# FDG KINETICS IMAGING WITH A DUAL-HEAD ROTATING SPECT/PET CAMERA: PRELIMINARY ANIMAL STUDIES

**Min Zhou (1), Anthony J. McGoron (1), Michael F. Georgiou (2), John W. Kuluz (3), Pablo Sanchez (2), and George N. Sfakianakis (2).**

(1) Florida International University, Biomedical Engineering Institute, Miami FL

(2) University of Miami, Department of Radiology, Division of Nuclear Medicine, Miami FL

(3) University of Miami, Department of Pediatrics, Division of Critical Care Medicine, Miami, FL

## INTRODUCTION

Emission tomography (ET), including positron emission tomography (PET) and single-photon emission computed tomography (SPECT) has been widely used to infer the kinetic parameters of compartmental models of biological processes. In the brain, ET can be used to examine alterations in blood flow and metabolism. Evaluation of brain perfusion, blood flow and metabolism can be performed through visual interpretation and qualitative assessment of images generated from SPECT and/or PET However, an accurate estimation of the functional state of the brain requires quantitative determination of the kinetic parameters, and thus dynamic imaging is necessary. Such quantitative measurements are extremely useful in the study of the cerebral function and in determining therapeutic options following injury, but accurate estimates of kinetics parameters are difficult to obtain from rotating head cameras because the basic premise for dynamic imaging, that the tissue tracer concentration is constant during collection of a set of projections, is violated. Our laboratory has validated a procedure to apply dynamic fluoro-deoxy-glucose (FDG) imaging using a dual-head rotating SPECT/PET camera and applied the method to measure brain glucose kinetics in a piglet model of traumatic brain injury. Glucose kinetics in normal and injured animals measured by PET was compared to perfusion images measured by SPECT in the same animals.

## RESEARCH DESIGN AND METHODS

**Animal Preparation:** Piglets (4-6 kg) were anesthetized with pentobarbital 40 mg/kg ip initially, followed by a continuous infusion of fentanyl 5 mcg/kg/hr, paralyzed with 0.2 mg/kg/hr iv pancuronium and ventilated through an intubation tube. Arterial and venous catheters were inserted for delivery of fluids and drugs, measurement of vascular pressures and blood sampling. A craniotomy was made over the left parietal cortex. A stainless steel cylindrical fitting was placed into the craniotomy. A fluid-percussion device was connected to the fitting so that traumatic brain injury could be accomplished using a weighted pendulum striking the fluid column, which was in direct contact with the dura. A catheter was inserted through a smaller craniotomy on the contralateral side to measure intracranial pressure (ICP). TBI was induced by fluid-percussion using either 1-3 ATM of force (or no injury in sham operated control experiments).

**Perfusion and Metabolism Imaging:** Approximately 3-4 hours after TBI, FDG (1 mCi) was injected into a venous indwelling catheter and dynamic imaging using the Philips-ADAC Vertex Plus MCD/AC camera was initiated immediately along with the collection of serial arterial blood samples. The tissue time activity curve (TTAC) was generated with dynamic imaging based on the Optimal Imaging Sampling Schedule described by Lau et al [1]. The plasma time activity curve (PTAC) was generated by collecting 0.4 mL arterial samples at prescribed times periodically over 120 minutes. The blood was immediately spun and the plasma weighed and 18-FDG activity counted in a gamma well counter along with 18-FDG standards that had previously been counted in the camera to enable the blood and tissue activity to be expressed in equivalent units. A transmission scan was performed following the last emission scan for attenuation correction. At the end of the imaging sequence piglets were sacrificed with KCl 4 mEq/kg iv and the brain removed.

**Compartmental Analysis of Regional Glucose Metabolism:** The rate of FDG phosphorylation, which is proportional to the glucose metabolic rate (CMRglc), was estimated using the three-compartment model (1-plasma, 2-tissue FDG and 3-tissue FDG-6-PO4, dephosphorylated FDG in tissue) containing four parameters. The CMRglc is derived from the rate constants, and the plasma level of cold (non-tracer) glucose, which is assumed to be in steady state. The solution of the model requires measuring the FDG in the plasma as a function of time (PTAC) and the FDG in the tissue (TTAC). The model requires dynamic PET imaging at a high enough temporal resolution to accurately capture the kinetics of the metabolic process and with high enough count statistics to provide adequately noise free images. The ability of the instrumentation to adequately generate tomographic images with fast enough temporal resolution and with high enough count statistics in each scan is the primary limitation of such studies. Therefore, dynamic PET studies have been limited to medical centers with dedicated PET systems. The introduction of the dual-head coincidence detection cameras has afforded more centers the ability to conduct FDG studies. However, due to instrumentation

limitations, FDG kinetics has not previously been evaluated with coincidence SPECT/PET systems.

Lau et al [1] have reported that for an optimal imaging sequence, the number of sampling intervals is equal to the number of parameters in the model. The FDG model has four parameters, so a four point imaging sequence (164s, 777s, 3683s, and 2575s) is sufficient to accurately estimate FDG kinetics. The FDG images were reconstructed. A ROI over the L and R sides of the cortex was defined. The cps in the ROI's over time defined the TTAC's and were used to estimate the kinetic parameters in the FDG kinetics model using an available optimization routine. A routine was developed to calculate the CMRglc from the model parameter estimates and the "cold" glucose level in the blood.

**Hybrid SPECT/PET Instrumentation:** The Philips-ADAC Vertex MCD/AC system, which is a hybrid SPECT/PET camera, was used for this study. The "hybrid" PET systems were developed in the last few years as a less expensive alternative to the traditional PET scanners. The basic difference between a "hybrid" and a "dedicated" PET scanner is that the latter utilizes a ring ($360^o$) detector while the former performs the coincidence detection using two opposing, by $180^o$, uncollimated detectors. The hybrid systems can be either in PET mode for coincidence 511 keV detection or they can switch into regular SPECT mode for routine imaging of nuclear medicine radiopharmaceuticals (e.g. brain perfusion). Attenuation correction is accomplished using two Cs-137 sources (662 keV photopeak) that translate axially along the field of view of the detectors and create a transmission map of the attenuation coefficients.

## RESULTS DISCUSSION

In animals that survived the brain injury, the ICP showed a large increase immediately after the injury then decreased to only 2X baseline at the time of FDG injection (2-3 hours after injury). But the mean arterial pressure did not change, resulting in a decrease in the cerebral perfusion pressure, and thus a reduced blood flow. The four PET frames of a control animal are shown in Figure 1a-d. Figure 2a-d shows the 4 frames from a TBI animal. The parietal cortex is at the top of the images. Note the defect on the upper left side of the brain in Figure 2(c-d). The TTAC's for the two experiments are shown in Figure 3a and b respectively. Note that there is no difference between the curves from ROI placed over the right and left parietal cortex in the control animal, but in the TBI animal the FDG uptake in the left (injured) side is reduced compared to the right (uninjured) side of the brain indicating reduced glucose metabolism. The curves have been normalized to maximum ROI cps. The resolution of the PET camera is not sufficient for differentiating white matter from gray matter. Therefore, the FDG uptake curves are representative of global glucose kinetics on either the right or left side of the brain. In this study we obtained dynamic PET images from a dual-head rotating camera and performed offline image processing using the Matlab© imaging toolbox. From the attenuation corrected dynamic images, TTAC's were generated. Cerebral glucose metabolism was estimated from the TTAC and the PTAC using the Matlab© optimization toolbox. The shape of the TTAC curves depends on the actual FDG activity injected, the animal's blood volume, the severity of the injury and the endogenous blood glucose concentration. In the experiments to date, there was not a significant difference in the glucose metabolism between the control and test animals. However, in a subset of test animals in which the dura was removed prior to injury, there appeared to be a decrease in uptake by the left (injured) side compared to the right side (Figures 2 and 3b).


## ACKNOWLEDGEMENTS

Supported by the American Heart Association, Fl/PR Affiliate.


## REFERENCES


[1] Lau, C.H., et al., Dynamic imaging and tracer kinetic modeling for emission tomography using rotating detectors. IEEE Trans Med Imaging, 1998. 17: p. 986-94.

[2] Phelps, M.E., et al., Tomographic measurement of local cerebral glucose metabolic rate in humans with (F-18)2-fluoro-2-deoxy-D-glucose: validation of method. Ann Neurol, 1979. 6: p. 371-88.


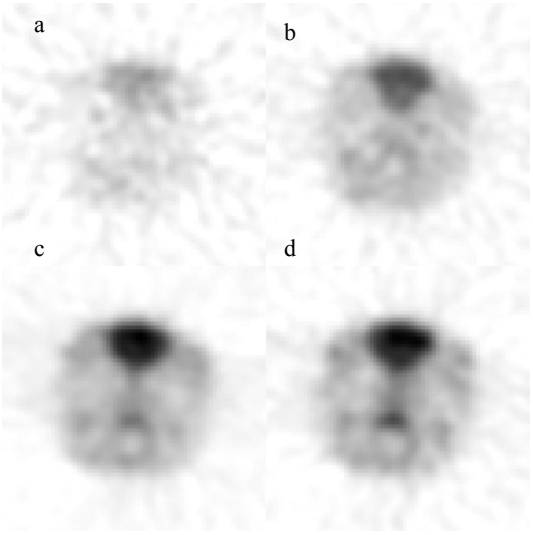


**Figure 1a-d: PET frames 1-4: Control experiment.**

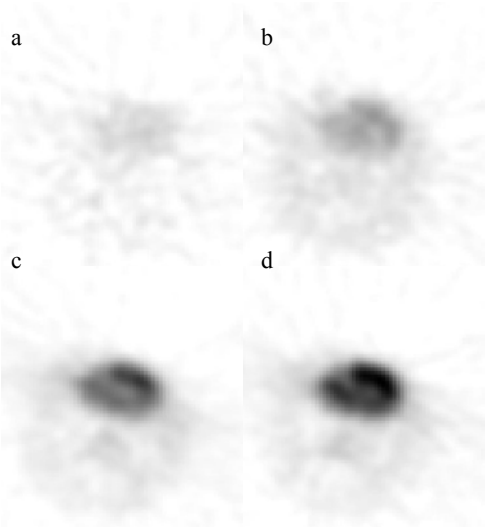


**Figure2a-d: PET frames 1-4: Test experiment.**

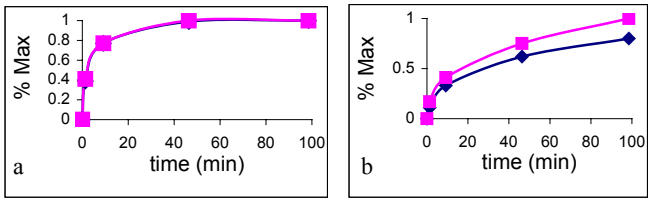


**Figure 3a-b: TTAC curves for control and test study respectively. Squares=Right, Triangle=Left.**