List-Mode Cardiac Gating Methods for SPECT Systems

A number of SPECT and SPECT/CT instruments are available in our laboratory. Virtually all of these were constructed in-house with technology developed in the Center for Gamma-Ray Imaging (CGRI), an NIBIB P41 research resource (H.H. Barrett, PI) dedicated to extending the state-of-the-art in spatial and temporal resolution in nuclear medicine. Each of the instruments offers unique advantages that determine whether they are the best choice for a particular experiment.

The largest instrument is FastSPECT II, a high-resolution, dynamic SPECT imager (Furenlid, 2004) housed in its own 284 square-foot laboratory (Fig. 1). FastSPECT II has 16 cameras acquiring SPECT projections simultaneously with a true-list-mode architecture designed in CGRI. Front-end "list-mode event processors" examine incoming digitized data streams for valid events and package up the measurements associated with an event in a byte packet, i.e., a list-mode data entry. PCI-bus back-end boards accumulate the data, which include the time of each event to the nearest 30 nanosecond clock tick, and which append each valid event packet as it arrives from a front end to the appropriate list. The system is very powerful, digesting 48 gigabits of raw information per second, and produces excellent static and dynamic images.

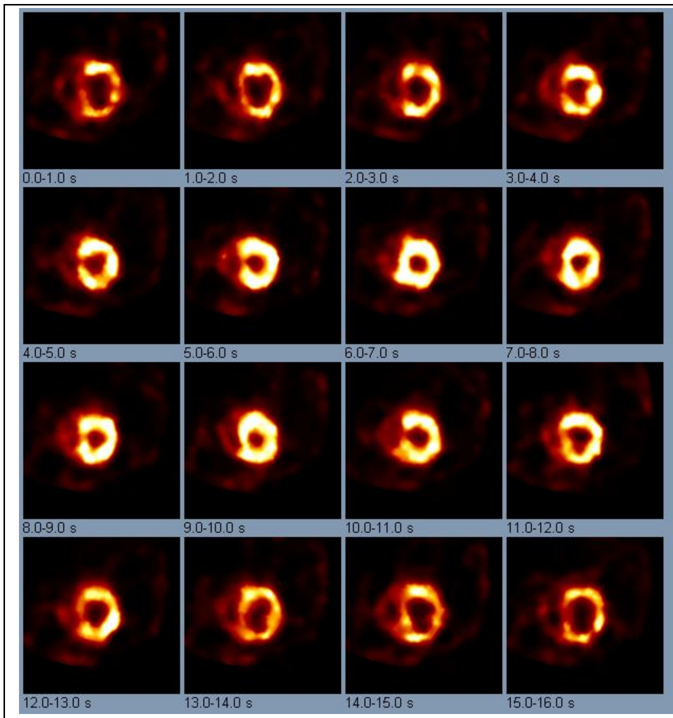

Fig. 1 Reconstructed gated transverse slices of a rat heart from systole to end diastole.

The FastSPECT II data-acquisition system has been programmed to interface with the SA Instruments physiological monitoring system in order to permit retrospectively gated dynamic cardiac imaging. Whenever an R wave is detected in the electrocardiogram, a trigger is distributed to the FastSPECT II acquisition computers that results in special event packets with accurate time stamps being inserted in the accumulating data lists. Post-processing software can manipulate the list-mode data in a variety of ways, including splitting events into time bins corresponding to phases of the cardiac cycle. Data can also be grouped according to a sliding time window, permitting imaging of both periodic motions and systematic dynamic trends such as uptake and clearance.

One promising technology for improving intrinsic resolution in SPECT is detector arrays based on wide-bandgap semiconductors. CGRI has developed 64 × 64 cadmium zinc telluride (CZT) arrays with 380-µm square pixels. A tabletop SemiSPECT system that uses eight detectors arranged in an octagonal lead-shielded ring has recently been completed. An aperture cylinder with a 64.7-mm diameter provides a cylindrical field of view of 32.0-mm diameter × 32.0-mm height with 0.8X magnification at the center. An object is imaged onto each detector through a pinhole, and each detector is operated independently with list-mode acquisition.

The third instrument available for cardiac studies is a dedicated small-animal, dual-modality SPECT/CT system that combines a single semiconductor (CZT) based SPECT camera of the kind employed in SemiSPECT with a transmission X-ray system based on an Oxford Instruments micro-focal X-ray source and a MedOptics commercial CCD X-ray camera (Kastis, 2002, 2003). In this system, planar projections for tomographic reconstructions for both modalities are acquired by rotating a mouse or small rat about the vertical axis. The system is providing very high quality images, with 400 micron SPECT resolution and better than 100 micron CT resolution, but with longer acquisition times due to its single-detector design.

The dual-modality system resides inside a compact 79 cm × 48 cm × 46 cm aluminum housing that is laminated with 1.5 mm of lead. Photographs of the enclosure are shown in Fig. 1. The instrument allows visual inspection of the animal during imaging through a CLEAR-Pb, leaded plastic window. This instrument resides in another 284 square-foot laboratory.