An Introduction to Breast Specific Gamma Imaging

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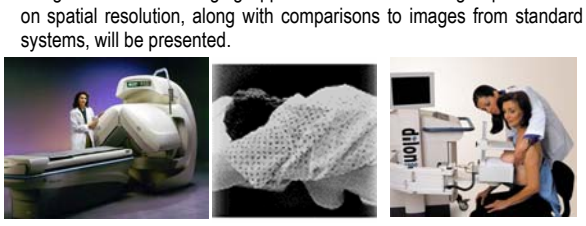
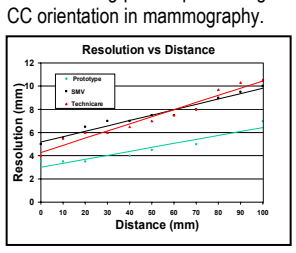
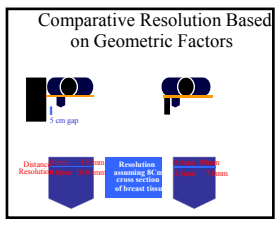
INTRODUCTION

Scintimammography performed with standard full field-of-view nuclear medicine systems has been studied and has been found to lack sensitivity for lesions under one centimeter and medially located lesions. These shortcomings indicate a poor study resolution and poor maneuverability of the system. More specifically, the prone pendant breast positioning does not allow the breast to be imaged directly against the collimator and, since spatial resolution decreases with an increase of target-to-collimator distance, poor study resolution is achieved with this configuration. In addition, since the only practical detector position for these large systems is the lateral view, medially located lesions suffer from even poorer resolution. In many regards, this imaging configuration resembles the early days of x-ray mammography when general-purpose systems were used with noticeably poor results as compared to dedicated mammography systems such as those used clinically today. To address this issue, several groups have embarked on the development of dedicated small field-of-view gamma cameras designed for breast imaging applications. The resulting improvements on spatial resolution, along with comparisons to images from standard systems, will be presented.



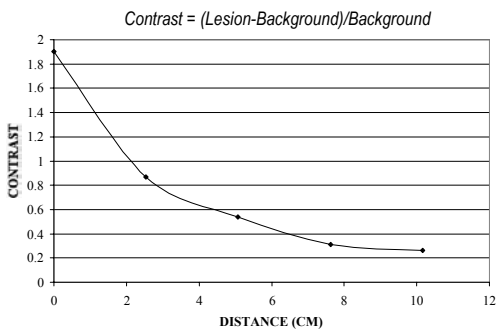
The photographs above demonstrate the positioning improvements available with dedicated breast imaging gamma cameras. The left image illustrates the standard nuclear medicine Camera. The prone breast pendant positioning required for standard imaging is shown in the center image. Compare these to the dedicated breast imaging system demonstrating patient positioning for the inferior view comparable to the CC orientation in mammography.





The left graph above demonstrates the relationship between collimator-to-object distance and spatial resolution for standard camera systems (red and black) and for the dedicated system (green). For this comparison, all systems were equipped with high resolution collimators. The diagram on the right demonstrates the impact of minimizing the object-to-collimator distance for breast imaging. By simply moving the detector closer to the breast, study resolution is significantly improved.

Another factor in the visibility of focal uptake is its depth in tissue. As depth is increased, attenuation of the gamma rays in the breast tissue increases. The graph below demonstrates lesion contrast as a function of depth for a 1cm diameter spherical lesion phantom in a 10cm thick water filled breast phantom with a 6:1 lesion-to-breast tracer concentration ratio. Note the rapid reduction in contrast as a function of lesion depth. This graph demonstrates why standard cameras positioned at the lateral aspect of the breast have poor sensitivity for medially located lesions. Dedicated detector systems allow imaging of the breast from any angle, including the medial aspect, thereby minimizing the lesion-to-detector distance.



THE STUDY

Results from four medical centers using three different dedicated breast gamma imaging devices will be presented. In order to provide a historical baseline for image contrast enhancement, two of these studies conducted comparative studies on standard nuclear medicine cameras. Three patient cases will be presented, one from each of the camera prototypes, along with the images from the standard camera. The lesion contrast for all images is calculated and, for each patient, the contrast enhancement resulting from the dedicated system is compared to the standard gamma camera image.

STUDY 1 CASE 1

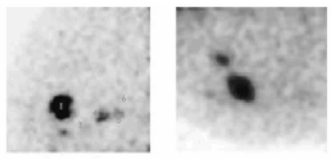
The first generation Jefferson Lab/Dilon dedicated breast gamma camera study was conducted at Johns Hopkins Medical Center. The prototype detector consisted of a 5 x 5 inch field-of-view. The results for 58 patients were published by Brem, et al. Images courtesy of Dr. Rachel Brem.

The first generation 5 x 5 prototype

Mammogram demonstrates a 2 cm. lobulated mass with 5 adjacent masses measuring between 0.7 and 1.5 cm. MLO mammogram demonstrates the 6 masses.

Gamma Camera Images

Scintimammogram with three enhancing foci, the largest with a contrast of 2.3.



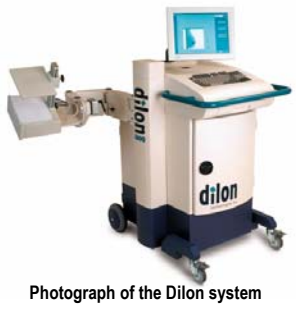
Dedicated camera lateral image (left) noting 6 foci corresponding to those noted in the x-ray mammogram above. The largest foci presented with a contrast of 5.1 in the lateral (MLO) view and 1.5 in the inferior (CC) image.

PATHOLOGY
Demonstrated 6 foci of infiltrating carcinoma corresponding to the masses demonstrated mammographically. At the pathologic evaluation, the smallest lesion measured 4 mm.

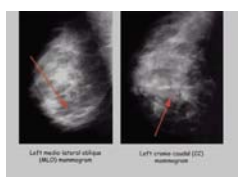
COMMENTS
The limits of traditional gamma camera resolution could not discriminate the 6 foci of carcinoma. The improved resolution of the dedicated camera demonstrated all the foci, including 1 focus measuring 4 mm. The standard camera demonstrates a contrast (SCC) of 2.3 for the largest lesion. Using the dedicated breast imaging camera, contrast (DCC) increases to 5.1. The resulting contrast enhancement is represented by a percentage from the following equation: (DCC-SCC)/SCC*100, in this case, 122%.

STUDY 2 CASE 2

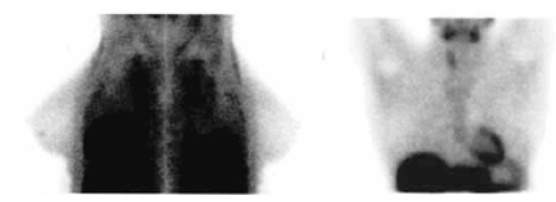
The Dilon Technologies dedicated breast gamma camera study was conducted at George Washington Medical Center. The detector for this system consisted of a 6 x 8 inch field-of-view. The results for 94 patients were published by Brem, et al. Images courtesy of Dr. Rachel Brem.



Photograph of the Dilon system

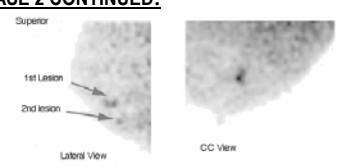


Mammogram demonstrates suspicious microcalcifications in the lower inner quadrant of the left breast.



Scintimammogram: Lateral scintimammogram (left) demonstrates focal uptake in the lower portion of the left breast. Note that a single focus of increased radiotracer uptake is present. Contrast = 0.67 Localization of lesion in the anterior view (right) is not possible due to limitations of the traditional gamma camera.

STUDY 2 CASE 2 CONTINUED:



Dedicated camera: the lateral image indicated two separate lesions. The superior lesion is larger with a contrast of 1.8 and the smaller inferior lesion demonstrates a contrast of 1.0. These foci appear to be superimposed in the CC view with significant contrast.

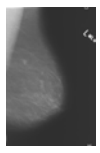
PATHOLOGY: Demonstrates a 1 cm in-situ and infiltrating duct carcinoma, nuclear grade II/III. The in-situ component compromised 90% of the tumor mass. A second focus of in-situ carcinoma was found separate and inferior to the main tumor mass.

COMMENTS: A single focus of radiotracer uptake is noted on the traditional gamma camera images which correspond to the 1 cm carcinoma. The Dilon images clearly demonstrate the second focus of DCIS, which was pathologically confirmed and measured 4mm. Additionally, the lesion is demonstrated in the cranio-caudal view of the Dilon camera. Contrast enhancement for the lateral view of the larger lesion is 113%.

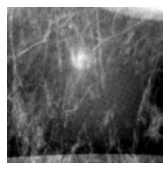
STUDY 3 CASE 3

A specially designed prototype camera was built by the detector group at the Thomas Jefferson National Accelerator Facility. This system was designed to mount on a Fischer Imaging stereotactic needle biopsy unit to allow image fusion to the digital x-ray image produced by that system. The camera was designed with a 2 x 2 inch field-of-view in order to match the imaging area of the digital x-ray detector. The results for 55 patients were published by Wymer, et al and Kieper, et al in separate submissions. Images courtesy of Dr. David Wymer and Dr. Rick Hoffer.

Photograph of the prototype detector mounted to a Fisher stereotactic biopsy table.



Mammogram: Demonstrating suspicious radiodensity measuring 5 x 8 mm.



Digital x-ray image from the Fischer system

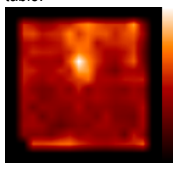
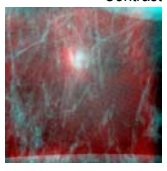


Image from the prototype gamma camera. Contrast = 1.44



Scintimammogram: no foci noted. Contrast = 0

The resulting image when the digital x-ray and camera images are combined

PATHOLOGY
Well differentiated ductal carcinoma approximately 6mm in diameter.

COMMENTS
While the traditional gamma camera image failed to demonstrate the lesion at all, the dedicated camera shows a region of high focal uptake corresponding to the 6mm carcinoma. Contrast enhancement can not be calculated since the lesion is not noted in the standard camera image. This case demonstrates that, at the limit of detection, the contrast enhancement gained with the use of dedicated cameras can significantly improve study sensitivity.

CONCLUSIONS

In nearly all cases, the use of a dedicated breast gamma camera greatly improved lesion contrast. Additionally, in at least 4 cases it identified lesions that would have been missed with standard imaging techniques. The table below lists the performance statistics for all of the previously mentioned studies with the addition of preliminary data from Norfolk General Hospital (courtesy of Dr. Nina Fabiszewski). From the total of 222 patients, 58 were conducted during prototype development or the clinical learning curve. The negative predictive value including these cases is 96% and for the 164 additional patients it improved to 99%. In addition, it should be noted that 66% of the cancers detected by the dedicated cameras were smaller than 1cm. Such improvements in lesion sensitivity significantly improve the clinical utility of scintimammography and specifically address the issues noted in studies conducted with standard cameras.

	Studies Post Learning Phase	All Studies
Total	164	222
True Positive	23	45
True Negative	129	157
False Positive	11	13
False Negative	1	7
Sensitivity	95.8	86.5
Specificity	92.1	92.4
PPV	67.6	77.6
NPV	99.2	95.7
Accuracy	92.7	91.0

Dilon Part Number 44-00031