European Journal of Nuclear Medicine: 20(10) Oct. 1993
from European Assoc. of Nuclear Medicine Congress

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K.BLAZEK,#F.DE NOTARISTEFANI,*G. DE VINCENTIS, *T.MALATESTA,*R.PANI,*R.PELLEGRINI,+A.SOLURI, *F.SCOPINARO,
PRECIOSA Co. Turnov Czech Republic *University of Rome "La Sapienza" Italy #INFN Sect.of Rome Italy+BioMed.Tech.Inst.CNR Italy

THE EFFECT OF RADIATION TRANSPORT ON SPATIAL RESOLUTION

In recent years gamma camera prototypes based on multianode or crossed wire anode photomultiplier are developing to obtain very high spatial resolution values in SPECT,PET or planar gamma camera. If spatial resolution increases up to a value less than 1 mm, it is worthwhile to know what is the theoretical limit related to the radiation transport inside the scintillation crystal. Such limit depends on crystal composition and from the energy of gamma ray. To this aim a Monte Carlo method was developed in combination with a scintillation crystal geometry consisting in solid of 10x10x30 mm^3 volume limiting a 3D-array of elements each of one with 0.1x0.1x0.1 mm^3 dimension. The Monte Carlo code is based on the variance reduction technique and considers all interactions of photons and electrons inside the crystal and records, step by step, the deposited energy in each element of the array. The compositions of four different scintillation crystals were simulated: NaI, CsI, BGO and YAP (Yttrium Aluminum Perovskit). They were irradiated with 140 keV and 511 keV photon energy under pencil beam geometry. The results show the transport of X-ray fluorescence as the most relevant effect in spreading the energy deposition.In particular 0.5 mm, 1 mm, and 2 mm were the maximum values of spot diameter obtained for CsI, NaI and BGO respectively. The smallest value of energy deposition spread was 0.3 mm for Yttrium Aluminum Perovskit (YAP).

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R. Trebossen, B. Bendriem, V. Frouin and A. Syrota.

CEA-Service Hospitalier F. Joliot, Orsay, France.

ASSESSMENT OF TRANSVERSE AND AXIAL SCATTER DISTRIBUTION IN 2D AND 3D PET WITH A SPHERICAL PHANTOM.

A spherical phantom (18 cm in diameter) has been designed to assess transverse and axial scatter distributions. The phantom uses a line source which can be oriented in either of two perpendicular directions. Scans of the line source centered in the sphere or in the usual 20 cm cylinder have been acquired using various lower level of discrimination (LLD) on the brain Positron Tomograph ECAT 953B/31 operated with and without septa (2D and 3D mode).

In the 2D mode, for a 250 keV LLD, the transverse scatter fraction (TSF, equal to the ratio of scattered over unscattered plus scattered events) ranges from 12% (edge plane) to 19% (central plane) for the cylinder and from 8% to 17% for the sphere. When the LLD increases up to 550 keV, the difference in TSF does not exceed 1% (8% for the cylinder and 7 % for the sphere). In the 3D mode, at 250 keV, TSF is about 53% for the cylinder and 48% for the sphere. Both values are lowered by a factor of about 2.7 at 550 keV. For all values of LLD, the slope of the exponential tails is similar for both phantoms, either in the 2D or in the 3D mode.

Axial scatter distribution can only be measured with the sphere. In the 3D mode, it is quite flat and the axial scatter fraction (ASF) is 48% whereas in the 2D mode, the scatter tails decrease sharply and the ASF is 19%. At 550 keV, the ASF is 13% in 3D and 6% in 2D and there are scatter tails up to 625 keV. For all values of LLD, the transverse scatter distribution is sharper than the axial one.

Our results experimentally demonstrate that the 20 cm cylinder overestimates SF for head scans and that the increase in scatter fraction, due to the removal of the septa, is as important in the axial direction as in the transverse one. We have also found that the ASF is more sensitive than the TSF to the value of the LLD.

This work is supported by a SIEMENS-FRANCE grant.

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J.Pawlowski, B.Kari

Rush-Presbyterian-St.Luke's Medical Center, Chicago, IL 60612

THE EFFECTIVENESS OF RESTORATION FILTERING IN A DEDICATED BRAIN SPECT SYSTEM (McSPECT).

We present the results of Restoration Filtering (RF) for McSPECT, and interpret them in terms of its novel design. McSPECT consists of a cylindrical collimator, surrounded by a stationary modular detector assembly. Fan beam projection data are acquired as the collimator rotates through 360 deg. The present study allows McSPECT's performance to be compared with other designs, and can supply guidelines for future designs to provide high resolution and sensitivity. In contrast, most previous RF studies utilized simulations and compared the performance of different filters. The restoration filters used in this study were constructed from a measured MTF combined with an apodizing Butterworth filter. The effectiveness of RF was measured on images of point sources, Derenzo and Hoffman phantoms, and human studies reconstructed from filtered projection data by ramp FBP. RF improved: resolution by appr. 20% (except in the periphery of the FOV, because of marginal angular sampling); uniformity and isotropy of the resolution; image contrast by 17%. McSPECT appears to be better suited for RF than conventional SPECT systems, because of its precise sampling characteristics due to accurate collimator motion and stationary detector assembly, and because the MTF is relatively stationary due to more uniform sampling beams provided by the focused collimator modules. These results point to the need for increased sampling frequency, and a compensation technique for sampling misalignment errors due to collimator inaccuracies.

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EP Ficaro, JA Fessler, RJ Ackermann, SR Pitt, WL Rogers, M Schwaiger.
University of Michigan Medical Center, Ann Arbor, MI.

CLINICAL APPLICATION OF ATTENUATION CORRECTION FOR CARDIAC SPECT STUDIES.

SPECT evaluation of myocardial perfusion with Tl-201 or Tc-99m tracers is limited by attenuation artifacts. To overcome this problem, we developed an approach to simultaneously acquire emission and transmission data using a triple head camera system (Picker Prism 3000). A 150mCi Am-241 line source was mounted at the focal distance of a converging collimator (65cm focal length) attached to one of the detectors to collect transmission and emission data. The other two heads were fitted with parallel hole collimators to acquire emission data. Am-241 was chosen for the transmission source due to its long half life (432yr) and its low photon energy (60 keV), which minimizes spillover contamination in emission energy windows. For Tl-201 myocardial perfusion studies, 60 frames of transmission and emission projection data were acquired over 360° in a 64x64 matrix for 20 minutes. Measured transmission count rates (59 ± 6 keV window) varied between 30 kcps for posterior to 17 kcps in lateral views, while the emission rate was 2.3kcps (74 ± 9 keV and 165 ± 12 keV windows). The Tl-201 downscatter into the Am-241 transmission window introduced approximately 1.5 kcps (5-10% of transmission counts). This noise was removed by transforming the measured emission downscatter from the emission detectors to fanbeam hole geometry which is subtracted from the measured transmission data. The corrected transmission projections iteratively reconstructed with an elliptical boundary support to produce attenuation maps which were used in the iterative reconstruction of the emission data. Processing was completed in less than 20 min. First results from normal Tl-201 cardiac studies demonstrated increased homogeneity of myocardial tracer distribution as expressed as the ratio of maximal to minimal counts in a midventricular slice. The ratio for non-corrected data was 1.20 ± 0.02 while the ratio for corrected data was 0.99 ± 0.03. Thus, Tl-201 cardiac studies can be attenuation corrected using simultaneous transmission-emission tomography without increasing patient imaging time. This correction is expected to improve the diagnostic accuracy for detection of CAD.