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The Diagnostic Accuracy of Digitized Mammography

Background/Objective: Digitized mammography has several advantages over screen-film radiography in data storage and retrieval, making it a useful alternative to screen-film mammography in screening programs. The purpose of this study was to determine the diagnostic accuracy of digitized mammography in detecting breast cancer.

Patients and Methods: 185 women (845 Images) were digitized at 600 dpi. All images were reviewed by an expert radiologist. The mammograms were scored on a scale of breast imaging reporting and data system (BIRADS). The definite diagnosis was made either on the pathologic results of breast biopsy, or upon the follow-up of at least one year. The overall diagnostic accuracy of digitized mammography was calculated by the area under receiver operating characteristic curve.

Results: 242 sets of mammograms had no lesions. The total counts of masses, microcalcifications or both in one breast were 39 (11%), 42 (12%), and 25 (7%), respectively. There were 321 (92%) benign and 27 (8%) definite malignant lesions. The diagnostic accuracy of digitized images was 96.34% (95% CI: 94%–98%).

Conclusion: The diagnostic accuracy of digitized mammography is comparably good or even better than the published results. The digitized mammography is a good substitute modality for screen-film mammography in screening programs.

Keywords: Breast Neoplasms, Digitized Mammography, Receiver Operating Characteristic Curve Analysis

Introduction

Breast cancer is one of the most significant health concerns in the world.[1] It is the most commonly diagnosed cancer in women and the first leading cause of cancer death in Iranian women.[2,3] Mammography is the established method for detection of non-palpable breast cancer at an early preclinical stage in asymptomatic women, and it has high sensitivity and sufficient specificity to be used in screening programs.[4] There is now general agreement that screening mammography reduces the rate of death from breast cancer among women aged 40 years or older.[5,6] Meta-analyses of eight large, randomized trials found a reduction in the mortality rate from 16% to 35% among women aged 50–69 years who were assigned to screening mammography. For women aged 40–49 years at entry, the mortality rate has a smaller but significant reduction of 15%–20%.[5-7]

The smaller benefit of screening in younger women is probably due to a lower incidence of breast cancer, more rapidly growing tumors, and greater radiographic density of breast tissue in women <50 years of age.[8] Greater density reduces the sensitivity of mammography[9,10] and increases the risk of breast cancer.[11-13] The positive predictive value of mammography is higher in women with a family history of breast cancer.[14]

Digital mammography, which was developed in part to address some of the limitations of film mammography,[15] separates image acquisition and display, allowing the optimization of both. Image processing of digital data allows the degree of contrast in the image to be manipulated, so that the contrast

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can be increased in the dense areas of the breast with the lowest contrast.[16-17]

However, digital mammography systems are very expensive and digitized mammograms are a good substitute for this purpose. Thereby, you can make a database from digitized mammograms, have easy access to and manipulate them, and use computer-aided detection (CAD) software in detecting lesions in mammograms. However, the diagnostic accuracy of digitized mammography of local database has not been assessed in Iran yet.

Breast imaging reporting and data system (BIRADS) is a reporting system introduced by the American college of radiology (ACR) for standardizing mammography reports. It has seven categories (0-6) of which zero means "requiring additional assessments" and the score of six is used when there is a known diagnosis of breast cancer before the mammography. Based on a mammogram's BIRADS category, the gold standard for diagnosis is different. Routine and short follow-up are the next steps to be performed for those with BIRADS scores two and three, respectively. Biopsy (fine needle biopsy or excisional biopsy) is the diagnostic test of choice for BIRADS scores four and five (Table 1).[18,19]

In this study, using ROC analysis, we assessed the diagnostic accuracy of digitized mammography for detection of breast cancer using the ACR recommendations.

Patients and Methods

One hundred and eighty-five women who attended our center for screening mammography were included in the study. We omitted patients with a history of breast cancer. All images were digitized in the medical imaging research center of Imam Khomeini hospital. The scanner device was ScanMaker 9800XL manufactured by MICROTEK company. The resolution, grayscale depth, color mode, and type of images were 600 dpi, 16 bit, gray scale, and TIFF, respectively. Left and right breast images were viewed on two 21-inch, 3 M-pixel WIDE monitors (Fig. 1). Window and level, zoom, pan, gray-scale inversion, rotation, flip vertically or horizontally capabilities were the digital manipulations allowed during clinical review of the images.

Digitized images were interpreted by a radiologist and classified into BIRADS categories (Table 1). Each breast of a woman has its own characteristics, so we assessed them separately. Those with BIRADS score 4 were heterogeneous, and therefore we divided this group to subgroups of a, b, and c based on the radiologist's opinion about the probability of the malignancy.[20] According to BIRADS categories, appropriate workups or follow-up were done. A BIRADS score of 0 indicated incomplete data and further evaluation was performed to reach a final diagnosis. For those with BIRADS scores 2-5, presence or absence of any lesions (mass, microcalcification, related findings) was also recorded. Workup, including a biopsy or aspiration of the suspicious lesion was performed according to the radiologist's recommendation.

To establish a reference standard, participants were considered positive for cancer if the breast cancer was pathologically confirmed within 365 days after the

Table 1. Breast Imaging Reporting and Data System Assessment Categories Used in the United States for Mammography Examinations

Assessment Category	Assessment	Definition
0	Needs additional imaging evaluation	A lesion is noted for which additional imaging evaluation is needed; used almost always in a screening situation
1	Negative	Breast appears normal
2	Benign finding	A negative mammogram result, but the interpreter wishes to describe a finding
3	Probably benign finding: short-interval follow-up suggested	Lesion with a high probability of being benign noted on mammogram
4	Suspicious abnormality- biopsy should be considered	A lesion is noted for which the radiologist has sufficient concern to recommend at biopsy
5	Highly suggestive of malignancy; appropriate action should be taken	A lesion is noted that has a high probability of being cancer
6	Known Biopsy proven malignancy	A lesion is noted that is definitely malignant

Fig. 1. The workstation and two 21", 3 M-pixel mammography medical monitors used in this study.

initial mammography. Participants were considered negative for cancer if they were not considered positive and if they were found negative on follow-up mammography and/or subsequent workups.

ROC analysis was used to assess the diagnostic accuracy of digitized mammography. An effective method of analyzing the performance of diagnostic tests is receiver operating characteristic (ROC) curve analysis, which is a plot of test sensitivity (the y axis) *vs* 1-specificity or false positive rate (the x axis).[21] The area under the ROC curve (AUC) is a general measurement of the diagnostic accuracy of the test. ROC analysis for the mammography was performed using Stata/SE 8.0 for Windows® (Texas, USA).

Results

One hundred and eighty-five women with 845 unilateral screening mammograms were included in this study. Images were digitized from year 2005 to 2007. The mean age of the participants was 44 (range: 31-80) years. Two-hundred and forty-two sets of mammograms had no lesion. The overall number of masses, microcalcifications, and both (mass+microcalcification) in one breast were 39 (37%), 42 (40%), and 25 (24%), respectively. Considering previous mastectomies, 22 patients had one breast (unilateral mammogram). In other words, we had no breast data either in the right or left side in 22

Table 2. Mammograms Classification Based on BIRADS Categories. Nine and 13 patients had no left and right breast, respectively

BIRADS	Left Breast		Right Breast		Total	
1	123		119		242	
2	23		19		42	
3	11		14		25	
4a	4	12	1	9	5	21
4b	6		3		9	
4c	2		5		7	
5	7		11		18	
Total	176		172		348	

patients. Thus, 348 sets of right and left mammograms were assessed according to the BIRADS score.

The results of BIRADS categorization of our mammograms are shown in Table 2. High numbers of BIRADS categories 1 and 2 in comparison to the suspicious results was attributed to the high number of screening cases. We had 321 (92%) out of 348 patients who came out to have benign lesions. Twenty-seven (8%) out of 348 patients had malignant pathologies confirmed by histopathologic studies.

Table 3 shows the distribution of lesion types in patients with different BIRADS scores.

Table 4 shows the relation between the type of lesion (mass, microcalcification or both in one breast) and their final diagnosis. One malignancy in a patient with BIRADS 3 had microcalcification. Two malignant lesions in patients with BIRADS 4a score had both lesions (mass+microcalcification) in one breast. One mass and one microcalcification and two with mass+microcalcification in one breast were found malignant in patients with BIRADS 4b score. One microcalcification and one mass+microcalcification were malignant and found in patients with BIRADS 4c score.

We had no cancer in patients with BIRADS 1 or 2 scores. From the BIRADS 3, 4, and 5 categories (total 67), we had 27 cancers diagnosed (Table 5).

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Table 3 Type of Lesions in Different BIRADS Categories

BIRADS / Lesion Type	1	2	3	4a	4b	4c	5	Total
No Lesion	242	0	0	0	0	0	0	242
Mass	0	10	12	3	5	1	8	39
Microcalcification	0	28	7	0	1	4	2	42
Both in one breast	0	4	6	2	3	2	8	25
Total	242	42	25	5	9	7	18	348

Table 4. Relation Between Type of the Lesion and the Final Diagnosis

Definite Diagnosis \ Lesion	Mass (%)	Microcalcification (%)	Mass + Microcalcification in One Breast (%)	Total (%)
Benign	30 (77)	37 (88)	12 (48)	79 (75)
Malignant	9 (23)	5 (12)	13 (52)	27 (25)
Total	39	42	25	106

(area under the ROC curve) was 96.34% (95% CI: 94%–98%) (Fig. 2).

Discussion

Photostimulabe phosphorus computed radiography (CR) was the first digital imaging system used for mammography. Developed in the early 1980's, CR is in widespread use for general radiography, but systems are also available for mammography. The next generations of digital mammography systems were based on charge couple device (CCD) technology, amorphous silicon based technology, and amorphous selenium-based technology.

The main advantage of any digital imaging system is the separation of image acquisition, processing, displaying, and allowing optimization of each of these steps. It is hoped that this will enable digital mammography to outperform its screen film counterpart. In addition, advanced applications such as computer-assisted detection/diagnosis (CAD), picture archiving and communication systems (PACS) and teleradiology, digital tomosynthesis and contrast digital mammography can be easily applied to the digital mammogram to assist an image interpretation.[22]

Image quality of digital mammography seems at least equivalent to screen film mammography (SFM). Soft-copy and hard-copy reading are equivalent in the interpretation of digital mammograms. Full field digital mammography (FFDM) seems at least equivalent to SFM in the detection and characterization of masses and microcalcifications. The potential of dose reduction with FFDM as compared to SFM, ranges from 30% to 50%. CAD is a helpful tool in the detection of early stage malignancies.[23]

Using viewer tools like changing the contrast or brightness of the image, magnifying glass with significant magnifying without resolution loss, gray-scale inversion of the image is particularly helpful when assessing microcalcifications and also introducing a digital environment to the radiologist before common use of digital images are the two main advantages of digitized mammography for radiologists.

The main disadvantage of digital mammography is the initial cost of the system and the discrepancy between this cost and the current rate of reimbursement. We can use digitized mammography to compensate this defect because of its lower expenses compared to digital mammography systems, which eliminates healthcare costs.

It must be reminded that the spatial resolution of digital mammography is lower than conventional mammography, but other capabilities like wider dynamic range and viewer tools would compensate this defect. However, in our study, we scanned the screen-film mammograms at 600 dpi which was equal to 40 μm of spatial resolution; it seems that at this resolution, there is no loss of image quality. It must also be reminded that digitizing mammography are very cheaper than digital mammography. For example, a digital mammography unit costs about US$ 400,000 to 500,000, while a professional scanner for digitizing images will cost about US$ 4,000 to 5,000. Because of many advantages of digitized mammography, while the costs of digital systems are not provided, it could be a good replacement modality for

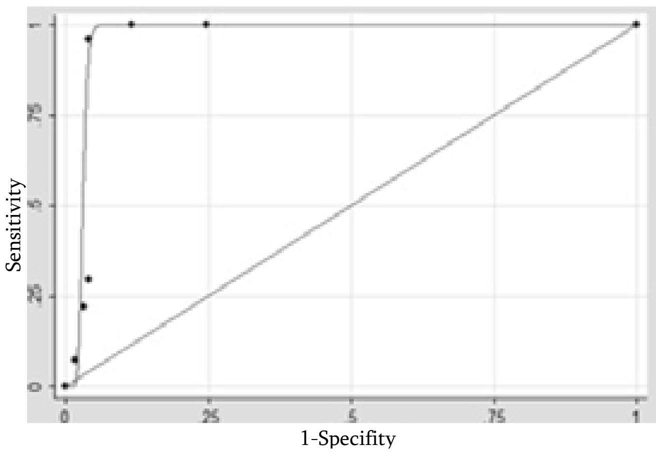

Fig. 2. ROC curve of digitized mammograms. Area under the ROC curve or diagnostic accuracy of digitized mammograms is 96.34%.

Table 5. Correlation Between Mammographic BIRADS Scores and the Definite Diagnosis

BIRADS / Definite Diagnosis	1	2	3	4a	4b	4c	5	Total
Benign	242	42	24	3	5	5	0	321
Malignant	0	0	1	2	4	2	18	27
Total	242	42	25	5	9	7	18	348

digital mammography systems.

One method used to define the accuracy of an imaging system is to evaluate the system's sensitivity and specificity. Sensitivity, also called true positive fraction (TPF), is the probability of diagnosing the presence of disease when it is actually present. Specificity, also called true negative fraction (TNF) is the probability of identifying the absence of disease when it is not present. A graphical representation of these factors is used to construct the ROC curve.[24] Sensitivity and specificity depends on the cut-off point used to define positive and negative test results. As the cut-off point shifts, the sensitivity increases while the specificity decreases and *vice versa*.[25] ROC analysis is a good method to assess the diagnostic accuracy of devices.

We published the ROC analysis results based on BIRADS scores which the radiologists are familiar with. By this classification, we have six cut-off points between BIRADS 1 and 5. The higher the BIRADS score, the higher the risk of malignancy is. However, the definite diagnosis of the mammography was defined by follow-up or biopsy according to the BIRADS classification.

In numerous studies about digital mammography,[4,26-29] the AUC ranged from 0.74–0.91 while AUC of screen-film mammography ranged from 0.71–0.88. The difference between digital and conventional mammography was not statistically significant in these studies. However, the accuracy of digital mammography was significantly higher than that of film mammography among women under the age of 50 years, women with heterogeneously dense or extremely dense breasts on mammography, and premenopausal women.[28]

Powell, et al,[30] used 60 sets of mammograms in their study which were digitized at spatial resolution of 100 μm. The observer's mean diagnostic accuracies using films and digitized images were 87.2% and 84.8%, respectively. The difference was not significant. The diagnostic accuracy or AUC of digitized mammography was 96.34% in our study. We used digitized images at spatial resolution of 40 μm (600 dpi). We did not reduce the quality of images and the radiologist could manipulate images by viewer tools. We believe that the reason of the difference between our study and Powell's study was the different spatial resolution, monitor qualities, and manipulation tools which we used.

In 600 dpi scanning with 16 bit gray scale, each image size was 45 megabytes. To reduce the image size without reduction of the image quality, lower scanning resolution is suggested. We recommend other radiologists to use the images of our database to produce another ROC analysis and compare them with each other. We also recommend other radiologists to compare the digitized mammograms of this study with the conventional mammographies because of the native properties of this database.

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