

# Experimental studies of SPECT scintimammography with combined cone-beam and parallel-beam collimators

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## ABSTRACT

Conventional SPECT Tc-99m sestamibi scintimammography (STSM) has limited clinical utility due to fairly low radiopharmaceutical uptake in the breast tissue as compared to the heart and the liver. We investigated the use of a cone-beam collimator (CBC) to STSM. Each detector on a multi-headed gamma camera can be equipped with parallel-beam (PBC) or cone-beam collimators (CBC). PBC can provide truncation-free SPECT projection sets, while CBC offers increased sensitivity in a limited field-of-view (FOV). Combined PBC and CBC SPECT data acquisition may provide improved lesion contrast and overall better imaging performance within CBC FOV with significantly reduced truncation artifacts in the reconstructed images. In this paper we evaluate the combined CBC&PBC SPECT method using a limited number of confirmed breast cancer patients and female chest phantoms with simulated breast lesions. We envision the combined CBC&PBC SPECT as a useful clinical tool in scintimammography.

## I. INTRODUCTION

The motivation for this work was the development of a combined CBC&PBC SPECT method for scintimammography. Presently, conventional SPECT approach to scintimammography results in images which are not clinically useful. This is due to relatively low uptake in the breast tissue, as compared to the heart or liver. The increased sensitivity of CBC might improve count-statistics but it might produce artifacts due to limited FOV of CBC. However, SPECT acquisition with a multi-headed gamma camera with at least one head equipped with PBC and the other head(s) equipped with CBC may alleviate truncation artifacts while affording increased sensitivity within CBC FOV. Previously, the algorithms for combined cone beam and parallel beam SPECT reconstruction [1,2] and the algorithms for combined fan beam and parallel beam SPECT reconstruction [3] have been derived and their performance was investigated on simulated and limited experimental data.

In this work, we investigate the performance of a modified OSEM algorithm for simultaneous CBC/PBC reconstruction for improved sensitivity and reduced truncation artifacts.

## II. METHODS

The combined cone-beam (CBC) and parallel-beam collimator (PBC) SPECT acquisitions were obtained for a female chest phantom and for a limited number of patients with confirmed breast cancer. These acquisitions were obtained using Trionix Triad camera (a triple-head gamma camera) as well as with a Siemens E-cam camera (a dual head gamma camera). An example of a data set obtained from a female chest phantom is shown in Fig. 1. A sample of the SPECT data set obtained from a patient using a triple-head gamma camera (Triad, Trionix) equipped with one high-resolution CBC (Nuclear Fields) with focal length  $f=100$  cm and two ultra-high-resolution PBCs is shown in Fig. 2.

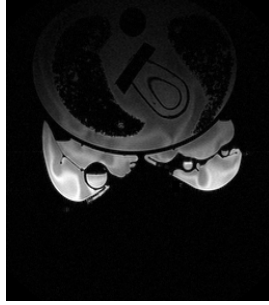


Fig. 1a.  
Transaxial MRI  
Cross-section of female  
chest phantom used in this  
work.



Fig. 1b.  
A cone-beam  
projection image of  
the female chest  
phantom shown in  
Fig. 1a.

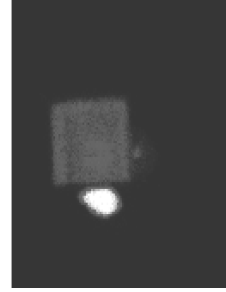


Fig. 1c.  
A parallel-beam  
projection image of  
the female chest  
phantom shown in  
Fig. 1a.

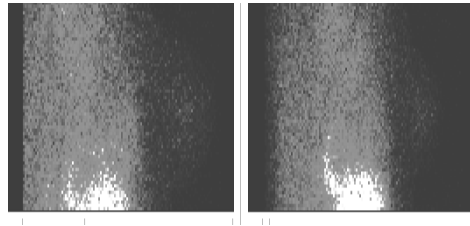


Fig. 2a.  
A cone-beam projection  
image obtained for a  
patient using a triple-  
head Trionix Triad  
camera

Fig. 2b.  
A parallel-beam  
projection image  
obtained for the same  
patient (as in 2a) using  
a triple-head Trionix  
Triad camera

The modified OSEM algorithm [4] for simultaneous CBC/PBC reconstruction uses separately obtained estimates of CBC and PBC at the first iteration; the subsequent CBC estimates are obtained as a linear combination of previous CBC and PBC estimates, as follows:

$$\mathbf{I}_{CBC}^n = \mathbf{a} \cdot \mathbf{I}_{PBC}^{n-1} + (1-\mathbf{a}) \cdot \mathbf{I}_{CBC}^{n-1} \quad (1)$$

with  $0 \leq \mathbf{a} \leq 1$

$$\mathbf{I}_k^n = \mathbf{I}_k^{n-1} \frac{1}{\sum_{i \in S_0} c_{ik}} \sum_{i \in S_0} \left[ c_{ik} \cdot \mathbf{g}_{ikj}^n \frac{Y_i}{\sum_{m \in P_i} \mathbf{I}_m^n \cdot c_{im} \cdot \mathbf{g}_{mj}^n} + c_{ik} (1 - \mathbf{g}_{ikj}^n) \right] \quad (2)$$

The meaning of the used symbols is as follows:  $i$  is the projection subscript;  $J_i$  is the number of pixels in the ray  $i$ ;  $j$  is the pixel subscript ( $j < J_i$ );  $P_i$  is the set of pixels contributing to projection  $i$ ;  $S_0$  is the subset of the projection bins corresponding to a particular set of views;  $Y_i$  is the total (random) number of photons recorded by the detector bin  $i$ ;  $\mathbf{I}_j^n$  is the current estimate of the mean number of photons emitted by pixel  $j$ ;  $\mathbf{g}_{ijm}^n$  is the probability of surviving attenuation between the source in the center of pixel  $j$  and the boundary of pixel  $m$  for the photon heading towards the detector bin  $i$ , evaluated using the current vector of parameter estimates  $\mathbf{m}^n$ ; and  $c_{ij}$  is the known probability that photon leaving pixel  $j$  is directed toward detector bin  $i$ .

### III. EXPERIMENTAL DETAILS

The SPECT experiments were performed using a triple-head gamma camera (Triad, Trionix) equipped with one high-resolution CBC (Nuclear Fields) with a focal length  $f=100$  cm and two ultra-high-resolution PBCs and on a dual-head gamma camera (E.Cam, Siemens) equipped with one high-resolution CBC (Nuclear Fields) with focal length  $f=70$  cm and one high-resolution PBC. The female chest phantom, described in Table I, with simulated various size lesions with activities 3X above the breast background was imaged.

Table I. Female chest phantom used.

Organ	Volume (ml)	Specific activity ( $\mu\text{Ci/ml}$ )
Thorax	4900	0.60
Myocardium	115	6.00
Left ventricle	65	0.60
Liver	500	6.00
Breast	400	0.30
Lt. Br. Distal Lesion	2 ml	0.90
Lt. Br. Proximal Lesion	10	0.90
Rt. Br. Distal Lesion	5	0.90
Rt. Br. Proximal Lesion	20	0.90

We acquired SPECT scans consisting of 90 views, 25 sec/view, 18% photopeak energy window, with  $128 \times 64$  or  $128 \times 128$  acquisition matrix and with a detector bin size of 0.356 cm and 0.48 cm for Triad and E.Cam camera, respectively. Circular orbits with radius-of-rotation of 25.0 cm were used.

The same scanning parameters were used to image a small number of patients using 20 mCi of Tc-99m sestamibi.

### IV. RESULTS AND DISCUSSION

We have investigated the quality of the reconstructed image as a function of the coefficient  $\alpha$  (see Eq. 1). This parameter defines the contribution of parallel-beam and cone-beam data in the reconstruction process. We have considered the following characteristics: (i) the linear profiles through the simulated breast lesions in the reconstructed transaxial slices; and (ii) the signal-to-noise ratio (SNR) defined as the ratio of mean number of counts to standard deviation in a small ROI containing the lesion.

Examples of linear profiles (1 channel width), obtained through the simulated 2 ml breast lesion in the reconstructed transaxial slices for the triple-head and the dual-head camera, are shown in Fig. 3 and Fig. 4, respectively.

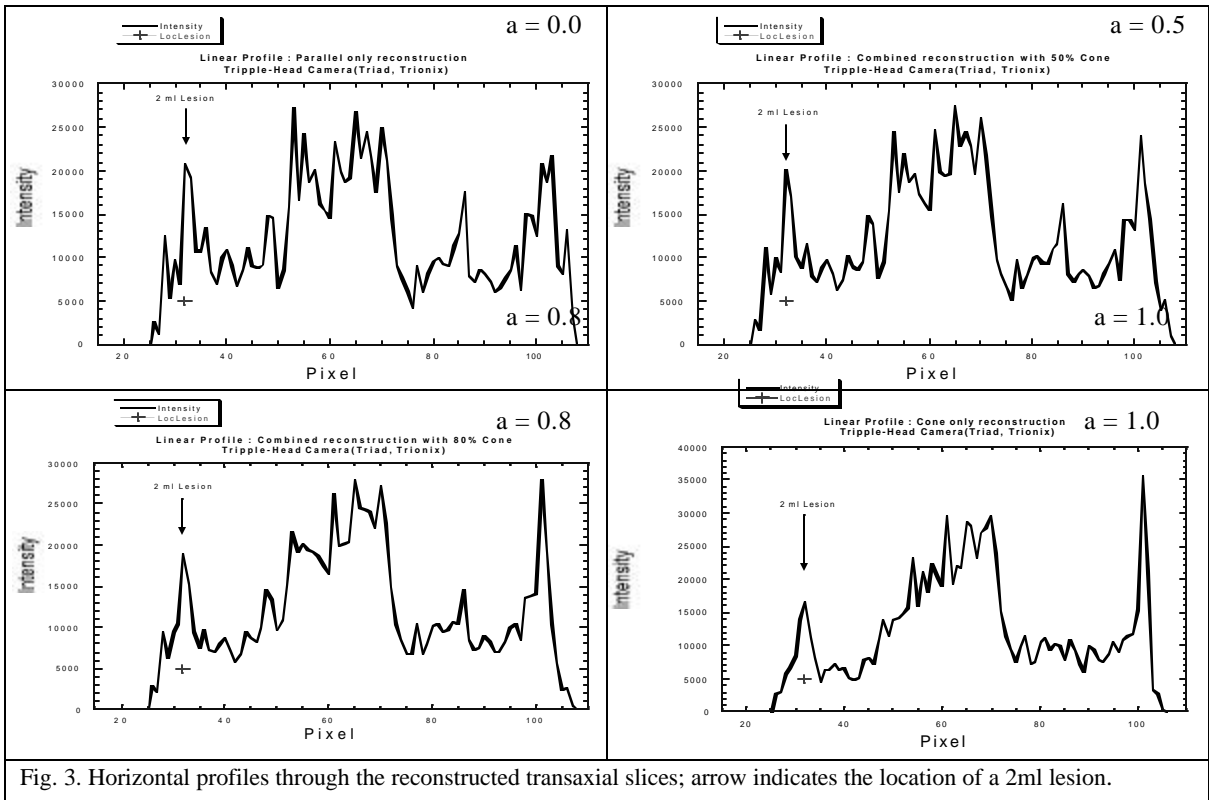


Fig. 3. Horizontal profiles through the reconstructed transaxial slices; arrow indicates the location of a 2ml lesion.

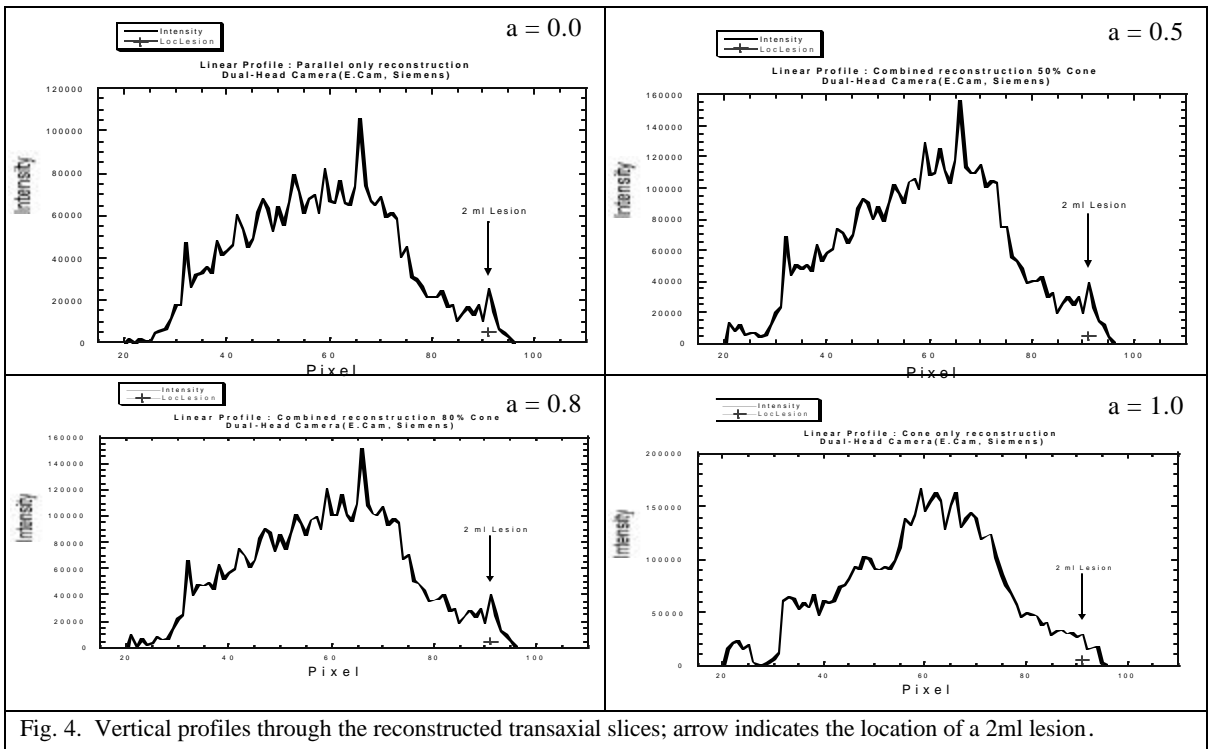
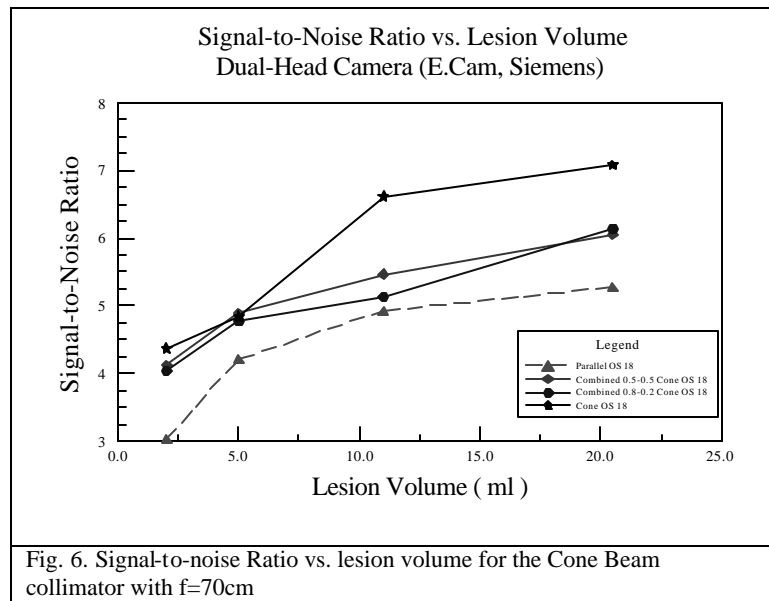
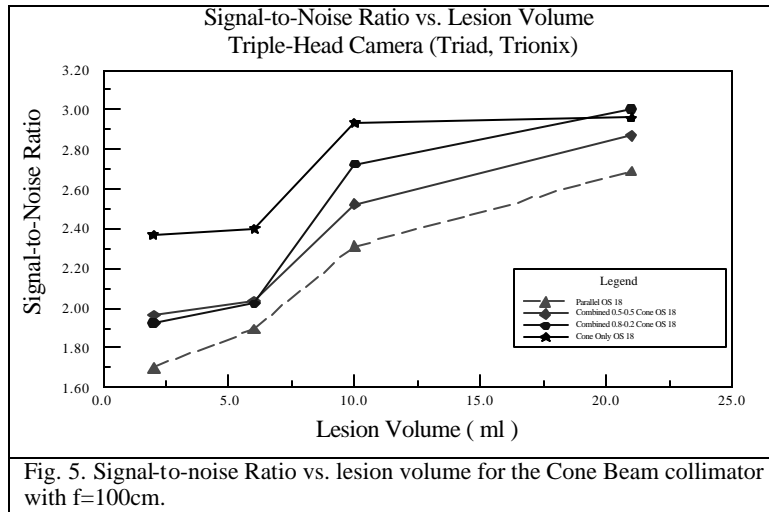


Fig. 4. Vertical profiles through the reconstructed transaxial slices; arrow indicates the location of a 2ml lesion.

Examples of the signal-to-noise ratio obtained for the simulated 2 ml breast lesion in the reconstructed transaxial slices for the triple-head and the dual-head camera are shown in Fig. 5 and Fig. 6, respectively.



An example of the maximum intensity projection (MIP) obtained for the physical phantom and a patient are shown in Fig. 7 and 8, respectively

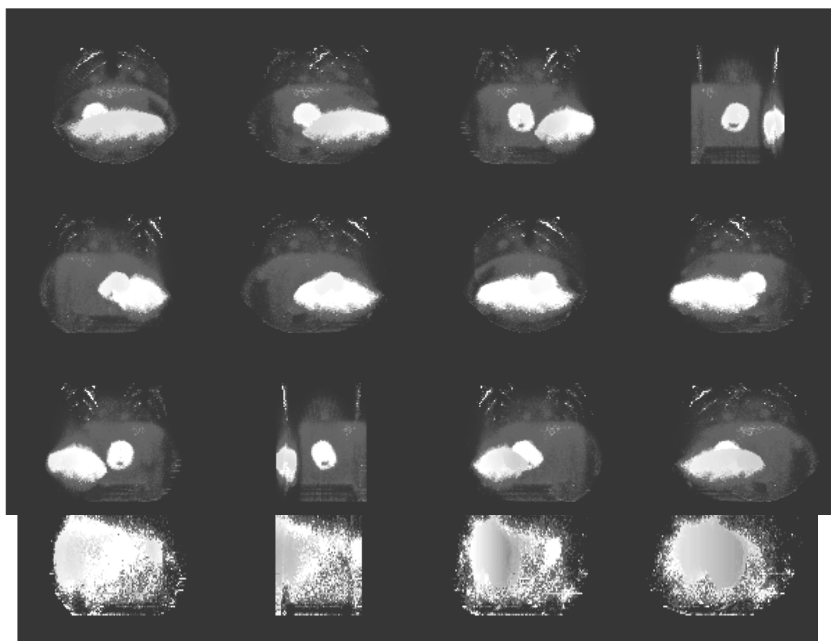


Fig. 7 Maximum intensity projection obtained for the physical phantom

Fig. 8 Maximum intensity projection obtained for a patient.

## V. CONCLUSIONS

The combined CBC&PBC SPECT method has been evaluated using physical phantoms and a limited number of patients. These studies indicate that the utilization of a cone-beam in addition to a parallel-beam collimator in a multi-headed gamma camera reduces noise level in the limited region of reconstruction without creating clinically unacceptable truncation artifacts. We imagine application of CBC&PBC SPECT in scintimammography.

## REFERENCES

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