Theoretical studies on optimization of tomographic performance of cone-beam collimator for SPECT scintimammography

R.B. Salgado, A. Krol, D.H. Feiglin, I. Echeruo**, A.S. Hardikar**, F.D.Thomas, E. Lipson*, A. Bordikar**, I. Coman** (SUNY Upstate Medical University, Department of Radiology, Syracuse, NY 13210) (Syracuse University, *Department of Physics, **Department of Computer Science, Syracuse NY 13244)

Purpose: To optimize sensitivity and tomographic field-of-view (FOV) of a cone-beam collimator for possible enhanced SPECT scintimammography (STSM). Presently, STSM is difficult to interpret due to relatively low radiopharmaceutical uptake in the breast tissue, as compared to the heart and the liver.

Materials and methods: Tomographic performance of a cone-beam collimator (CBC) as a function of its focal length (FL), the radius of rotation (ROR) and the spatial frequency (SF) of the imaged object was modeled. An OSEM algorithm was used. Simulated (scatter-free) data obtained with Defrise phantom were used. For the model verification we utilized experimental data obtained with a triple-head gamma camera (Triad, Trionix) equipped with a high-resolution CBC with FL=100 cm. The advantage of CBC is its enhanced sensitivity; the disadvantage is its limited FOV, possibly resulting in truncation artifacts.

Results: The tomographic FOV and the sensitivity of CBC were obtained as a function of FL, SF and ROR parameters. We observe strong dependence of the tomographic FOV on SF and FL. We conclude that FL=70 cm provides FOV diameter of about 10 cm that is reasonable for SPECT scintimammography with the average sensitivity in FOV that increased by a factor of 7 as compared to PBC.

Conclusion: The STSM performed with and optimized CBC will result in better contrast resolution, as compared to PBC, in the FOV that is sufficiently large. Consequently, breast lesions with smaller uptake could be detected.

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(SUNY Upstate Medical University, Department of Radiology, Syracuse, NY 13210) (Syracuse University, *Department of Physics, **Department of Electrical Engineering and Computer Science, Syracuse NY 13244)

SUMMARY

We have investigated the tomographic performance of a cone-beam collimator (CBC) as a function of its focal length (FL), the radius of rotation (ROR), and the spatial frequency (SF) of the imaged object. An OSEM algorithm was used. Simulated (scatter-free) data obtained with a modified Defrise phantom (see Fig. 1) were used. For the model verification, we utilized experimental data obtained with a triple-head gamma camera (Triad, Trionix) equipped with a high-resolution CBC with FL=100 cm. (See Fig. 2b.) The advantage of CBC is its enhanced sensitivity; the disadvantage is its limited field-of-view (FOV), possibly resulting in truncation artifacts. For this reason, we performed these optimization studies.

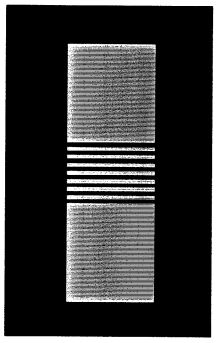

Fig. 1a.
A synthetic semi-Defrise phantom.

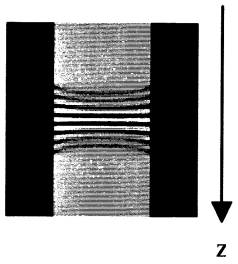

Fig. 1b.
An example of a simulated cone-beam projection image obtained for the semi-Defrise phantom shown in Fig. 1a.

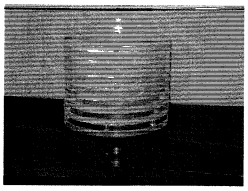

Fig. 2a.
A physical Defrise phantom.

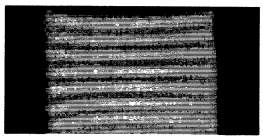

Fig. 2b.
A cone-beam projection image obtained for the physical Defrise phantom shown in Fig. 2a.

The tomographic FOV and the sensitivity of CBC were obtained as a function of FL, ROR, and SF parameters. We used an arbitrary value of 10% of the reconstructed emission loss for the determination of the useful FOV. As an example, in Fig. 3, a strong dependence of the tomographic FOV on spatial frequency is shown for FL=60 cm and ROR=16 cm.

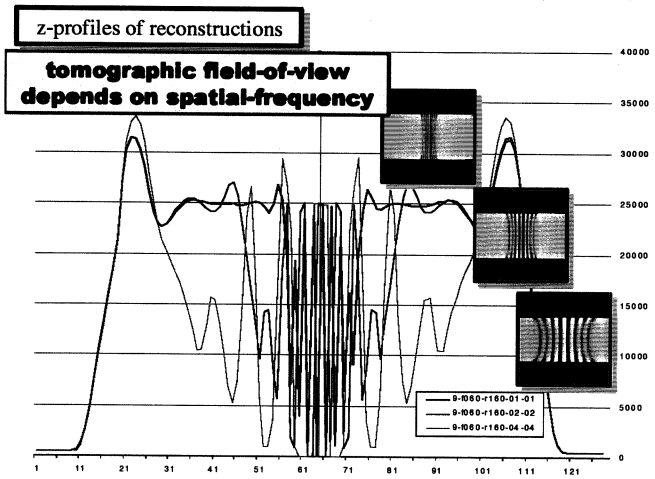

Fig. 3.
The z-profiles obtained for the reconstructed semi-Defrise phantom shown in Fig.1a for spatial frequencies 2.08, 0.52 and 0.26 cm^{-1}, with FL=60 cm and ROR=16 cm.

The useful FOV and the average sensitivity of CBC within that useful FOV were evaluated as a function of FL and ROR parameters. Some of the results are shown in Fig. 4. We observe strong dependence of the sensitivity on FL and ROR. We have also evaluated a figure of merit measure defined by sensitivity×FOV. This is shown in Fig. 4.

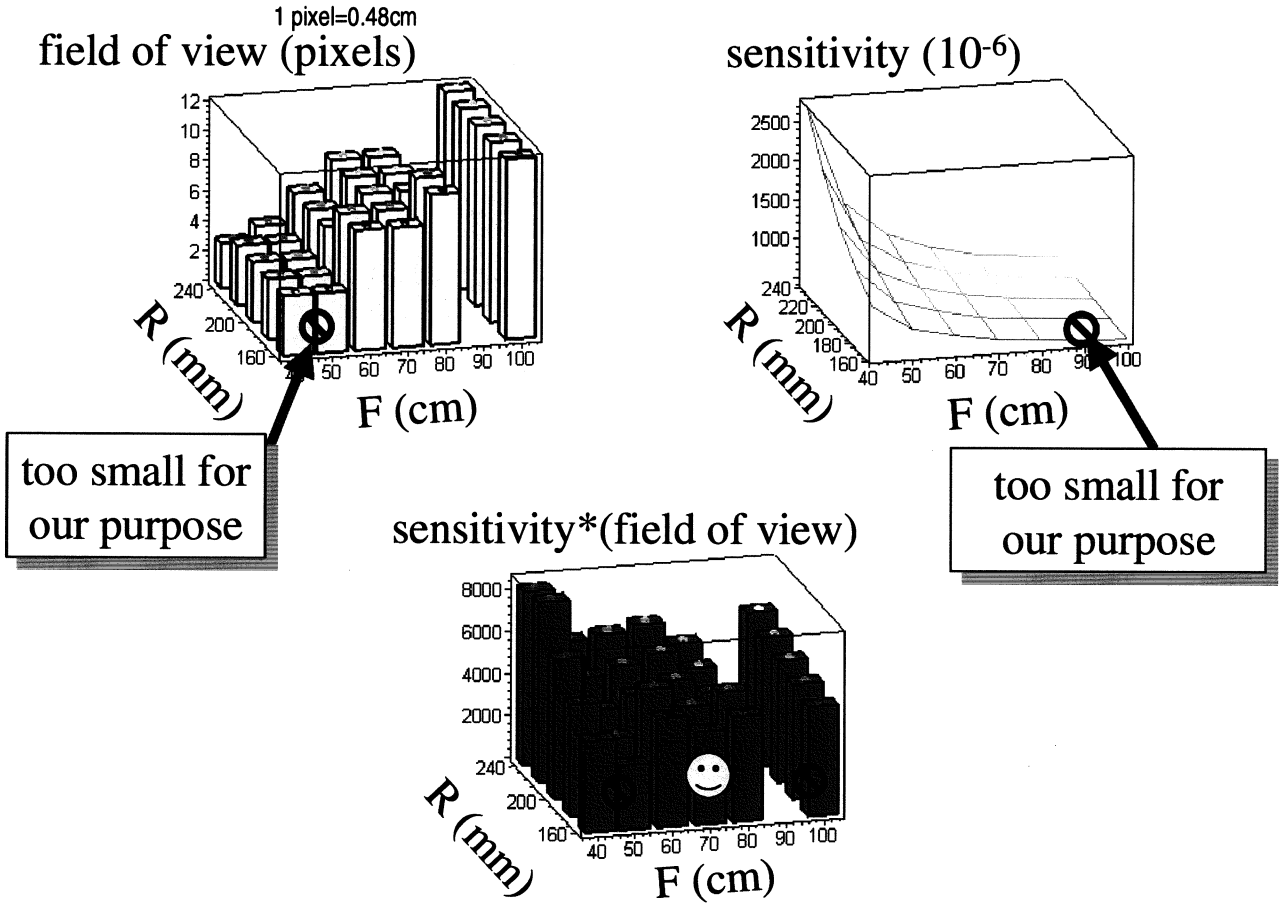

Fig. 4. The useful FOV (top left), the average sensitivity (top right) of the cone-beam collimator within that useful FOV, and the figure-of-merit = sensitivity×FOV (bottom) are plotted as functions of focal length F and radius-of-rotation R.

We conclude that FL=70 cm provides a useful tomographic FOV with a diameter of about 10 cm, sufficiently large for SPECT scintimammography, and a gain in the average sensitivity by a factor of 7 as compared to the parallel-beam collimator.