Another EM motivation: Elliptical Orbits

Instrumentation and Data Analysis: SPECT: Optimization and Quantitation—Cardiac

8:30–10:00 **Session 27** **Rooms 200–201**

No. 156

A COMPARISON OF MYOCARDIAL DEFECT DETECTION IN TL-201 SPECT USING PARALLEL-HOLE, FAN BEAM AND CONE BEAM COLLIMATORS J.A.Terry, B.M.W.Tsui, J.R.Perry, G.T.Gullberg*, G.L.Zeng*. U. of North Carolina, Chapel Hill, NC and *U. of Utah, Salt Lake City, UT.

We have investigated myocardial defect detection in Tl-201 SPECT using three collimator designs, namely parallel-hole, fan beam and cone beam collimators, with the same spatial resolution of 7.4 mm at 10 cm from the collimator. The fan and cone beam collimators provide increased detection efficiency with a decreased field-of-view (FOV) when compared with the parallel-hole design. A computer generated three-dimensional (3D) phantom of the upper torso was used in the investigation. The phantom consisted of realistic models of the heart, lungs, rib cage, liver and kidneys; each organ is described by mathematical equations. The 3D distributions of Tl-201 uptake and attenuation coefficients were defined for the organs in the phantom; myocardial defects were simulated as 3D Gaussian-shaped decreases in uptake and were placed at various locations in the left ventricular wall and in the interventricular septum. Emission projection data were generated from the uptake distribution and included the effects of attenuation, Poisson noise, spatially variant collimator and scatter response functions. Projections covering 180° for the parallel-hole, and 180° plus the fan angle for the fan and cone beam collimators were used. The total acquisition time was set for 30 minutes for each of the three collimators giving average total projection counts, for a 3 mm thick central slice through the heart, of 24,300, 44,400 and 46,300 for the parallel-hole, fan and cone beam collimators, respectively. Reconstructed images were obtained using the filtered backprojection method for parallel-hole and fan beam collimators, and the Feldkamp method for the cone beam collimator. The signal-to-noise (S/N) ratio of a 50% myocardial defect in the reconstructed images, defined as

S/N = (amplitude of defect)/(std. dev. of count fluctuations in the myocardium),

was 0.81, 1.02, and 1.25 for the parallel-hole, fan and cone beam collimators, respectively. Simulated images from the phantom were generated for use in observer performance experiments for detection of myocardial defects, and results from ROC analysis are compared to the S/N ratios. These studies indicate that the fan and cone beam collimators, despite their associated decrease in FOV, are superior in the detection of myocardial defects in SPECT imaging.

No. 157

QUANTITATIVE MYOCARDIAL SPECT IMAGING: EFFECT OF LV LONG AXIS ORIENTATION AND RECONSTRUCTION ARC. J.E. Stuhlmuller, M.T. Madsen and P.T. Kirchner. University of Iowa, Iowa City, IA.

Myocardial SPECT images are normally reconstructed over a 180° arc in a standard RAO to LPO orientation. This provides symmetric angular sampling when the LV long axis is oriented at 45° LAO, but is asymmetric when the heart is otherwise oriented. We have quantified regional count variations due to changes in the LV long axis orientation with the standard reconstruction arc. We also examined the effect of altering the reconstruction arc to maintain symmetric angular sampling with respect to the long axis of the LV. A heart phantom containing either Tl-201 or Tc-99m was imaged with the long axis of the LV oriented at three different horizontal positions: A) 45° LAO , B) Anterior and C) 90° Left Lateral. The projection data were acquired over 360° . Three different reconstruction arcs were utilized: 135-315° (standard RAO-LPO), 90-270°(symmetric arc for A) and 180-360° (symmetric arc for C). Circumferential profiles of the short axis slices located at the mid ventricular level were generated. Profile comparisons were made for orientations A vs B and A vs C reconstructed with the standard arc (RAO-LPO). Orientation B reconstructed over 90-270° arc and orientation C reconstructed over 180-360° arc were also compared to A reconstructed with the standard arc. The maximum % differences are tabulated below:

		Maximum Difference(%)	
LV Orientation	Reconstruction Arc	Tl-201	Tc-99m
B	135-315°	16	23
	90-270°	8	8
C	135-315°	23	21
	180-360°	11	13

Asymmetric angular sampling with respect to the long axis of the LV produces regional count reductions that may lead to artifactual defects in both Tl-201 and Tc-99m images. These defects can be reduced by proper selection of the reconstruction arc.

No. 158

REDUCTION OF IMAGE ARTIFACTS AND DISTORTIONS IN MYOCARDIAL SPECT IMAGING. B.M.W. Tsui, X.D. Zhao, E.C. Frey, J.R. Perry and *D.J. Nowak and *T. Bernstein. The University of North Carolina at Chapel Hill, Chapel Hill, NC and *General Electric Medical Systems, Milwaukee, WI.

Clinical myocardial SPECT images obtained from conventional data acquisition and reconstruction methods are subject to artifacts and distortions. We have studied the causes of these image degradations and developed reconstruction and compensation methods to reduce their effects for improved image quality. The image degradation factors considered included nonuniform attenuation distribution in the chest region and spatially variant detector and scatter response functions enhanced by the use of elliptical orbit. To study the individual and combined effects of these factors, we used a realistic computer-generated cardiac phantom derived from patient data. The projection data were generated from the phantom by incorporating the effects of attenuation, detector response and scatter. Reconstruction algorithms included the conventional filtered backprojection (FB) with and without filtering, the Chang algorithm and the iterative ML-EM algorithm using a projector/backprojector pair modeling attenuation and/or detector response. We found that artifacts and distortions caused by the nonuniform attenuation distribution in the chest region can be reduced effectively using either the Chang or the iterative algorithms with attenuation compensation as compared to the FB algorithm without compensation. The spatially variant detector response causes uneven activity distribution along the myocardium from FB reconstruction, especially with high eccentricity elliptical orbits. Several compensation methods were evaluated including (1) a fixed Metz filter, (2) a Metz filter which varies with projection view, and (3) an iterative ML-EM algorithm which incorporates the spatially variant detector response function. In a simulated myocardial SPECT study using a general purpose collimator and an elliptical orbit with a long and short axis ratio of 2, the reconstructed image from the FB algorithm showed a maximum variation of 33% in the activity concentration along the myocardium. The fixed and variable Metz filtering reduced the variation to about 28% and 20%, respectively, and the iterative method reduced the variation to less than 10% after 50 iterations. In conclusion, the iterative reconstruction methods with compensation for attenuation and detector response provide the best reconstructed image quality in terms of reduced artifacts and distortions with a trade-off of increased processing time.

No. 159

A NEW METHOD FOR DETERMINATION OF CARDIAC VOLUMES WITH SPECT IMAGES. C.K. Hoh, R.C Brunken, K.S. Nitahara, R.A. Hawkins. Division of Nuclear Medicine and Biophysics, UCLA School of Medicine, Los Angeles, CA.

A rapid method was implemented for determining the total cardiac volume from a set of short axis Tl-201 SPECT images. This method measures the mid-myocardial wall (MMW) volume, defined as the left ventricular (LV) volume measured out to the middle of the LV wall rather than to the endocardial or epicardial wall. The method requires the location of the approximate cavity center near the base and apex of the LV. Each short axis image was zoomed and a derivative edge detection technique (DEDT) was applied from the center of the LV cavity to identify the MMW (where the first derivative changes from positive to negative). Determination of the base and apex of the heart was operator independent. The base was identified when a complete concentric ring of myocardium was detected by the DEDT as it interpolated towards the apex from an extreme basilar plane. The pixels in each short axis image were converted to voxels (using the plane thickness) and summed for the total MMW volume. If the DEDT failed operator intervention was allowed. The method was calibrated and tested for reproducibility with a concentric cylindrical phantom of Tl-201 in various orientations and the results differed by less than 3%. The DEDT detected the MMW even in cases where large and severe perfusion defects were encountered. With this technique the transient ischemic dilatation ratio (TIDR) on 22 CAD pateints was measured. The TIDR was defined as the stress divided by the resting LV volume. Average TIDR of patients with normal coronary arteries (n=6) was 0.70 ± 0.24, with one vessel disease (n=6) was 1.03 ± 0.16, with two vessel disease (n=9) was 1.04 ± 0.24, and with 3 vessel disease (n=7) was 1.06 ± 0.15. A significance difference ($p<0.003$) was found between normal and all patients with CAD .

With this robust technique LV volumes can acurately and easily be determined from SPECT Tl-201, MIBI, or PET short axis images in the clinical setting.

No. 160

EFFECTS OF SIDE INFORMATION ON MYOCARDIAL BLOOD FLOW ESTIMATION AND OPTIMAL SPECT COLLIMATOR RESOLUTION. P. Chiao, W.L. Rogers, A.O. Hero, J.A. Fessler,

N.H. Clinthorne and G.D. Hutchins. Division of Nuclear Medicine, University of Michigan, Ann Arbor, MI.

The compromise between resolution and sensitivity establishes lower bounds on the accuracy with which one can determine myocardial blood flow using SPECT with diffusible radiotracers. We have investigated the usefulness of boundary side information in improving estimates of k1, and the effect this side information has on the optimal collimator resolution. The uncertainty in k1 and other model parameters is determined from the inverse of the Fisher information matrix for a range of collimator resolution and side information accuracy for several models of the heart.

The simplest heart model used was two concentric circles specified by two unknown radii. If the two radii are time-invariant, they can be accurately estimated from SPECT measurements. Therefore, even side information of 1mm uncertainty does not improve the accuracy of k1 estimates. However, as a characterization of a moving heart, when the two radii are allowed to change with time, the resulting much higher k1 uncertainty can be substantially reduced by almost a factor of 3 using side information with 1mm uncertainty, and the k1 uncertainty becomes less sensitive to collimator resolution. As a more realistic representation of the heart, we have used a first order spline to model n myocardial segments with n nodes which are specified by their distance from the center. Even if the nodes are not allowed to vary with time, k1 uncertainties of both ischemic and normal myocardial regions can be reduced by over 16% with 1mm side information and a similar decrease in the sensitivity of k1 uncertainty to collimator resolution can also be observed.

We conclude that side information of sufficient accuracy can improve k1 estimation, that the effect of side information on k1 estimates depends on model assumptions, and that the use of side information changes optimal collimator design.

No. 161

A NEW ALGORITHM FOR DETECTION AND CORRECTION OF GRADUAL OR ABRUPT HEART MOTION IN SPECT TL-201 MYOCARDIAL PERFUSION IMAGES. K Durski., A.C.Civelek, M.Ozguven, H.N. Wagner, Jr., E.E.Camargo, The Johns Hopkins Medical Institutions, Baltimore, MD.

We have developed a new method for detection and correction of the misalignment of the heart in Tl-201 SPECT images. The position of the heart was determined by minimizing an absolute difference and residual variance between heart regions in the adjacent frames of projection images. The difference between calculated and detected positions of the heart was used to realign the images applying a linear interpolation method. The accuracy of motion detection was measured as one standard deviation between detected and calculated points. When a point source was detected, the standard deviation for linogram was 0.13 mm and for sinogram 0.55 mm. For a motionless heart phantom with different sizes of cold lesions the standard deviation for linogram was 0.84 mm and for sinogram 0.52 mm. To determine the accuracy of the algorithm, 15 different motion artifacts were simulated by computer, and the images were corrected using the described algorithm. Standard deviation for linogram was 0.42 mm and for sinogram 0.27 mm. Linear correlation between detected displacement and acquisition angle in a motionless heart phantom was 0.26. When a 0.1 pixel continuous motion in consecutive images was created, the linear correlation was 0.99. The correlation was significantly increased demonstrating the utility of the described algorithm in both gradual and abrupt motion. However, due to limited accuracy in organ tracking and interpolation technique for image realignment during motion correction, a final image resolution for a point source was degraded 1.2 mm or about 10%. Although the algorithm operates on matrix data, the time required for motion detection and correction for an average sized heart was about 15 seconds when the Toshiba GMS 550 computer system was used. The application of this algorithm as a routine procedure may decrease the incidence of artifacts and improve accuracy in the interpretation of Tl-201 SPECT studies.

Cardiovascular Basic: Teboroxime

8:30–10:00 **Session 28** **Rooms 222–232**

No. 162

THE RELATIONSHIP OF TECHNETIUM-99M TEBOROXIME RETENTION AND MYOCARDIAL BLOOD FLOW. R. Beanlands, O. Muzik, N. Nguyen, N.Petry, M. Schwaiger. University of Michigan Medical Center, Ann Arbor, MI

Tc-99m teboroxime (SQ) is a new neutral lipophilic myocardial perfusion agent which is highly extracted by the myocardium, but clears rapidly. To better define the temporal relationship between SQ retention and myocardial blood flow determined by microspheres, we compared the myocardial retention of SQ at 1 (GR I), 2 (GR II), and 5 min (GR III) after simultaneous injection into the left atrium of 7 open chested dogs. A wide range of flows was induced by IV dipyridamole (0.3-0.56 mg/kg over 4 min) and LAD occlusion. The myocardial retention of SQ was expressed in arbitrary units, normalized for the integral of the tracer activity in plasma determined from arterial sampling. For 194 myocardial segments in GR I, 308 in GR II and 86 in GR III, SQ tissue retention versus microsphere determined flow data were best fitted to non-linear functions. The correlation coefficients were 0.94, 0.91 and 0.95 in GR I, II and III respectively. From the curves, tracer retention was determined at flows of 1,2, 3, and 4 ml/min/g, as shown below:

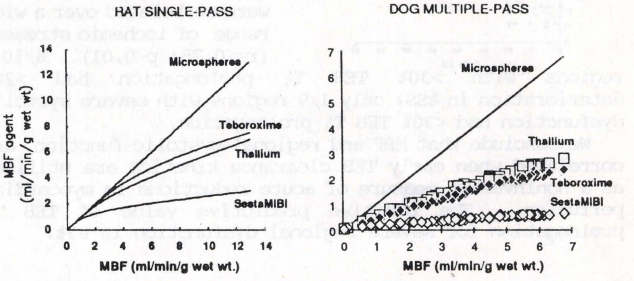
	time	Retention at flows of			
GR	(min)	1.0 ml/m/g	2.0	3.0	4.0
I	1	0.089	0.178	0.256	0.323
II	2	0.052	0.088	0.118	0.141
III	5	0.027	0.048	0.061	0.068

In conclusion, at 1 min SQ myocardial retention has an almost linear relationship to blood flow in this canine model. However, the slope of the retention-blood flow relationship decreases rapidly after injection resulting in underestimation of true flow, and a decrease in absolute increments of retention. Thus for SQ, rapid acquisition protocols are necessary to fully exploit the potential of this promising new tracer in the evaluation of myocardial flow .

No. 163

SIMULTANEOUS MEASUREMENT OF MYOCARDIAL BLOOD FLOW IN THE SAME ANIMAL USING TECHNETIUM-99m TEBOROXIME, TECHNETIUM-96 SESTAMIBI AND THALLIUM-201. R.J. Di Rocco, L. Belnavis, C. Hood, W.L. Rumsey, B. Kuczynski, K.E. Linder, J. Pirro, R.K. Narra and A.D. Nunn. Bristol-Myers Squibb Pharmaceutical Research Institute, New Brunswick, NJ.

Using two Technetium radionuclides, we have determined the ability of Teboroxime, SestaMIBI and Thallium to measure myocardial blood flow (MBF) by simultaneous injection of the three agents with radiolabeled microspheres in the same animal. Studies were performed using rats in a single-pass model to obtain global MBF and using dogs in a multiple-pass model to determine regional MBF. To provide a wide range of MBF in the dogs, adenosine was administered intravenously and the left anterior descending coronary artery was then ligated. The microsphere formula for determining MBF was applied to all agents. When MBF (agent) is plotted as a function of true MBF measured by microspheres, the sensitivity of each agent to changes in MBF is indicated by the proximity of the function to the line of identity. Shown below on the left are nonlinear fit functions from the rat single-pass experiments. The graph on the right shows values for 1-2 g sections of dog ventricle.



In both models, the closer proximity of the Teboroxime and Thallium data to the line of identity indicates that these agents are more sensitive to changes in MBF than is SestaMIBI.

No. 164

DIAGNOSTIC ACCURACY OF DIFFERENTIAL POST-STENOTIC MYOCARDIAL TECHNETIUM-99m TEBOROXIME CLEARANCE FOLLOWING NON-EXERCISE CARDIAC STRESS.

DD Miller, RE Stewart, B Heyl, RA O'Rourke. Univ. of TX Health Sci.Ctr., San Antonio, TX & St. Louis Univ.Med.Ctr.

To determine whether regional differences in the myocardial clearance of Technetium-99m (Tc-99m) Teboroxime (TEB) occur in vivo following non-exercise cardiac stress, 5 pre-instrumented dogs were given 10mCi IV TEB at peak ischemic LV stress induced by ≥90% coronary stenosis (STEN)