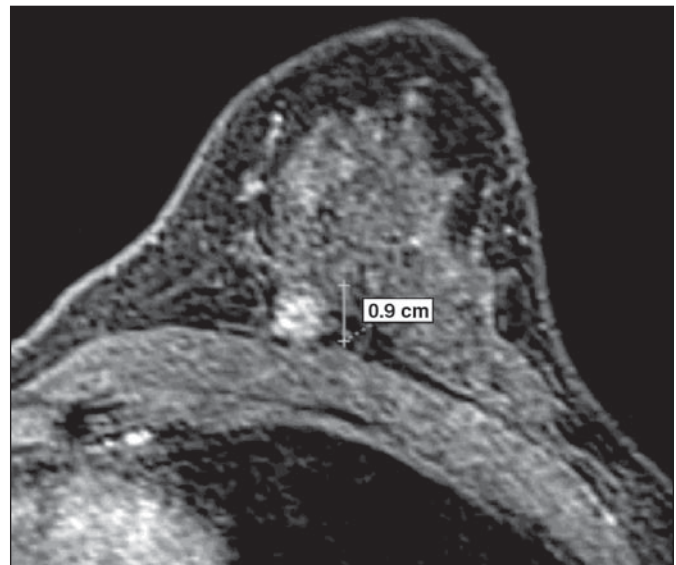
**Fig. 1**—Inaccurate lesion size measurement from magnification mammography in 40-year-old woman. **A**, Geometrically magnified digital image indicates lesion is 1.9 cm. Image was acquired on an Instrumentarium Performa mammography unit (GE Healthcare) with a Fuji CR image receptor (Clearview, Fujifilm USA). Images were displayed and lesion size was measured using Fuji PACS (Synapse, software version 3.2.1).

**B**, Ultrasound image of same lesion as that shown in **A** indicates lesion is approximately 1.0 cm.

**C**, Cropped contrast-enhanced 3D gradient-echo MR image of same lesion shown in **A** indicates size is approximately 0.9 cm.



B



C

and in each magnification mode at the acquisition systems available at each of three Mammography Quality Standards Act–approved mammography sites. These images were displayed on the review workstations used clinically with those acquisition systems at the three sites. Using the review workstation available to the radiologist at each site, we used electronic calipers to measure the size of the acrylic disk in each magnification mode.

**Results**

Phantom results for the clinical site with system X, as described earlier, are shown in Figure 2. In contact mode, the 1-cm acrylic disk measured 1.05 cm (Fig. 2A), whereas in 1.6× magnification mode, the 1-cm acrylic disk measured 1.64 cm (Fig. 2B).

Phantom results for a second clinical site using a different digital mammography sys-

tem (Senographe Essential, GE Healthcare) and different PACS (iSite [software version 3.6.51], Philips Healthcare), which we refer to as “system Y,” are shown in Figure 3. The 1-cm acrylic disk was measured as 0.99 cm in contact mode (Fig. 3A), 0.66 cm in 1.5× magnification mode (Fig. 3B), and 0.56 cm in 1.8× magnification mode (Fig. 3C).

The third site tested used another acquisition system (Selenia, Hologic) and PACS (Horizon Medical Imaging, McKesson) (system Z) and gave accurate measurements of approximately 1 cm for the acrylic disk in both contact and 1.6× magnification modes.

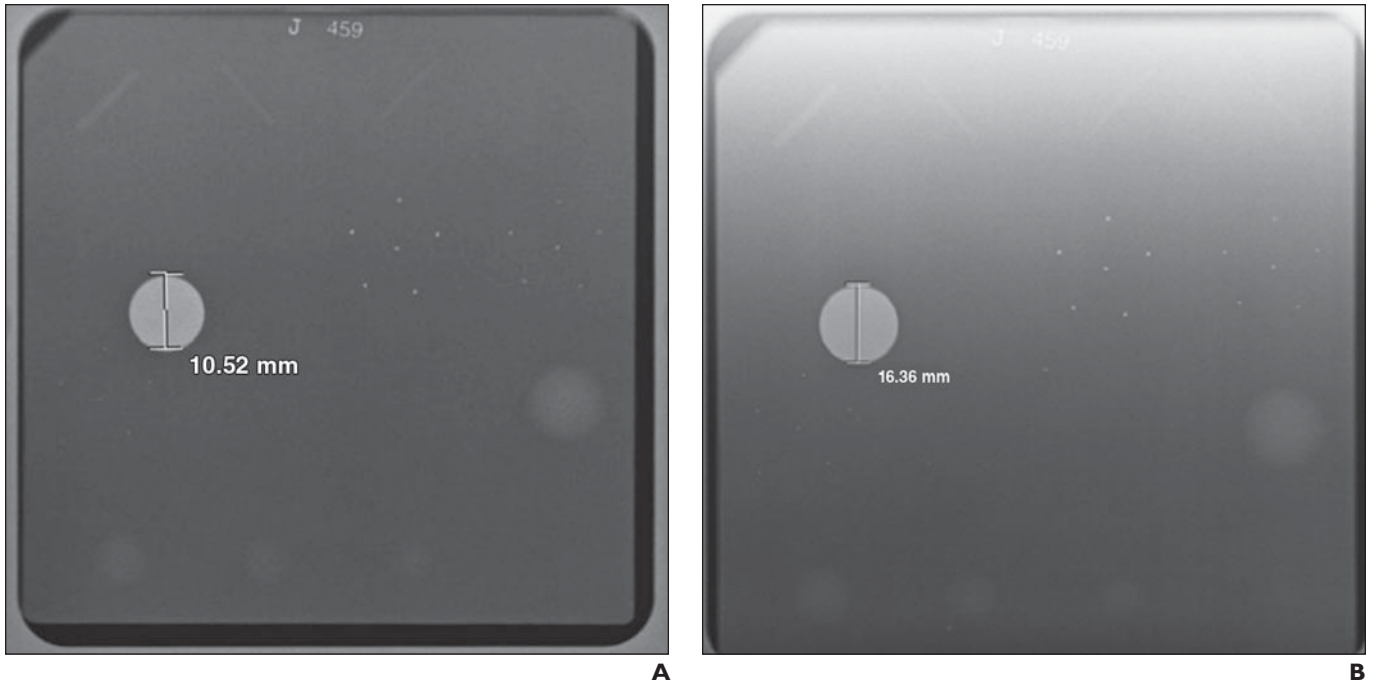
**Discussion**

Measuring lesion sizes accurately in mammographic images is important for correlation of mammography with adjunctive techniques,

such as ultrasound and breast MRI. Cancer size estimates are among the factors affecting the type of breast surgery and whether neoadjuvant therapy is appropriate. Inaccurate lesion size estimates have the potential to inappropriately affect treatment planning. Although lesion size can usually be measured in contact mode, in some cases, as in the clinical case described earlier, the lesion is adequately shown only on magnification images.

One reason that mammographically displayed lesions might appear somewhat larger than the same lesion displayed on breast ultrasound or MRI is that greater breast compression is used during mammography. Still, breast lesions, particularly invasive carcinomas and some benign lesions such as fibroadenomas, tend to be less compressible than other breast tissues [6]. Thus, greater com-

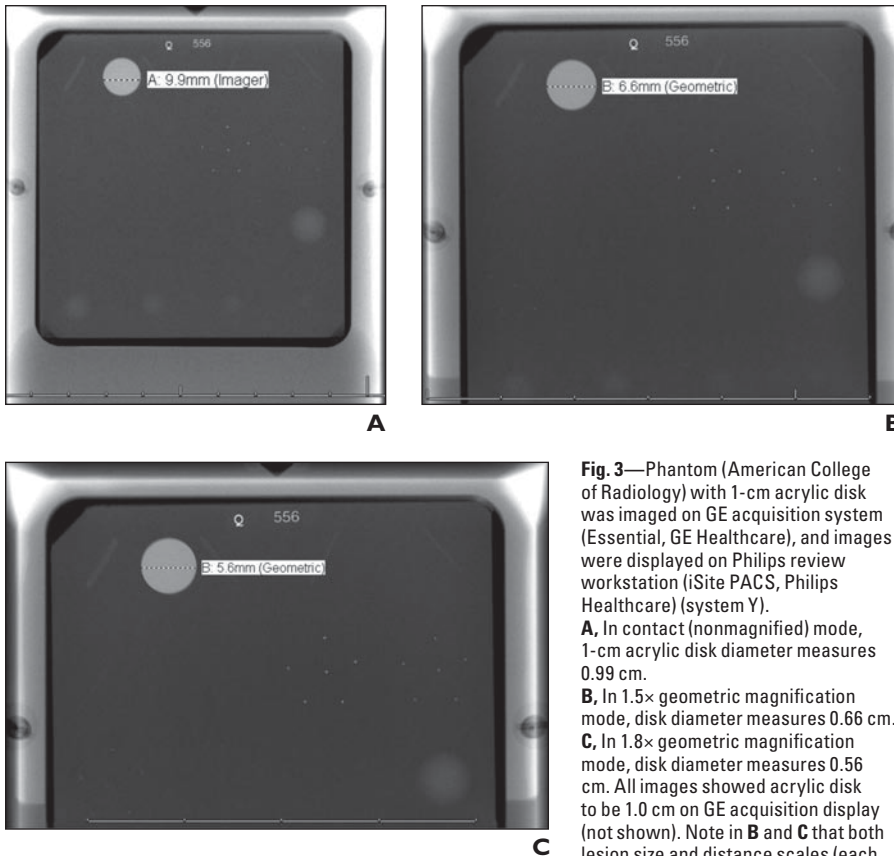
## Inaccuracies in Digital Mammography



**Fig. 2**—American College of Radiology phantom with 1-cm acrylic disk was imaged and measured using same acquisition–display system (system X) as in Figure 1.

**A**, Diameter of acrylic disk is measured to be 1.05 cm in contact (nonmagnified) image.

**B**, Acrylic disk is incorrectly measured to be 1.64 cm on 1.6× geometrically magnified image displayed on PACS.



**Fig. 3**—Phantom (American College of Radiology) with 1-cm acrylic disk was imaged on GE acquisition system (Essential, GE Healthcare), and images were displayed on Philips review workstation (iSite PACS, Philips Healthcare) (system Y).

**A**, In contact (nonmagnified) mode, 1-cm acrylic disk diameter measures 0.99 cm.

**B**, In 1.5× geometric magnification mode, disk diameter measures 0.66 cm.

**C**, In 1.8× geometric magnification mode, disk diameter measures 0.56 cm. All images showed acrylic disk to be 1.0 cm on GE acquisition display (not shown). Note in **B** and **C** that both lesion size and distance scales (each scale step is supposed to be 1 cm) are incorrectly displayed on PACS.

pression during mammography should not be responsible for the 60–100% error in lesion size found in our clinical example. Greater compression during mammography may explain why the lesion in our clinical example appeared 20–30% larger than it did with other techniques when the proper magnification factor was included ( $1.9 \text{ cm} / 1.6 = 1.2 \text{ cm}$ , compared with 1.0 cm on breast ultrasound and 0.9 cm on breast MRI) (Fig. 1).

Geometric magnification is a function peculiar to mammography and rarely occurs in most other PACS-displayed techniques. On the basis of our results, it cannot be assumed that PACS systems or third-party review workstations will necessarily display and measure lesion sizes correctly on magnified images even though they are FDA approved for primary interpretation of digital mammography.

In system X, the magnification mode information was not passed from the mammography acquisition system (the same type of acquisition system used for screen-film mammography) to the Fuji CR processor or PACS. Therefore, distances measured on geometrically magnified images were overestimated by a factor approximately equal to the magnification factor (1.6×). This problem occurred even though the CR processor and PACS display were provided by the same manufacturer.

In system Y, magnification factors were passed from the digital acquisition system to the PACS display system. As a result of software incompatibilities, however, the magnification factor was accounted for twice (once by each system), thus registering a smaller lesion size for higher magnification factors.

These two different examples (systems X and Y) show that lesion size display and measurement on geometrically magnified images cannot be assumed to be correct. These two systems further show that lesion sizes can be either markedly overestimated or underestimated on magnification images. For sites using several different PACS, third-party, or manufacturer-provided review workstations for mammography interpretation, distinctly different distance measurement results could occur for geometrically magnified images displayed on different review workstations.

Some variations in lesion size measurement occur even when magnification factors are passed correctly from acquisition to display systems. These variations can be caused by poorly defined lesion margins and slight additional geometric magnification of lesions, as a result of lesions' being located above the image receptor, breast support plane, or plane of distance calibration. These geometric magnification effects typically contribute maximum variations of less than 10% (6 cm displacement of a lesion from the plane of calibration in a 60-cm source-to-image receptor system). Other variations in lesion size measurement can occur because of operator variation using distance measurement tools, the fact that the lesion is not necessarily in a single plane parallel to the image receptor, and the blurring of the edges of lesions resulting from the penumbra caused by a finite-sized focal spot. These additional effects, however, should add only a few percentage points in lesion size variation. Altogether, these magnification and other measurement effects should cause variations of less than 10–15%, consid-

erably smaller than the 60–100% errors described in this situation, when system magnification factors were incorrectly passed from the digital mammography acquisition system to the display system.

One option for identifying lesion measurement errors inherent to the system would be to have a radiographically visible ruler included at the plane of the image receptor or compression paddle in every digital image, including magnification images. This option is not practical, however, for several reasons. The radiographically visible ruler has the potential to obscure breast tissue in some images (especially in magnification images where the field of view is small), to interfere with the automatic exposure control function on some systems because of its added attenuation, and to get "calibrated away" by the flat-field calibration procedure on most fixed-detector digital systems (e.g., GE, Hologic, and Siemens Healthcare digital systems). A better approach would be to include a distance measurement accuracy test using a phantom in the medical physicist portion of digital mammography QC, something not currently recommended by any digital system manufacturer.

Our results indicate that distance measurement accuracy should be tested in the contact mode and in each magnification mode for each digital acquisition–display system combination. This test should be performed by the medical physicist at acceptance testing of new digital mammography systems, new PACS systems, new PACS review workstations, or dedicated review workstations used for mammography and after changes in hardware or software for digital acquisition systems, PACS, or display systems. A distance measurement QC test should be considered for all digital mammography systems, including digital breast tomosynthesis, when it becomes available for clinical use. Sizeable inaccuracies in lesion size measurement revealed by phantom mea-

surements (> 10–15%) in any acquisition mode should be brought to the attention of both the facility and the lead interpreting physician.

## Conclusions

We show that some combinations of digital mammography acquisition and display systems can lead to clinically significant over- or underestimation of lesion size in magnification mode. This phenomenon can occur even with acquisition and display systems from the same manufacturer. Thus, the accuracy of lesion size in each magnification mode should be a routine QC acceptance test performed on each digital mammography acquisition–display system combination.

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