EDITORIAL

Clinical Cone-Beam SPECT

The potential advantages of rotating camera SPECT over planar imaging are well known: improved lesion detection and quantitation. In practice, full realization of the advantages of gamma camera SPECT often can be challenging.

One major limitation of rotating camera SPECT is the gamma camera collimator, i.e., the component of the camera system that most influences image resolution and noise. Because parallel-hole collimators have such low sensitivity, tomographic projection images are relatively count poor. Unfortunately, noise in the set of planar projection images is amplified in the tomographic image reconstruction process necessitating some level of smoothing in the final images and some sacrifice in resolution and quantitative accuracy. One can reduce reconstructed image noise up front by using a more sensitive collimator. But the increased sensitivity comes at the expense of decreased spatial resolution owing to the geometric nature of parallel-hole collimators. One could simply increase image acquisition times to improve count density, but this strategy is not without problems either, including decreased patient throughput and the increased likelihood of movement and/or changing in vivo activity concentration artifacts.

How can we fully realize the potential of rotating-camera SPECT? There are several ways to approach this deceptively complicated proposition. The most obvious approach to overcoming the low sensitivity of gamma camera collimators is to utilize a multiple-head camera configuration. Reliable dual-, triple- and even quadruple-headed cameras are commercially available now, so sensitivity gains of 2, 3 or 4 are possible over the single rotating head. This increase in sensitivity, however, may come at an additional cost of several hundred thousand dollars. For clinical nuclear medicine at many hospitals and outpatient facilities, especially in the current changing health care climate in the U.S., this additional expense might be hard to justify. Such an expense might be easier to rationalize if one knew that diagnostic accuracy would be improved significantly using a multiheaded camera. Indeed, an unanswered question that is germane to developing and realizing optimized clinical SPECT is what is the minimum system sensitivity and spatial resolution needed to perform acceptably in the diagnostic tasks of the clinic?

Another avenue to enhancing rotating camera SPECT is through the use of different (nonparallel-hole) collimator designs, e.g., cone-beam (converging) and fanbeam collimators (*1,2*). This inexpensive approach to improving system sensitivity has been under investigation almost since the advent of SPECT (*3*). Cone-beam collimators offer the greatest gain in sensitivity, almost a factor of two as compared to parallel-hole collimators with similar spatial resolution. Because of the nonparallel sampling of projection data and the changing spatial resolution as a function of distance from the focal point of the collimator, both fanbeam and cone-beam SPECT require more complicated reconstruction algorithms and computational time to create the transaxial images.

In this issue of the *Journal*, Li et al. (*4*) report their investigation of the effect of collimator sensitivity on lesion detectability. The detectability of a single, small thalamic lesion in the Hoffman brain phantom was evaluated by continuous receiver operating characteristic (ROC) analysis for cone- beam, fanbeam and parallel-hole collimator geometries. The authors attempted to control for factors other than sensitivity in their simulation. Their finding that the cold lesion located in the posterior portion of the thalamus is best detected using cone-beam collimation (with a relative sensitivity of 1.7 over the parallel-hole collimation), followed by fanbeam collimation (1.38) and lastly by parallel-beam collimation (1.0) is believable.

What does this tell us about the utility of cone-beam collimation in clinical studies? At first thought one might argue that the simulation study of Li et al. is somewhat artificial and too far removed from a clinical situation to help us evaluate this imaging technique. There are relatively few imaging studies of small cold lesions in the central part of the brain. Phantoms hold very still and the Hoffman brain phantom isn't shaped like a human head. Further, there are actual patient-to-patient variations of imaging parameters (e.g., variations in tracer kinetics, radius of rotation, attenuation, pathology and time of acquisition, to name a few) that influence overall image quality and diagnostic accuracy.

In spite of these criticisms, the work by Li et al. is very enlightening for several reasons. It demonstrates that cone-beam data of the head can be reconstructed with good fidelity. Gains in collimator sensitivities are real and the increased count density translates into significantly improved overall "diagnostic accuracy" as evidenced by the area under the ROC curve.

In fact, for the detection of a small focal lesion, the detectability jumped from 0.76 to 0.89 with a collimator sensitivity increase of 70%. The authors note that with a dual- or triple-headed (parallel-hole) camera, the area under the ROC curve might improve another 20%. Given that the majority of defects one attempts to locate with a brain scan are larger than the simulated ~1-cm^3 defect, the

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present results suggest that a fully developed single-headed cone-beam system or a dual-headed, parallel-hole camera system might be adequate for routine clinical work of this nature. The results of Li et al. also suggest that a triple-headed camera might be slight hardware overkill unless there is a frequent need for rapid dynamic scans. For clinics that do not intend to invest in multiheaded cameras, cone-beam SPECT might offer them enhanced imaging performance.

Confirmation of these suspicions would be valuable. To this end it would be helpful to extend the work of Li et al. to lesions located at different locations within the brain, different sized lesions and slightly varying the imaging parameters per a real clinical setting. Obviously, clinical trials would be preferable but for practical and ethical reasons realistic simulations are probably the method of choice to obtain the additional performance information. It should be noted that other clinical applications for cone-beam SPECT are under investigation and currently look promising as well (*5*).

Let us not forget the importance of the tracer in rotating camera SPECT. The maximum system sensitivity gain physicists can provide through practical collimator alterations is around a factor of two. My radiochemistry colleagues potentially can have a greater impact than that on image count density. A new single-photon tracer with an accumulation in the organ of interest that is significantly greater than existing imaging agents would offer direct improvements in image quality. Improved tracers, coupled with collimator improvements could go a long way in enhancing rotating single-head camera SPECT.

Currently there are no vendors offering a cone-beam collimator/SPECT reconstruction package commercially. With the ongoing improvements in nonparallel ray and incomplete field of view reconstruction techniques (*6,7*), processing hardware and our knowledge of imaging performance criteria, medical instrumentation companies will be more comfortable with offering cone-beam capabilities with their commercial systems.

REFERENCES

1. Jaszczak RJ, Greer KL, Coleman RE. SPECT using a specially designed cone-beam collimator. *J Nucl Med* 1988;29:1398–1405.
2. Tsui BMW, Gullberg GT, Edgerton ER, Gilland DR, Perry JR, McCartney WH. Design and clinical utility of a fan-beam collimator for SPECT imaging of the head. *J Nucl Med* 1986; 27:810–819.
3. Jaszczak RJ, Chang LT, Murphy PH. Single photon emission computed tomography using multi-slice fan-beam collimators. *IEEE Trans Nucl Sci* 1979;NS-26:610–618.
4. Li J, Jaszczak RJ, Turkington TG, Metz CE, Gilland DR, Greer KL, Coleman RE. An evaluation of lesion detectability with cone-beam, fan-beam and parallel beam collimation in SPECT by continuous ROC study. *J Nucl Med* 1994;35:135–140.
5. Gullberg GT, Christian PE, Zeng GL, Datz FL, Morgan HT. Cone-beam tomography of the heart using single-photon emission-computed tomography. *Invest Radiol* 1991;26:681–688.
6. Li J, Jaszczak RJ, Greer KL, Coleman RE, Cao ZJ, Tsui BMW. Direct cone-beam SPECT reconstruction with camera tilt. *Phys Med Biol* 1993;38:241–258.
7. Welch A, Webb S, Flower M. Improved cone-beam SPECT via an accurate correction for non-uniform photon attenuation. *Phys Med Biol* 1993;38:909–928.

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