TEHRAN UNIVERSITY OF MEDICAL SCIENCES

TUMS PRECLINICAL CORE FACILITY (TPCF)

MICRO-PET AND MICRO-SPECT IMAGING AND APPLICATIONS

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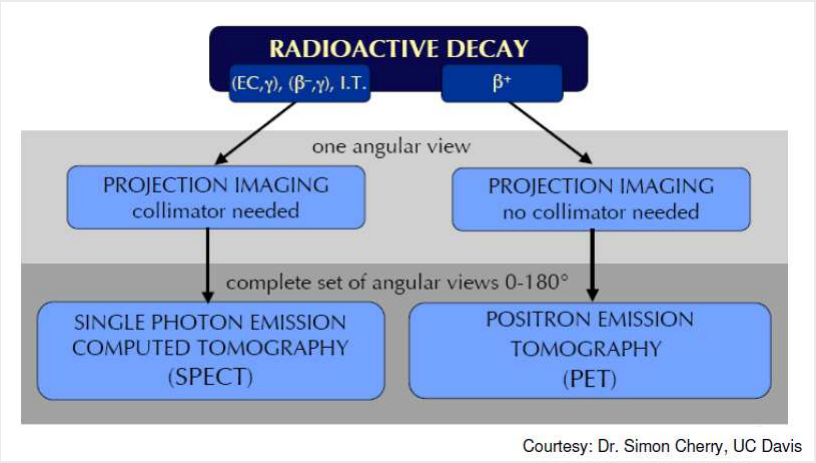
TPCF Workshop

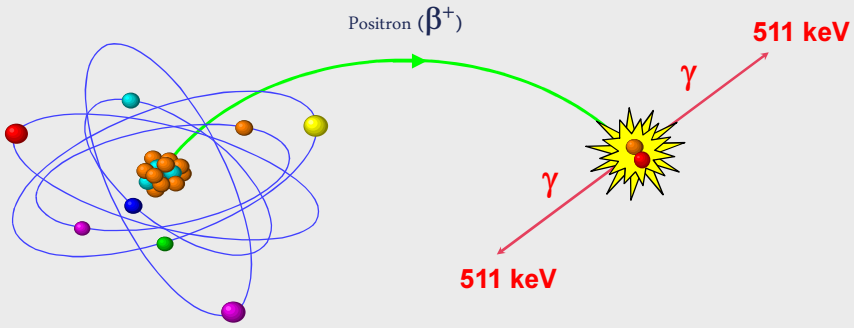
May 28th-29th 2019, Manila, Philippines

Forms of Nuclear Imaging



Courtesy: Dr. Simon Cherry, UC Davis

PET Physics: Positron Decay



The radioisotope emits a positron. The positron produced interacts with an electron. A reaction transforms the two particles into two photons of 511 keV emitted in exactly opposite directions.

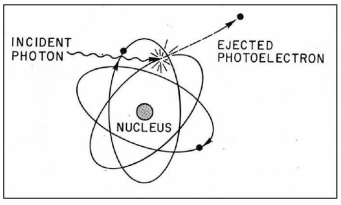
Photon Interactions

Physical interactions

Photoelectric effect

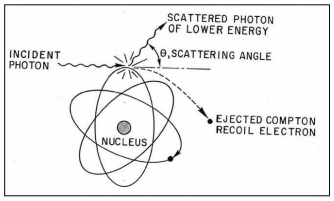
Atom completely absorbs energy of incident photon

Absorbed energy is used to eject an orbital electron from the atom - photoelectron

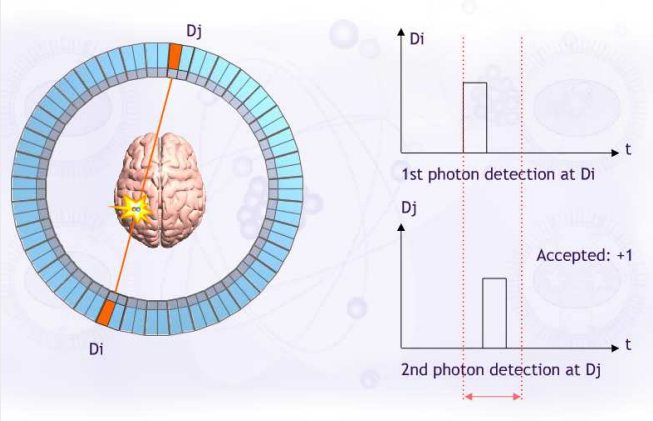


Compton Scattering

Collision between a photon and a loosely bound outer shell orbital electron of an atom

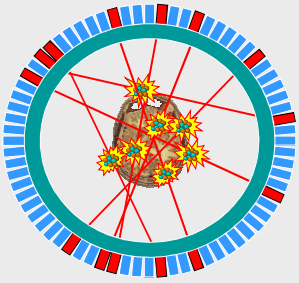


Coincidence Detection



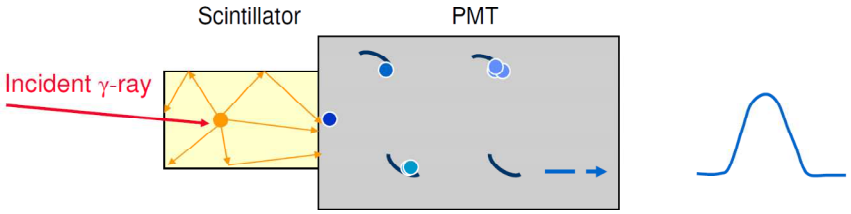
PET Data Acquisition

Detector ring



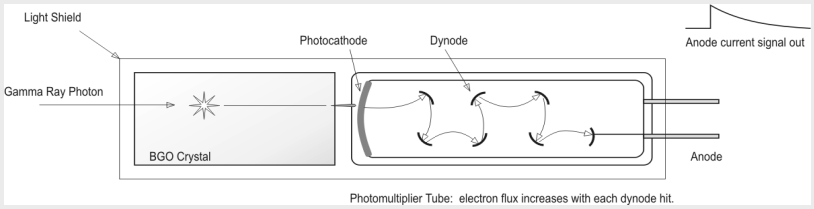
The response lines joining the detector pairs having recorded coincidence events are used for clinical data reconstruction

PET gamma-ray detector principle



Scintillator converts gamma rays into light

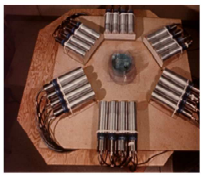
Light detector converts light into electronic signal

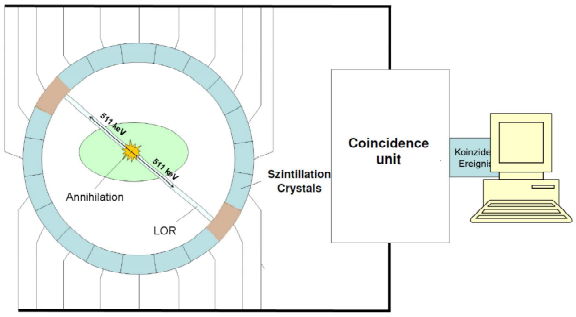


Tubes? Why are we using tubes?

- High Gain (>1,000,000)
- Low-noise signal
- Fast timing response
- Small timing variance

Operation of a PET Scanner





- Coincidence detection defines line along which positron emission occurred (LOR)
- No need for collimators (tungsten/ lead) – electronic collimation
- Coincidence unit needs time window in the nanosecond range

Commercial Small Animal PET Scanners

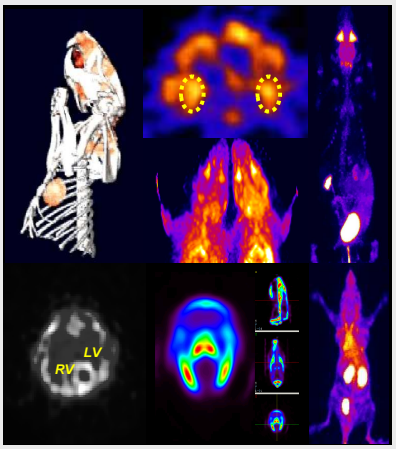
Pre-Clinical PET Applications

Oncology
- Tumor biology
- Metastasis
- Therapeutic effect

CNS
- Receptor density
- Occupancy studies

Disease biology
- Metabolic function
- Gene expression
- Cell trafficking

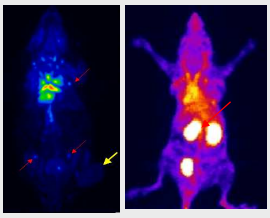
Cardiovascular disease
- Vascular disease & development
- Injury/repair



Policlinico S.Orsola, University of Bologna
Martin Pomper, Johns Hopkins

PET :Versatile applications

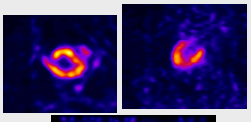
High sensitivity for superior organ-specific imaging
High resolution and uniformity for whole body imaging

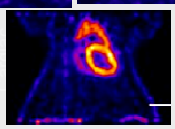


Greater sensitivity

Flexibility

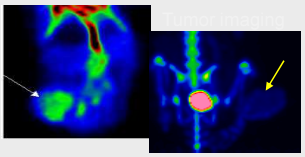
Higher resolution



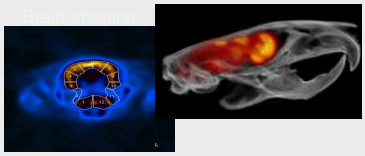


Resolution uniformity

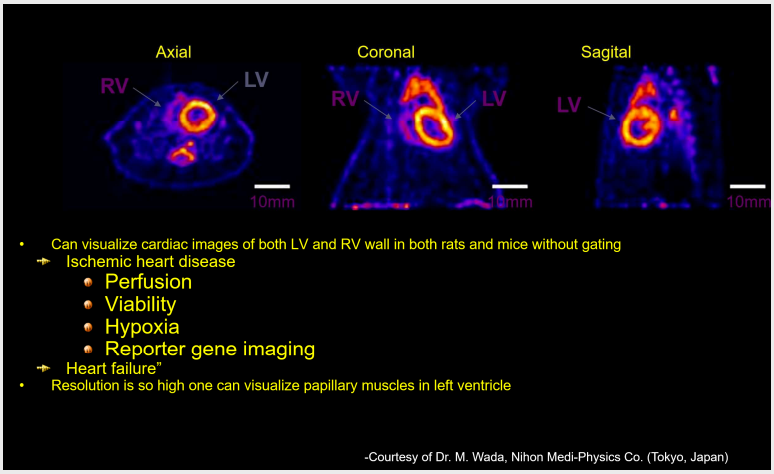
Tumor imaging



Brain imaging



Cardiology – Viability Model



- Can visualize cardiac images of both LV and RV wall in both rats and mice without gating
  - Ischemic heart disease
    - Perfusion
    - Viability
    - Hypoxia
    - Reporter gene imaging
  - Heart failure"
- Resolution is so high one can visualize papillary muscles in left ventricle

-Courtesy of Dr. M. Wada, Nihon Medi-Physics Co. (Tokyo, Japan)

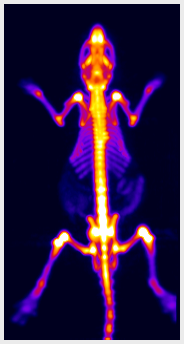
Influence of Reconstruction Algorithms

F18-Fluoride Whole Body Mouse - Bone

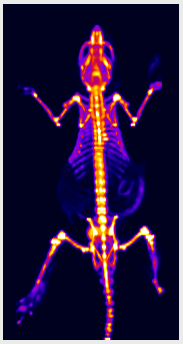
Protocol:

30 gm mouse
100 µCi F18 Fluoride
45 min uptake
3 bed positions
20 min / bed position
4 slice overlap
3D OSEM (20 min/bed position)

FBP Reconstruction



3D-OSEM Reconstruction



Detector Design Challenges in PET

APD

High spatial resolution

PMT

High sensitivity

What is the most important?

It depends on the kind of experiment?

Recover details (e.g. bone scan)

Small lesion detection

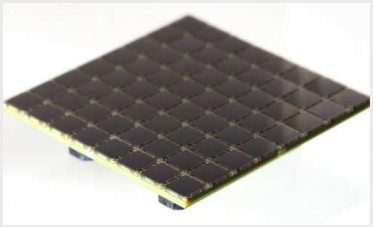
Short scan (dynamic & gating)

Fine organ tissue activity uptake

Broad organ tissue activity uptake

SiPM Based Animal PET Scanner

We are developing the fast PET electronic and also software. The concept is based on using SiPM.



Animal PET Detector Concept

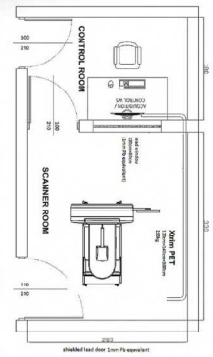
PNP preclinical solutions are removing the limits on driving medical research from the laboratory to the clinic. Xtrim provides the high performance and versatility available to address your preclinical imaging research needs. From basic science and disease progression, to drug discovery and development, Xtrim offers an unrivaled solution for optimizing your research outcoms.

Xtrim Animal PET Scanner

Scanner Specifications

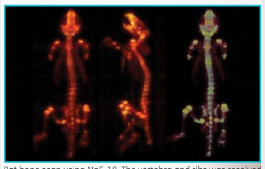
Characteristics	
Single bed axial FOV	5cm
Number of detector rings	24
Transaxial FOV	100mm
Bore opening	110mm
LYSO crystal size	2mm×2mm×10mm
Crystal pixel pitch	2.1mm
Total number of crystals	5760
Spatial Resolution	1.7mm @ center
Energy Resolution	17%

Room Requirements	
Minimum room size	10m²
Single phase operation	220V
Size (W×D×H)	120cm×140cm×180cm
Weight	250kg
Standard air condition	20-25°C

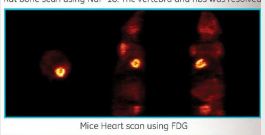


IEC 61010-1:2013
IEC 61326-1:2005

Animal Imaging Example

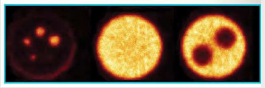


Rat bone scan using NaF-18. The vertebra and ribs was resolved

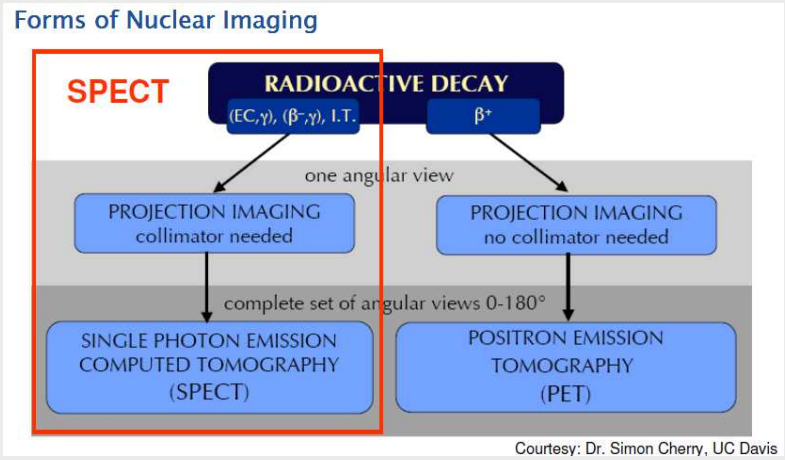


Mice Heart scan using FDG

NEMA Image Quality Phantom



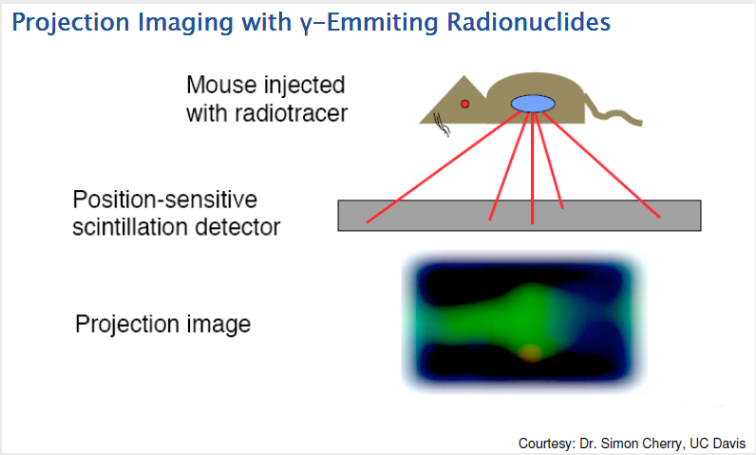
SPECT Principal



Courtesy: Dr. Simon Cherry, UC Davis

SPECT Principal

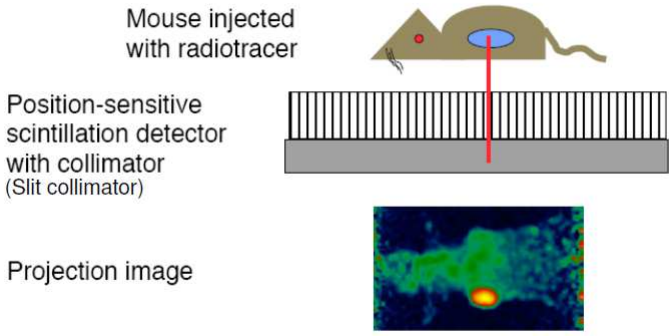
Projection Imaging with γ-Emmiting Radionuclides



Courtesy: Dr. Simon Cherry, UC Davis

SPECT Principal

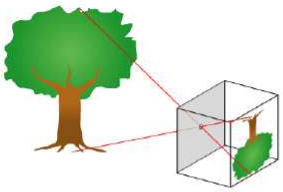
Parallel-Hole Collimation



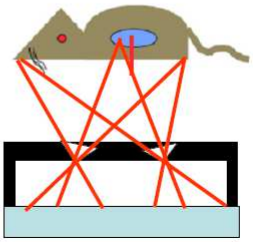
Courtesy: Dr. Simon Cherry, UC Davis

SPECT Principal

Pinhole Collimation



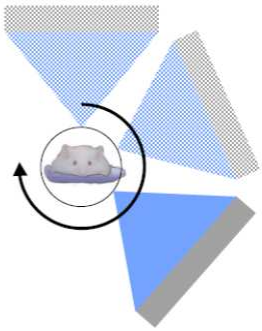
- Like with very first cameras: use pinhole to obtain projection
- Magnification possible due to distance variation
- Multi-pinhole for higher sensitivity



SPECT Principal

Data Acquisition of a SPECT system

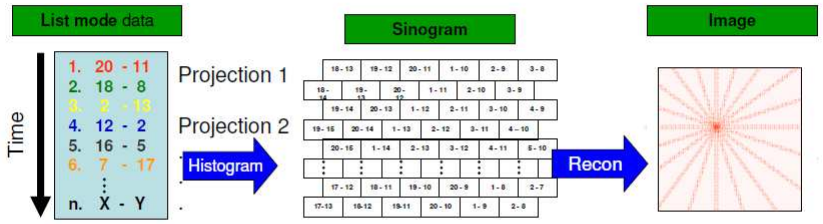
- Rotate imaging system to collect projection views around the object
- Use reconstruction algorithms to determine 3-D distribution of radiotracer
- Multiple pinholes often used to improve sensitivity



Courtesy: Dr. Simon Cherry, UC Davis

SiPM Based Animal PET Scanner

Workflow of Static SPECT Acquisitions



Considerations:

- Dynamic framing is in theory determined by the time for one revolution
- Different Pinhole configurations allow for choice of different sensitivity and image resolution
- More pinholes , lower resolution → higher sensitivity

High Resolution SPECT

HiReSPECT is a Dual Head Small Animal SPECT (Single Photon Emission Computed Tomography) imaging system that provides in vivo high resolution three-dimensional (3D) images of physiological functions in small laboratory animals.

HiReSPECT Platform

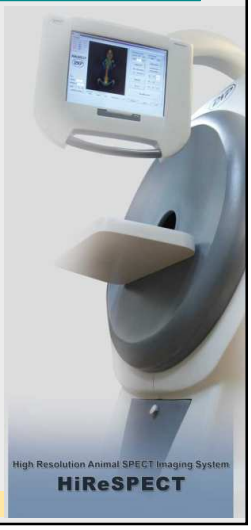
Detector Architecture

The HiReSPECT pre-clinical system detector design includes the latest technology for detection of gamma radiation with high accuracy including pixelated scintillator crystal with the FOV of 50x100 mm and position sensitive H8500 PMT.

Integrated Front End Electronic

HiReSPECT's versatile data acquisition electronics provides optimal SPECT performance on a platform designed as a true molecular imaging system.

Networked computers embedded in the gantry coordinate SPECT data acquisition, and an innovative new nuclear pulse processing and event handling architecture for high resolution, high count rate gamma ray processing



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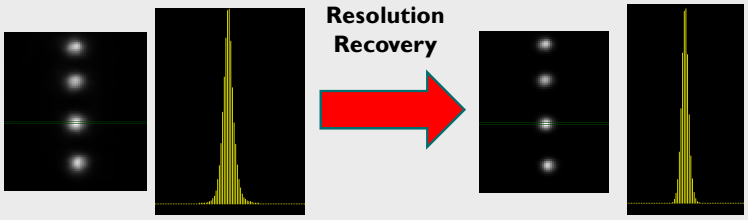
HiReSPECT Image Reconstruction

Image Reconstruction

The HiReSPECT system uses a newly developed accelerated iterative reconstruction algorithm with adjustable percentage of resolution recovery using accurate modeling of collimator detector response.



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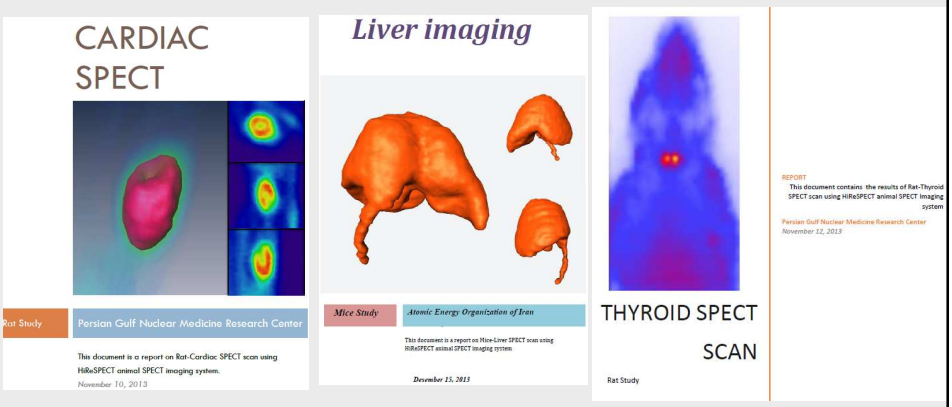
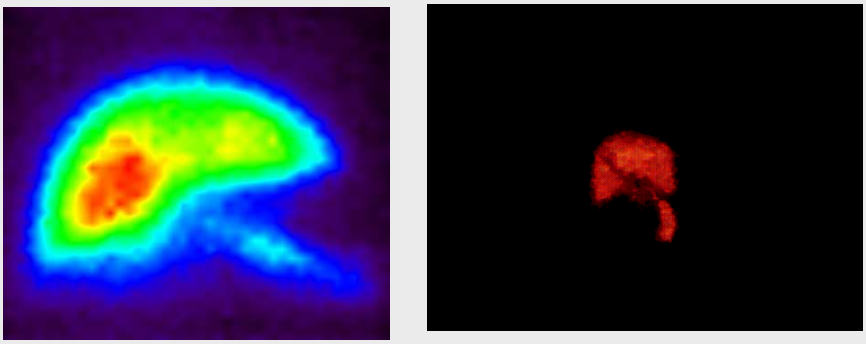
Some Typical SPECT Images

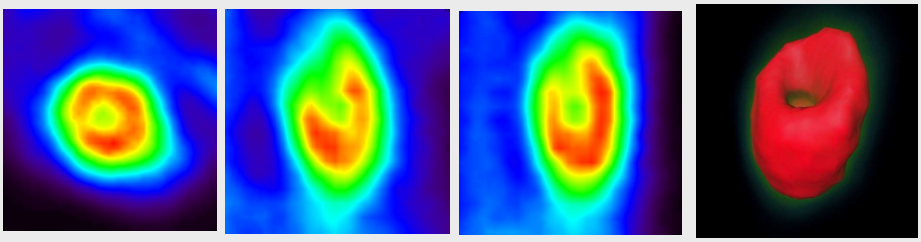


Images from our Studies in TPCF



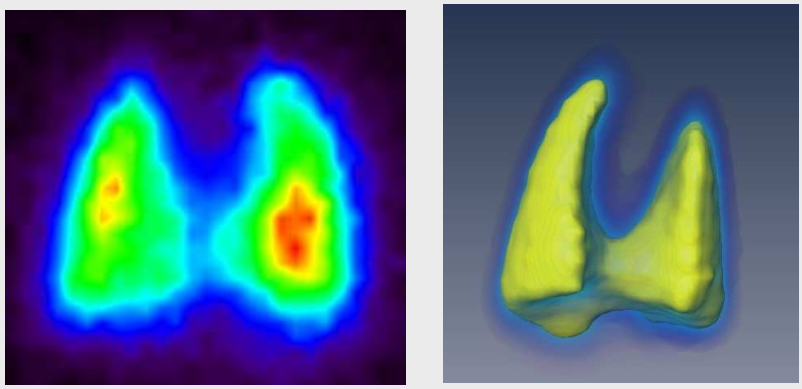
- SPECT scan of rat's liver with ^{99m}Tc-PHYTATE

Images from our Studies in TPCF



- Cardiac SPECT scan of rat with ^{99m}Tc-MIBI

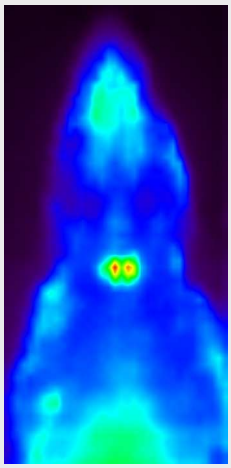
Images from our Studies in TPCF



- SPECT scan of rat's lung with ^{99m}Tc-MAA

Images from our Studies in TPCF

- SPECT scan of rat's thyroid with ^{99m}Tc



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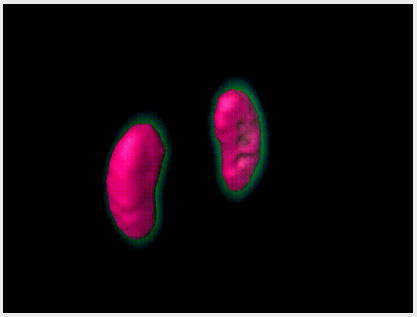
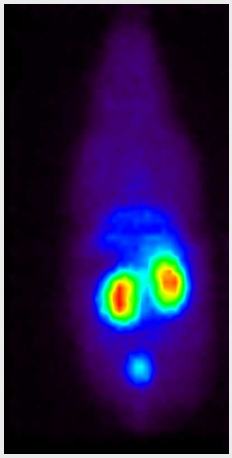
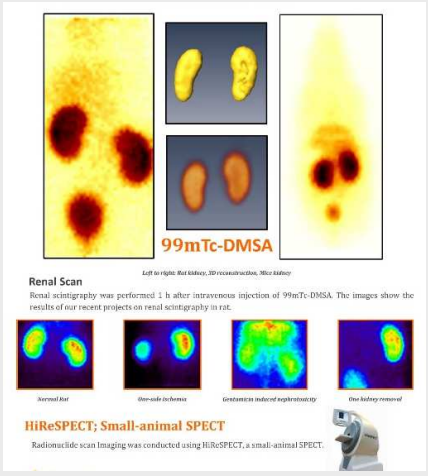
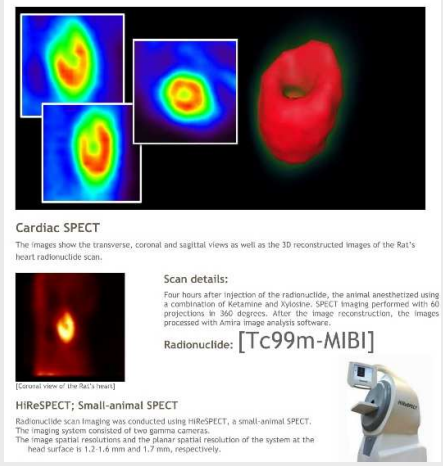




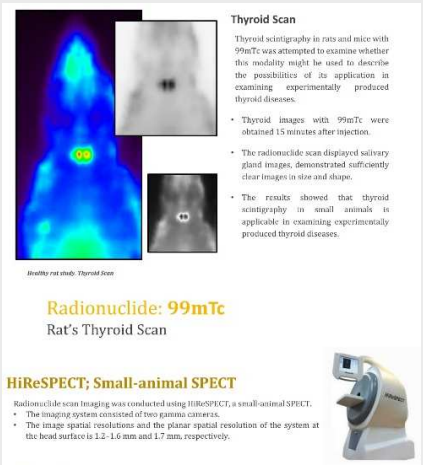
- SPECT scan of kidney with ^{99m}Tc-DMSA

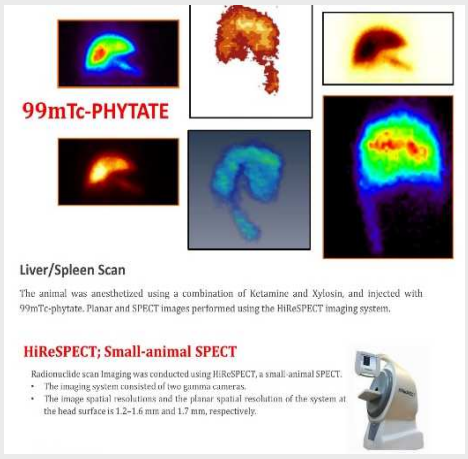
Typical Quantitative Report



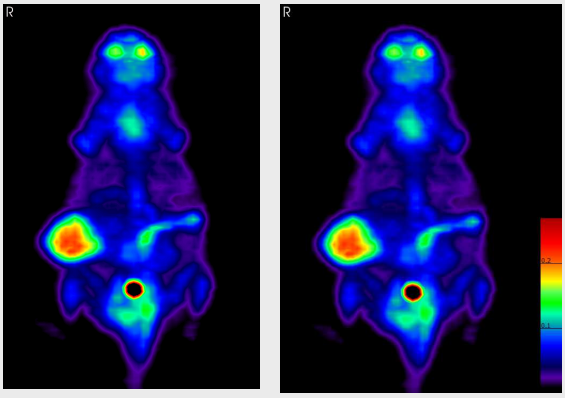


Typical Quantitative Report



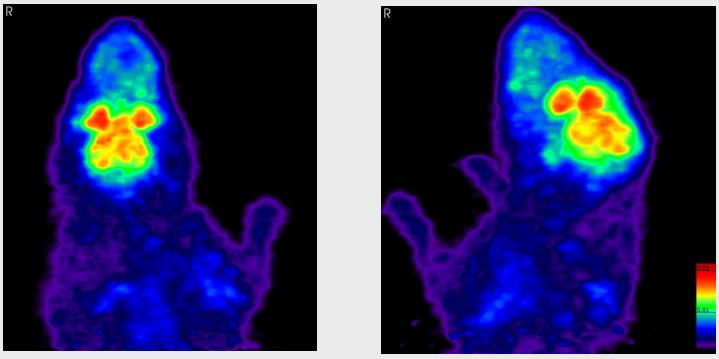


Images from our Studies in TPCF



- PET scan of a C57 mice with melanoma tumor using ^{18}FDG. The image shows the size of the tumor and radionuclide uptake.

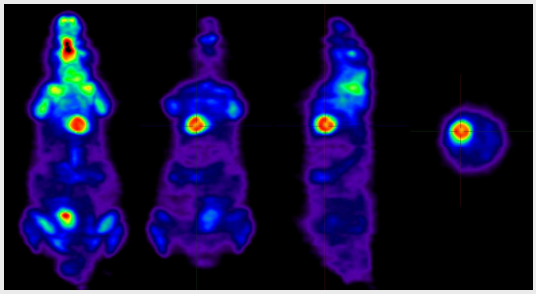
Images from our Studies in TPCF

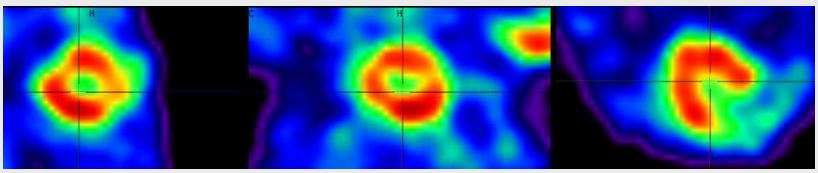


- PET scan of rat with Glioblastoma (GBM) tumor using ^{18}FDG.

Images from our Studies in TPCF

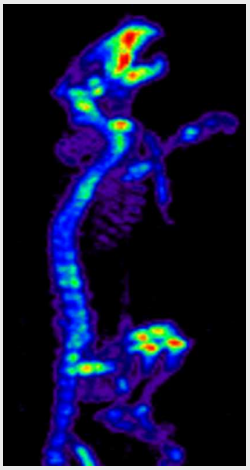
- Cardiac PET scan of rat using ^{18}FDG.





Images from our Studies in TPCF

- Bone scan



	Quantitative Analysis Report	Doc. No.:
		Project No.: I97-067
		Date: 1397.10.26

Materials and Methods:

Small-Animal PET Imaging and Image Analysis:

The small-animal PET scans were obtained with a micro-PET scanner (Xtrim PET). Mice were each injected via the tail vein with about 100 µCi of the ^{18}FDG under general anesthesia. For each small-animal PET scan, 3-dimensional regions of interest (ROIs) were manually drawn over the abdomen area on whole-body coronal images. The ROI's were converted to the activity uptake ratio as: 100 * (ROI counts) / (total body counts – ROI counts).

Results:

Small-Animal PET Imaging

Table 1 – The amount of the radionuclide uptake ratio of the selected ROIs for each mouse. The uptake ratio calculated as 100*(ROI counts) / (Total body counts - ROI counts).

Radionuclide Uptake Ratio (%)					
11.9.1397		18.9.1397			
Normal	Tumor	N1	N2	T1	T2
22.31	60.09	14.65	16.82	30.13	30.6

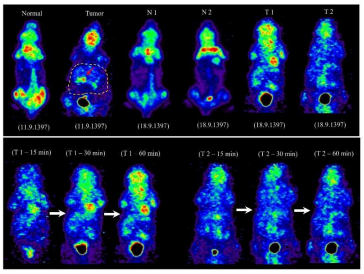
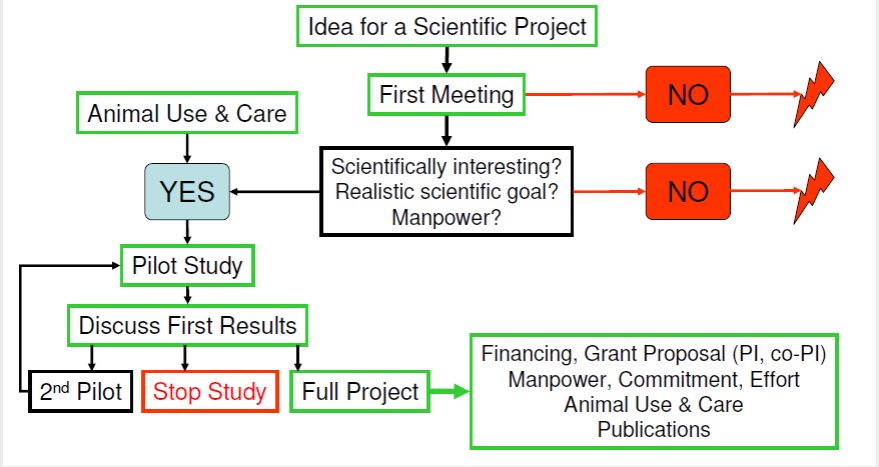


Figure 1 – Representative small-animal PET images for each mouse 1 hour after injection of FDG. The Red arrow indicates the higher amount of radionuclide uptake (Tumor). The yellow dash line shows the selected region of interest (ROI).

Quantitative Analysis Report

Organizing a Research Collaboration



Thanks for Your Attention

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