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ITERATIVE VS ANALYTIC RECONSTRUCTION METHODS FOR POSITRON EMISSION TOMOGRAPHY'S: COMBINING THE BEST OF BOTH APPROACHES

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Dedicated small animal positron emission tomography (PET) scanners have become one of the main tools in biomedical research. New technologies and new reconstruction methods have been developed to reach the high spatial resolution and sensitivity that these studies require. Among them, statistical reconstruction algorithms like OSEM, have shown superior image quality than conventional analytic reconstruction techniques, like Filtered Back-Projection (FBP). One of their key advantages is the ability to incorporate an accurate model of the PET acquisition process through the use of a modeled system response matrix (SRM). These two families of emission tomography reconstruction methods have been developed independently of each other, and this has created some difficulties in both approaches. For example, there is a lack of knowledge about how to find the optimal filter for the FBP reconstruction, or how to get rid of the increasing noise in the image as the iteration number progress in OSEM. Frequency analysis of PET data, commonly applied in analytical methods, can provide useful information for statistical reconstruction. On the other hand, the main parameters of the SRM can be used to deduce analytically how to create a filter for FBP. A link between system response matrix parameters and the filters employed in FBP reconstructions is established in this work. Based on such a relationship, we propose a new method that combines data processing in the frequency domain, based on the SRM properties with the advantages of iterative reconstruction. The improvement in the quality of the images reconstructed with this new method is quantified.

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SMALL ANIMAL POSITRON EMISSION TOMOGRAPHY SCANNERS DESIGN OPTIMIZED FOR STATISTICAL RECONSTRUCTION METHODS

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Positron emission tomography (PET) Scanners are commonly designed bearing in mind analytical reconstruction methods. High sampling density is one of the main design goals. On the other hand, iterative methods are less sensitive to the sampling density, their performance being more related to the properties of the System Response Matrix. In small animal PET scanners, iterative techniques have proved to yield superior image quality. Specific design strategies can be followed in order to obtain optimal results with iterative techniques. For example, reducing the size of the crystals beyond certain point will not further improve the resolution of iterative methods because the average number of counts in each Line of Response will decrease and the relative importance of noise will be larger. We discuss the main issues (number of LOR's, size of the crystals, noise level) to be consider during the design of high resolution and high sensitivity PET scanners, in order to optimize the images obtained with iterative reconstructions, and comment on the improvement achievable in the image quality of a typical clinical study, and on the quantitative estimate of design parameters.

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REPRODUCIBILITY OF BIOLUMINESCENCE AND MICRO POSITRON EMISSION TOMOGRAPHY IMAGING MEASUREMENTS IN TUMOR BEARING MICE

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Quantitative micro positron emission tomography (PET) with 2-deoxy-2-[F-18]fluoro-D-glucose (FDG) and bioluminescence imaging are increasingly used to monitor the effects of therapy in murine tumor models. The reproducibility of these measurements is largely unknown. Methods: SCID-mice bearing U251 glioblastoma xenografts transfected with Renilla luciferase were imaged twice within two to four days by FDG-PET (microPET Focus, 60 minutes after i.p. injection of 200 uCi FDG under isoflurane anesthesia) and bioluminescence imaging (Xenogen, IVIS system, 15 minutes after injection of i.p injection of 100ul of 0.2 ug/ul coelenterazine in PBS). For the FDG-PET studies, mice were fasted and warmed by a heating pad (30°C). Tumor FDG-uptake was expressed by tumor/liver ratios (T:L). The optical signal was quantified by maximum photons/second/cm^2/steridian. The inter-tumor variability (for all animals scanned on one day) and the intra-tumor variability (for two serial measurements in individual mice) were compared by coefficients of variation (CV). Results: The average T:L ratio was (2.10±0.62, 16 mice, 2 scans). The CV for intra- and inter-tumor analysis of T:L was 20% and 28%, respectively. The inter- and intra-tumor CV for optical imaging was 59% and 49%. The average tumor diameter in the baseline and the follow-up scan was 7.5 mm and 8.1 mm, respectively. Conclusion: microPET imaging of tumor FDG-uptake provides more reproducible quantitative parameters than bioluminescence imaging with Renilla luciferase. However, even under carefully controlled conditions, tumor FDG uptake in mice demonstrates a significant inter- and intra-tumor variability that needs to be considered when designing studies assessing treatment effects by microPET.

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SMALL-ANIMAL SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY / COMPUTED TOMOGRAPHY PRE-CLINICAL IMAGING SYSTEM

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We have built prototypes of a new micro single photon emission computed tomography (SPECT)/ computed tomography (CT) system designed for small-animal preclinical imaging applications, including quantitative biodistribution of radiolabeled molecules, dynamic uptake/washout kinetics, and multiple isotope imaging. These prototypes will be evaluated at several preclinical research sites in early 2006. The microSPECT system consists of a fixed ring of CZT gamma-ray detectors. A cylindrical multi-pinhole collimator was designed for small field-of-view applications (eg, heart, brain). In addition, a unique cylindrical multi-slit collimator was designed for whole-body and dynamic studies, one size with a 2.5 cm transaxial field of view for mice and another 8 cm for rats. As the collimator rotates continuously or in stop-and-shoot mode, projections are acquired in list mode for iterative reconstruction. Septa provide axial slice definition. The axial field of view is 8 cm, the in-plane spatial resolution is 0.5 mm for mice and 2.5 mm for rats, and the system sensitivity is 0.015% for mice and 0.030% for rats. A higher sensitivity (0.055%), lower resolution (1.5 mm) collimator for mice was also designed. This scanner will perform in 10-15 minutes whole-body studies that now take an hour or more. Dynamic studies with 10-second timing resolution are enabled by this design. A microCT imager is located adjacent to the microSPECT on the same gantry axis and a horizontal bed moves the animal by servo-motion control. The CT images are used for attenuation and scatter correction of the SPECT images, as well as anatomical reference in fused SPECT/CT images.