Functional Imaging FDG

S. Gambhir
Nuclear Medicine
SGPGIMS, Lucknow
COINCIDENCE IMAGING

**Positron Decay**

\[ ^{18}\text{F} \rightarrow e^+ \]

**Positron Annihilation**

- Two 511 keV photons
- Emitted *simultaneously*
- 180° apart

\[ e^+ + e^- = 180° \]
PET tracers annihilate with emission of two 511 Kev gamma rays emitted at 180 degree apart.
PET RADIOPHARMACEUTICALS

PET tracers in Oncology.

- Fluodeoxyglucose F-18
- Water O-15
- Sodium acetate C-11
- Carbon monoxide C-11
- Fluoride F-18
- Methionine C-11
- Thymidine C-11
- Ammonia N13
FLUORINE-18 FLUORODEOXYGLUCOSE (F-18 FDG)

Extracellular

Glucose

FDG

Intracellular

Glucose

Hexokinase

FDG

Hexokinase

G-6-Phosphatase

FDG-6-P

Metabolic pathway of glucose and $^{18}$F FDG
Oncological PET

HCFA / CMS Approved

Lung
Malignant Lymphoma
Colorectal
Malignant Melanoma
Esophagus
Head & Neck Cancer
Breast
Brain

Melanoma
Pancreas
Bone & Soft Tissue
Ovarian Cancer
Thyroid Ca.
Imaging Function with $[^{18}F] - FDG$

Normal FDG-PET Scan
What is an FDG-PET scan?

• It is not a cancer scan
  – Wide range of potential false positive and false negatives

An FDG-PET scan is:
• A map of glucose metabolism in the body
  – In 3D space (spatial domain)
  – At a particular time (temporal domain)
    • Dual time point imaging
      (DDx cancer vs infection)
Role of FDG-PET in oncology

- Shown to be more accurate than conventional staging and restaging in a range of malignancies
  - Upstage cancer – reduces futile and toxic therapies (also cost savings)
  - Downstage cancer – allows more therapeutic options
  - More accurately restage and assess treatment response of cancer
Tumours with low FDG uptake or otherwise difficult to visualise on PET scans

- BAC lung
- Mucinous adenocarcinomas
- Carcinoid
- Low grade sarcoma
- Some low grade lymphomas esp MALT, SLL
- Hepatocellular carcinoma
- Cerebral metastases
- Prostate
- Renal
SUMMARY OF EVIDENCE FOR FDG PET IN LUNG CANCER

For Staging:
• An estimated 37% change was noted in management effect, based on 1,565 patient studies

COLON CANCER

Metastatic Colon Cancer
Advantages of Nuclear Medicine?

- Metabolic imaging
- Quantitation is possible especially with PET
- PET provides ideal solution to quantitate tumor biological parameters such as metabolism, receptor quantity, cell proliferation and uptake of therapeutic agents.
EVALUATING TREATMENT RESPONSE

- Tumor response to chemotherapy:
  - Biologic and metabolic decrease in metabolic function and trapping of radiopharmaceuticals occurs:
    - Very early after initiation of treatment
    - Precedes clinical decrease in tumor size
    - Precedes decrease in size detected by X-ray, CT or MRI.
- Important to be evaluated early in the course of treatment in order to either continue on same chemotherapy or change to a different regimen before bone marrow depression.
NHL Pre-chemotherapy
NHL Post-chemotheray
FDG-PET PREDICTION OF RESPONSE TO NEOADJUVANT CHEMOTHERAPY IN CARCINOMA OF THE GE JUNCTION

FDG-PET PREDICTION OF RESPONSE TO NEOADJUVANT CHEMOTHERAPY IN CARCINOMA OF THE GE JUNCTION

Baseline

Day 14

Responder

Non-responder

METABOLIC RESPONSE TO GLEEVEC IN GIST
DANA-FARBER CANCER INSTITUTE
OTHER PET APPROACHES FOR ASSESSING RESPONSE TO THERAPY

- Monitoring
  - Blood flow
  - Amino acid metabolism
  - DNA synthesis (proliferation)
  - Apoptosis
- Predicting
  - Chemotherapeutic agents
  - MDR substrates
  - Hypoxia tracers
  - Receptor ligands
PREDICTING RESPONSE OF ADVANCED BREAST CANCER TO HORMONAL THERAPY

- Hormonal therapy
  - Low morbidity alternative to chemotherapy
  - Only 50-60% of patients with ER+ breast cancer respond to hormonal therapy
  - Suggests that receptors not always functional
- Hypothesis: FDG-PET can be used to define functional estrogen receptors by detecting metabolic response to receptor agonist
**PREDICTING RESPONSE TO HORMONAL THERAPY**

"Metabolic Flare"

- FDG-PET before and after 7-10 days tamoxifen in 40 pts. with advanced ER+ cancers
- With change ≥ 10%:
  - PPV 91%
  - NPV 94%
  for predicting response

Mortimer, et al. JCO 2001; 19:2797
BREAST CARCINOMA: THERAPY FDG-PET PREDICTING OF RESPONSE TO HORMONAL

Before Hormonal Therapy | After Hormonal Therapy
---|---
Responder

SUV=4.7 | SUV=7.5

Non-responder

SUV=5.7 | SUV=5.5
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Monitor the response of tumors to antiproliferative treatment

3'-Deoxy-3'-[18F]fluorothymidine ([18F]FLT)

FLT is a substrate for thymidine kinase (first step in DNA synthesis)

F-18 FLT shows regions of cell proliferation

Compare with Ki-67 (MiB-1) immunoperoxidase stain
The Role of Hypoxia in Clinical Response to Stereotactic Radiosurgery in Head and Neck Cancer (Drs. Lai, Grandis)

Hypoxia Tracer Development
F-18 Fluoromisonidazole (F-18 FMISO)

Hypoxia reduces tumor sensitivity to radiation therapy and chemotherapy
Left. MicroPET images show increased FDG uptake in the anterior metabolic portion of the tumor, while FMISO uptake was increased in the posterior hypoxic portion of the tumor.

Right. Time-activity curves of tumor uptake.
Ethmoid Sinus Carcinoma – CT and PET contours for tumor areas depicting anatomic and functional abnormalities

GTVc = gross tumor volume on CT
GTVp = gross tumor volume on PET
CT and PET contours for nodal areas depicting anatomic and functional abnormalities.

ABNc = abnormal nodal region on CT; ABNp = abnormal nodal region on PET.

Additional areas of FDG avidity on PET, not discernable as abnormal on CT.
21 patients were simulated for treatment on PET-CT for IMRT in Varian Eclipse planning system

Volumes for the primaries were larger anatomically (CT) compared with PET

In 8/21 patients, additional areas of disease were seen on PET compared to CT
CT/PET Image Fusion

- Guide surgery or biopsy
- Oncology
  - fibrosis vs. active tumor
  - evaluation of therapy response
  - uptake of FDG vs. size on CT
- Radiotherapy Applications
  - Tailor field size to viable tumor
  - Assessment of residual mass on CT post therapy
Clinical Integration

From Imaging to Planning to Therapy
Therapy Connectivity

- Therapy Connectivity
  - PET and CT DICOM
  - Established connectivity with:
    - Varian, Nomos, Nucletron...etc
Limitations of PET

General Limitations:

High cost.
Require large space.
High training for the operating staff is a must.

Specific Limitations:

FDG-is a non-specific agent.
False positive uptake in granulomas.
Difficult to interpret in areas of normal uptake.
Depend on glucose transport, that’s why not sensitive in mucine & mucinous secreting tumors.