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Soft Copy versus Hard Copy Reading in Digital Mammography

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The objective of this study was to compare soft copy reading at a mammography work station with hard copy reading of full-field digital mammographic images. Mammograms of 60 patients (*n* = 29 malignant, *n* = 31 benign) performed with full-field digital mammography (Senographe 2000D, GE, Buc, France) were evaluated. Reading was performed based on hard copy prints (Scopix, Agfa, Leverkusen, Germany) and on 2 k × 2.5 k high-resolution monitors (Sun Ultra 60, Sun Microsystems, Palo Alto, California, USA). Four readers with different levels of experience in mammography categorized the mammograms according to the BI-RADS classification. The comparative study was performed by four readers, and at least 2 months elapsed between the reading sessions. Postprocessing, of course, was available only at the work station (windowing and leveling, zooming, inversion). Sensitivity, specificity, and positive predictive value were evaluated. Diagnostic accuracy of the evaluation was determined. Sensitivity for malignant lesions in hard copy versus soft copy reading was 97% vs 90%, 97% vs 97%, 93% vs 97%, and 76% vs 76% for the four readers, respectively. Specificity was 52% vs 68%, 58% vs 74%, 65% vs 48%, and 61% vs 68%. Accuracy for the classification of malignant lesions according to the BI-RADS categories showed no difference between hard copy and soft copy reading. Soft copy reading is possible with the available system and enables radiologists to use the advantages of a digital system.

KEY WORDS: Soft copy reading, hard copy reading, digital mammography

MAMMOGRAPHY REPRESENTS THE FIRST LINE of defense against breast cancers. It allows early detection and treatment that may lead to a reduction in mortality. Current guidelines recommend periodic mammography screening for women 40 years of age and older. Because of the large number of mammographics performed and the low yield of abnormalities detected in a screening setting, it is a tedious, difficult, and time-consuming task for most radiologists to detect an abnormality.[1-5] Hence, there is a growing interest in improving mammography. One promising development is the introduction of a digital imaging technique that might allow faster mammography interpretation from soft copy rather than printed film displays.[6]

Further potential for improving the diagnostic accuracy and efficiency of mammography lies in the application of direct full-field digital mammography (FFDM). The major advantages of digital mammography systems are improved handling, postprocessing, computer-assisted diagnosis (CAD), communication (teleradiology), and archiving of image information. However, these benefits are available only in a soft copy reading situation. With FFDM, the daily workflow in a mammography unit could be increased, which would be of major importance in a screening situation. However, soft copy reading has not yet been routinely employed in mammography.[7-16]

The aim of this study was to compare soft copy reading, using a work station of a com-

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Fig 1. Soft copy reading set-up. Two 2 k × 2.5 k monitors. Processor with 512 MB RAM.

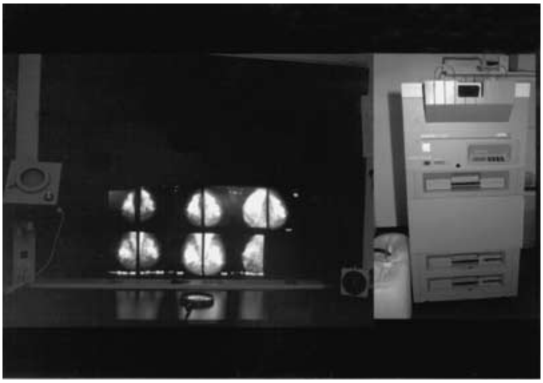

Fig 2. Hard copy reading set-up. Viewing box and laser imager (Scopix LR 5200, Agfa, Leverkusen, Germany).

mercially available full-field digital mammography system, with hard copy reading for the interpretation of mammograms.

MATERIALS AND METHODS

The study was performed using an FFDM system (Senographe 2000D, GE, Buc, France). The system has a dual track x-ray tube with a molybdenum and a rhodium anode track and a 0.03 mm molybdenum or a 0.025 mm rhodium filter. The digital detector is composed of a cesium iodide scintillator with an amorphous silicon detector. The matrix is 1900 × 2300 pixels with a pixel size of 100 μm. After exposure, the images are displayed on two high-resolution monitors (2 k × 2.5 k) that are part of the review work station (Sun Ultra 60, Sun Microsystems, Palo Alto, California, USA). This work station has two processors with 512 MB RAM (Fig 1). Images can also be printed on a high-resolution imager (Scopix LR 5200, Agfa, Leverkusen, Germany). The pixel size of the printer is 40 μm with a high resolution of 8820 × 10710 pixels for the 14 × 17 inch format. The modulation depth is 16 bit (Fig 2).

Mammograms of 60 patients (n = 29 malignant; n = 31 benign) performed on the Senographe 2000D were evaluated by four readers with different levels of experience in mammography and categorized according to the BI-RADS classification (category 1: no findings; category 2: benign; category 3: probably benign; category 4: suspicious for malignancy; category 5: highly suggestive for malignancy).[17] The tumor patients were enrolled from a screened population within the Oslo screening program. These cases were mixed and displayed in random order with "negative" mammograms of 31 women without cancerous lesions in a 2-year follow-up.

The radiologists were told to feel free to adjust window and level and to magnify each image interactively on the work station. Mammograms were interpreted in a darkened room for both the hard copy and soft copy readings. A minimum of 2 months elapsed between the two interpretation sessions. Sensitivity, specificity, and the positive predictive value (PPV) were evaluated. Diagnostic reliability was determined by investigating the deviation of BI-RADS steps from the best characterization for each case (best for benign = BI-RADS 2; best for malignant = BI-RADS 5). This means if the reader categorized a malignant lesion into BI-RADS class 3, the deviation steps are 2, because the best result for this lesion would be BI-RADS class 5. Category 3 lesions mean probably benign lesions with a probability of malignancy of about 3%. In a diagnostic setting, follow-up is recommended. In a screening setting a classification of a particular lesion as BI-RADS class 3 suggested further diagnostic work-up, as BI-RADS class 3 lesions are related to the malignant cases. Therefore the results are divided into two groups (diagnostic setting: classes 1-3 benign: classes 4-5 malignant; screening setting: classes 1-2 benign; classes 3-5 malignant).

RESULTS

Histopathology revealed 31 benign and 29 malignant lesions. Malignant lesions encompassed 8 ductal carcinoma in situ, 6 invasive lobular carcinoma (ILC), and 15 invasive ductal carcinoma (IDC). Tumor size varied between 9 mm and 55 mm (mean: 15 mm). Sensitivity, specificity, and PPV for the malignant lesions (BI-RADS classes 3-5) in the hard copy versus soft copy reading are presented in Table 1. The results were also evaluated for malignant lesions (BI-RADS classes 4-5) when BI-RADS class 3 were treated if they were benign cases (Table 2). Little or no difference in sensitivity was found with hard copy reading versus soft copy reading. Three of the four readers showed improved specificity and PPV with soft copy reading compared with hard copy reading.

Diagnostic accuracy of the classification of the malignant lesions according to the BI-RADS categories showed no difference between hard copy reading and soft copy reading. The devia-

Table 1. Sensitivity, Specificity, and PPV for Malignant Lesions Classified as BI-RADS Classes 3-5 in Soft Copy and Hard Copy Reading for the Four Readers

	Sensitivity (%)		Specificity (%)		PPV (%)	
Reader	Hard Copy	Soft Copy	Hard Copy	Soft Copy	Hard Copy	Soft Copy
1	97	90	52	68	65	70
2	97	97	58	74	68	78
3	93	97	65	48	71	64
4	76	76	61	68	65	69

Table 2. Sensitivity, Specificity, and PPV for Malignant Lesions Classified as BI-RADS Classes 4-5 in Soft Copy and Hard Copy Reading for the Four Readers

	Sensitivity (%)		Specificity (%)		PPV (%)	
Reader	Hard Copy	Soft Copy	Hard Copy	Soft Copy	Hard Copy	Soft Copy
1	93	85	71	87	77	85
2	76	79	87	97	85	96
3	83	83	97	90	96	89
4	69	69	77	87	74	83

Table 3. Deviation Steps of BI-RADS Classification from 5 of the 29 malignant cases in Soft Copy and Hard Copy Reading for the Four Readers

	Deviation Steps	
Reader	Hard Copy	Soft Copy
1	0.97	1.07
2	0.90	0.97
3	0.93	0.86
4	1.14	1.17

tion of the BI-RADS classification from the highest score of 5 for the 29 malignant cases is shown in Table 3. The average deviation is approximately 1 for both hard copy and soft copy reading, indicating a typical classification of 4. Figures 3 and 4 demonstrated two examples of the hard copy and soft copy reading cases.

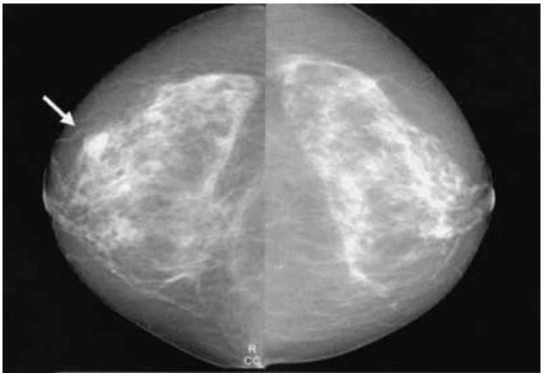

Fig 3. Example of a mammogram of a patient with a histologically proven tumor (IDC) that was classified by 1 of the 4 readers as benign in soft copy and hard copy reading. This reader seems to expect a cyst because of the round character of the mass. The other readers classified this case as malignant in both soft copy and hard copy reading (≥BI-RADS Class 3).

DISCUSSION

To introduce digital mammography into the screening program, systems must enable radiologists to read digital mammograms on a display device with the same efficacy and quality achieved in the film-reading process.[9,18,19]

Our results indicate that evaluation of mammograms could be performed with the two high-resolution monitors of the Senographe 2000D work station easily and accurately. The system provides quick access to postprocessing, which is used intraindividually. Personal habits and experience influence the preference of radiologists for hard copy or soft copy reading. In particular, the reader with up to 30 years of experience in screen-film mammography preferred the hard copy format. However, sensitivity showed no relevant differences between the two modalities. There appear to be differences in specificity and PPV for three out of

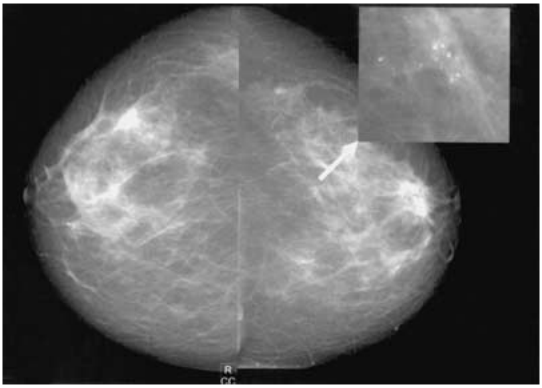

Fig 4. Example of a mammogram of a patient with a cluster of amorph microcalcifications that were detected by all readers with all modalities and classified into a BI-RADS category higher than 3. Histology revealed ductal carcinoma in situ (DCIS).

four readers who prefer soft copy reading. However, these differences seem to be based on interindividual differences in preference for soft copy or hard copy reading of mammograms. Further studies with more patient data should be performed.

In a pilot project of Nijmegen, software called MammoTrainer was successfully employed for mentor-guided training and self-training of radiologists in an electronic classroom. Self-training on a PC could be useful preparation for the transition to a professional soft copy reading station for digital mammography.[20] In addition, the SCREEN project conducted in the Netherlands revealed that soft copy screening performance was as good as conventional reading, in terms of both detection and reading speed.[21]

Further studies will be needed to evaluate the potential benefits for a screening population of the tools available in soft copy reading (e.g., windowing and leveling, zooming, inversion, computer-assisted diagnosis).

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