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NUCLEAR MEDICINE AND IMAGING RESEARCH
(Instrumentation and Quantitative Methods of Evaluation)

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R.N. Beck, M. Cooper and C.-T.Chen

The Franklin McLean Memorial Research Institute
The Department of Radiology
The University of Chicago
Chicago, Illinois

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**THE
FRANKLIN McLEAN MEMORIAL RESEARCH INSTITUTE
DEPARTMENT OF RADIOLOGY**

**PROGRAM OF
NUCLEAR MEDICINE AND QUANTITATIVE IMAGING RESEARCH**

**THE
UNIVERSITY OF CHICAGO**

**INSTRUMENTATION AND QUANTITATIVE
METHODS OF EVALUATION**

**Principal Investigator: Robert N. Beck
Co-Principal Investigator: Malcolm Cooper, M.D.
Co-Principal Investigator: Chin-Tu Chen**

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Section I

Theoretical Studies of Imaging Systems and Methods

Projection data and sagittal slices of 3D reconstructions of the five-disk Defrise phantom obtained from a SPECT system with a parallel-beam collimator and a system with a parallel-plus collimator. Three-dimensional reconstruction in PET and SPECT involved large numbers of computations. A fast general inversion algorithm that rebins line integrals into plane integrals, correctly normalizes data, and produces accurate images was developed in 1993.

Collimator model and generalized collimator transfer function (GCTF). Analytic modeling of collimators is grounded in the pioneer work of the Principal Investigator. During the last decade, numerical and analytic modeling has resulted in a ray-tracing program that has led to the UC Penetration Criterion for optimal collimator design, and to the development of the GCTF used in the analysis of the problem of hole pattern visibility in collimated images.

The constant attenuation Radon transform and a novel inversion formula. The effects of object attenuation and imaging system point spread function are significant in emission tomography. In addition to performing laboratory experiments in the study of these phenomena, investigators from the Frank Center for Image Analysis (FCIA) developed analytic models of emission imaging. Their work has produced analytic models that provide an exact inversion for constant attenuation and numerical inversion for arbitrary attenuation.

$$P(\xi, \phi, \mu) = \int a(\xi \cos \phi - \eta \sin \phi, \xi \sin \phi + \eta \cos \phi) e^{-\mu(\eta + D)} d\eta$$

$$A_k(v_a) = \omega_k^{(n)} \gamma^k M_k(v_m) + (-1)^k \omega_{-k}^{(n)} \gamma^{-k} M_k(-v_m)$$

Sinograms, moments, and reconstructions. SPECT reconstruction generally assumes perfect data. In reality, data are not perfect; noise, attenuation, depth-dependent point-source response, and other effects degrade data. In 1993, our investigators formulated and examined consistency conditions that quantify the nature and magnitude of imperfections. These efforts may lead to techniques for reduction of noise amplification during reconstruction and to stopping criteria for iterative algorithms.

Simple Bayesian Data Augmentation-Iterative Conditional Average (BDA-ICA) and Multi-modal BDA-ICA Reconstructions from MRI Boundary Prior Generated from an MRI Image Used as an Anatomical Prior. Bayesian and more generally statistical reconstruction and multi-modality registration, reconstruction, and analysis have been studied extensively in the Frank Center for Image Analysis (FCIA). These topics were the basis of dissertation research for several medical physics and statistics graduate students.

Transverse Slices of a Three-dimensional (3D) PET Reconstruction of a Rods-and-Bars Phantom. Most 3D PET reconstruction is performed using projection-reprojection techniques. FCIA investigators developed 3D PET reconstruction techniques that produce images with equivalent or better quality in one-fifth the time that projection-reprojection techniques take. The projection data used to generate the displayed images were provided by FMI European collaborators.

Real-Data Tests of the Superresolution Reconstruction Technique. These are images of a test object designed to measure the level of detail apparent in nuclear medicine images. The superresolution technique developed and patented by FCIA investigators improves the quality and quantitative accuracy of PET and other tomographic images. The resolution improvement of the new technique is quickly seen by comparison of the bottom wedges in the reconstructed images.

“Superresolved” PET Image (labeled POCS). The image demonstrates enhanced detection of fine detail achieved by a new reconstruction method for which FCIA investigators have received a patent. The improved resolution of the cold spot indicated by the arrow is a measure of the enhanced image quality obtained with the new method. The image on the right was reconstructed by conventional techniques. The patented approach is being extended to other imaging modalities such as spiral CT.

Section II

Hardware Development

The University of Chicago Miniature Gamma Camera (UC MGC) and transport cart. Two small gamma camera systems have been constructed. One is used routinely for characterization experiments in the FMI Instrumentation Development Laboratories. The other is used routinely for imaging of animals in experiments in the study of electrical injury and treatments for electrical injury--a study being done with collaborators in the Department of Surgery.

Technetium-99m pyrophosphate uptake in a rat. The UC MGCs are high-resolution single-photon imagers (2-4 mm) that use a single position-sensitive photomultiplier tube (PSPMT) rather than several conventional photomultiplier tubes. The high resolution is accomplished by the use of a maximum-likelihood position estimation calculation rather than conventional Anger calculations. The systems were also used to develop fundamental knowledge about PSPMTs.

Reduced Tc-99m PYP uptake in surfactant-treated electroporated skeletal muscle. The three time-activity curves represent the uptake of Tc-99m in the skeletal muscle of the hind limb of a rat. They demonstrate that the uptake of PYP is significantly reduced in an injured limb following a novel surfactant treatment. The lower curve is the uptake in an uninjured limb; the upper curve, the uptake in an electroporated, saline-treated limb; the middle curve, the uptake in an electroporated, surfactant-treated limb.

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