

An Investigation of the Effects of Mammographic Acquisition Parameters on a Semiautomated Quantitative Measure of Breast Cancer Risk

Nicholas J. Hangiandreou, Carol J. Mount, Kathy R. Brandt, Jeffrey P. Quam, Armando Manduca, Celine M. Vachon, and Thomas A. Sellers

The aim of this work was to investigate the effect of mammographic acquisition parameter variations on the estimation of percent density (PD) produced by a particular semiautomated algorithm. The PD algorithm requires the user to specify a threshold pixel value segmenting breast tissue of greater and lesser density. A whole breast specimen was imaged using a variety of acquisition techniques, and the image data were processed as prescribed by the PD algorithm. PD estimates for all possible values of the user threshold were calculated for all the images. The image data were normalized so that PD varied between 30% and 80% over a fixed threshold range of 23, and a PD value of 50% was obtained for a threshold value of 195. PD differences between all the images and a baseline standard mammographic acquisition technique were calculated. We also estimated PD differences caused by small (3%) variations in operator selection of the threshold value. We found that the largest differences in PD involved changes in the density control of the mammography unit, and changes in the detector (either film type or computed radiography). The maximum PD differences due to technique were all less than 10%, with root-mean-square (RMS) variations less than 4%. PD differences due to operator variation were 24% (maximum) and 6.1% (RMS). These findings suggest that PD differences due to mammographic technique will be considerably less than those inherent to the technique, due to operator variation. All of these estimates are likely larger than differences seen in practice since optimization of the threshold by the operator was not considered in this analysis.

Copyright © 2000 by W.B. Saunders Company

ANALYSIS OF THE RELATIVE density of breast tissue in mammograms has been shown to correlate with the risk of developing breast cancer.¹⁻³ Computer-based methods have been developed in order to reduce operator dependence when deriving risk parameters from mammograms.^{4,5} In many potential applications, the acqui-

sition parameters employed during mammography may vary widely (eg, between imaging sites, and over time). This work attempted to measure the amount of variation in one computer-based risk parameter induced by variations in mammographic image acquisition technique.

METHODS

We are using a variation of the semiautomated technique for computing the percentage of mammographically dense breast tissue previously reported by Boyd, Byng, and others.^{4,5} In this technique, a standard screen-film mammogram is obtained and digitized, producing a Digital Imaging and Communications in Medicine (DICOM) format image file. This high-resolution 12-bit file is then decimated to an approximately 675 × 925 pixel matrix, reduced to 8 bits (mapping the full observed range of original image pixels), and written to a bitmap format file. The image is cropped to remove bright pixels caused by positioning markers and identification tags, and image regions corresponding to the pectoral muscle are excluded. The final bitmap format image is then displayed by a custom computer application, and a viewer interactively sets a threshold dividing the dense from the less dense pixels of the breast. The percentage of mammographically dense pixels (denoted percent

Table 1. Summary of Image Acquisition Parameters

Acquisition No.	Description of Mammographic Technique
1	Mayo Standard Acquisition (MSA): Kodak min R 2000, mammographic processing, density = 0, 25 kVp, moly-moly, ~30-35 lb compression force
2	MSA, but rapid mammographic processing
3	MSA, but general radiographic processing
4	MSA, but density = -2
5	MSA, but general radiographic processing and density = -2
6	MSA: but Kodak min R M
7	MSA: but Kodak min R M, and rapid mammographic processing
8	MSA: but Kodak min R M, and general radiographic processing
9	MSA: but Kodak min R M, and density = -2
10	MSA: but Kodak min R M, general radiographic processing and density = -2
11	MSA, but 29 kVp
12	MSA, but ~10 lb compression force
13	Computed radiography
14-16	Repeat MSA, after initially repositioning and recompressing

From the Departments of Diagnostic Radiology and Epidemiology, Mayo Clinic and Foundation, Rochester, MN.

Address reprint requests to Nicholas J. Hangiandreou, PhD, Department of Diagnostic Radiology, Mayo Clinic-Rochester, 200 First St SW, East 2, Rochester, MN 55905. E-mail: hangandreou@mayo.edu.

Copyright © 2000 by W.B. Saunders Company

0897-1889/00/1302-1045\$10.00/0

doi:10.1053/jdim.2000.6875

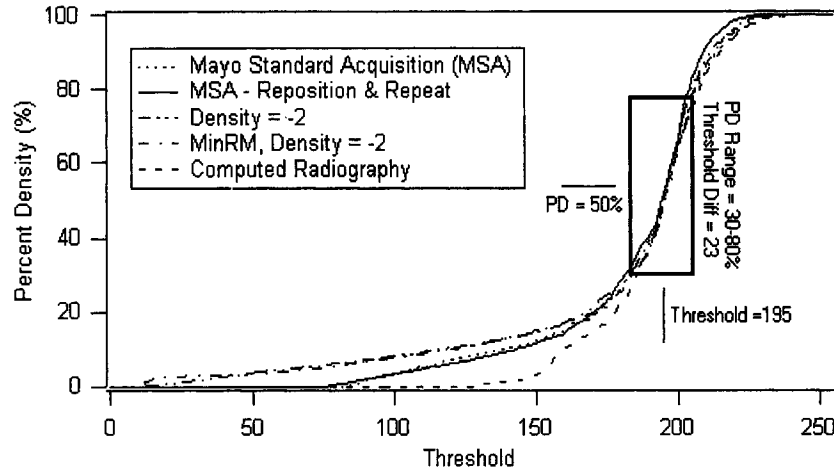


Fig 1. Plot of PD versus threshold value for acquisitions 1, 4, 9, 13, and 14. The window normalization of the data is also illustrated.

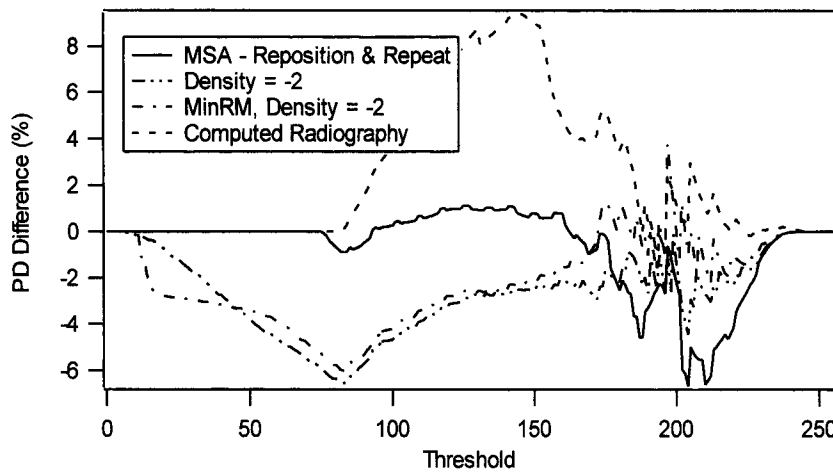


Fig 2. Plot of PD difference (as compared to acquisition 1, the Mayo Standard) versus threshold value for acquisitions 4, 9, 13, and 14.

density [PD]) is then computed by the application based on this threshold.

We obtained a whole breast specimen (including the pectoral muscle) from a cadaver, and obtained images using the standard mammographic technique used in our practice (Mayo Standard Acquisition [MSA]), as well as a variety of other acquisition techniques representative of those that might have been used clinically over the past few years. We also repeated the MSA, both with and without repositioning and recompressing the breast specimen. Image collection is summarized in Table 1. We submitted all of the images to the standard processing described

above to produce bitmap files, and then plotted the PD parameter as a function of all possible threshold choices (ranging from 0 up to 255). The bitmap image pixel values were normalized by adjusting window width and level so that PD varied between 30% and 80% over a threshold range of 23, and a PD of 50% was obtained for a threshold value of 195. PD differences between the MSA and the other PD curves were calculated versus threshold, along with maximum and root-mean-square (RMS) values. The difference analysis was also performed with a shifted version of the Mayo Standard PD curve in an attempt to simulate small (~3%) variations in observer selection of the threshold value.

Table 2. Maximum and Root-Mean-Square (RMS) Differences in the PD Parameter as Compared to the Mayo Standard Acquisition Technique

Acquisition No.	PD Difference (%)	
	Maximum	RMS
4	6.5	3.2
9	6.0	2.8
13	9.4	3.9
14	6.7	1.8
MSA, no reposition	3.0	0.1
Estimated operator variation	24.0	6.1

RESULTS

The three variable-technique acquisitions that resulted in the largest differences as compared to the MSA were numbers 4, 9, and 13. These cases, along with acquisition 14 in which the MSA was repeated following repositioning and recompression, are shown Figs 1 and 2. Table 2 summarizes the PD difference values for these cases. We also found that simulated approximately 3% variations in threshold value selection induced maximum and

RMS PD differences of 24.0% and 6.1%, respectively. Repeating the MSA without repositioning and recompression induced maximum and RMS PD differences of 3.0% and 0.1%, respectively.

DISCUSSION AND CONCLUSIONS

PD differences caused by variations in screen-film mammographic technique (acquisitions 4 and 9) were found to be similar to those caused by repositioning and recompression (acquisition 14), which are intrinsic to the PD technique. These maximum and RMS differences are less than 10% and 5%, respectively. The data obtained with computed radiography (acquisition 13) showed greater PD differences. These PD differences were all smaller than those estimated due to variability in determination of the particular threshold value by the operator. This suggests that PD

differences due to variations in screen-film mammographic technique will be smaller than or comparable to variations inherent to the current semiautomated PD method. The maximum and RMS differences computed in this work likely overestimate the amount of PD variation seen in practice (especially the estimations of operator-induced variation), since we did not consider image-specific optimization of particular threshold values set by the operator. These findings should be considered to be preliminary until they can be repeated with additional breast specimens. The normalization of the PD (and image) data windows performed as part of the current study should improve the efficiency of the operator's interaction with the PD calculation program, and should be included as part of the standard PD measurement protocol in the future.

REFERENCES

1. Wolf JN, Saftlas AF, Salane M: Mammographic parenchymal patterns and quantitative evaluation of mammographic densities: A case-controlled study. *Am J Roentgenol* 148:1087-1092, 1987
2. Brisson J, Verrault R, Morrison A, et al: Diet, mammographic features of breast tissue and breast cancer risk. *Am J Epidemiol* 130:14-24, 1989
3. Saftlas AF, Hoover RN, Brinton LA, et al: Mammographic densities and risk of breast cancer. *Cancer* 67:2833-2838, 1991
4. Byng JW, Boyd NF, Fishell E, et al: The quantitative analysis of mammographic densities. *Phys Med Biol* 39:1629-1638, 1994
5. Boyd NF, Byng JW, Jong RA, et al: Quantitative classification of mammographic densities and breast cancer risk: Results from the Canadian National Breast Screening Study. *J Natl Cancer Inst* 87:670-675, 1995