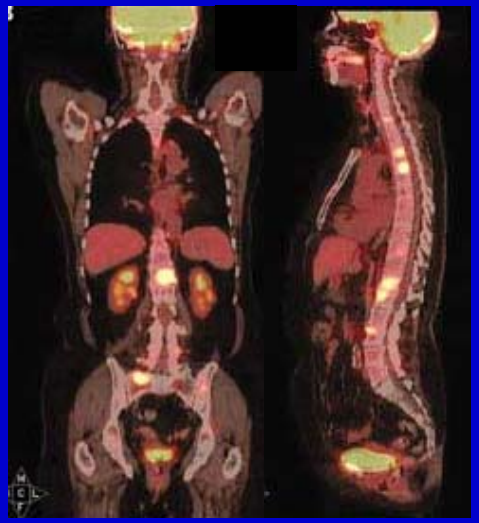

PET/CT: Basic Principles, Applications in Oncology

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Overview

- PET – Basics and Limitations
- PET/CT - Advantages and Limitations
- Applications of PET/CT in oncology
- Summary

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Principles of PET

- PET = Positron Emission Tomography
- Functional or metabolic assessment of tissue
- Used in neurology, cardiology, oncology

Principles of PET

- Choose biologically important molecule
- Label with positron-emitting radiotracer
- Infuse in patient
- Certain tissues take up molecule
- PET scanner detects location molecule in body as tracer decays

Principles of PET

- Many molecules to choose from
  - glucose, thymidine, methionine, estradiol, annexin V, etc.
- Positron-emitting radiotracers produced in cyclotron
  - Expensive
  - Practical obstacles to obtaining labeled molecule

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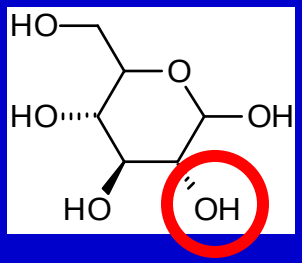
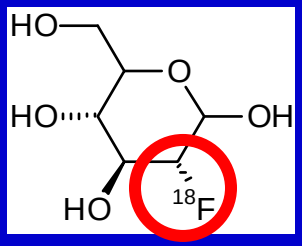
PET in Oncology

- FDG (^{18}F-fluorodeoxyglucose): Glucose analog
  - Most commonly used oncologic PET tracer
  - Non-specific: All glucose-utilizing tissues take up FDG
  - Once taken up, FDG becomes “metabolically trapped”

glucose



FDG



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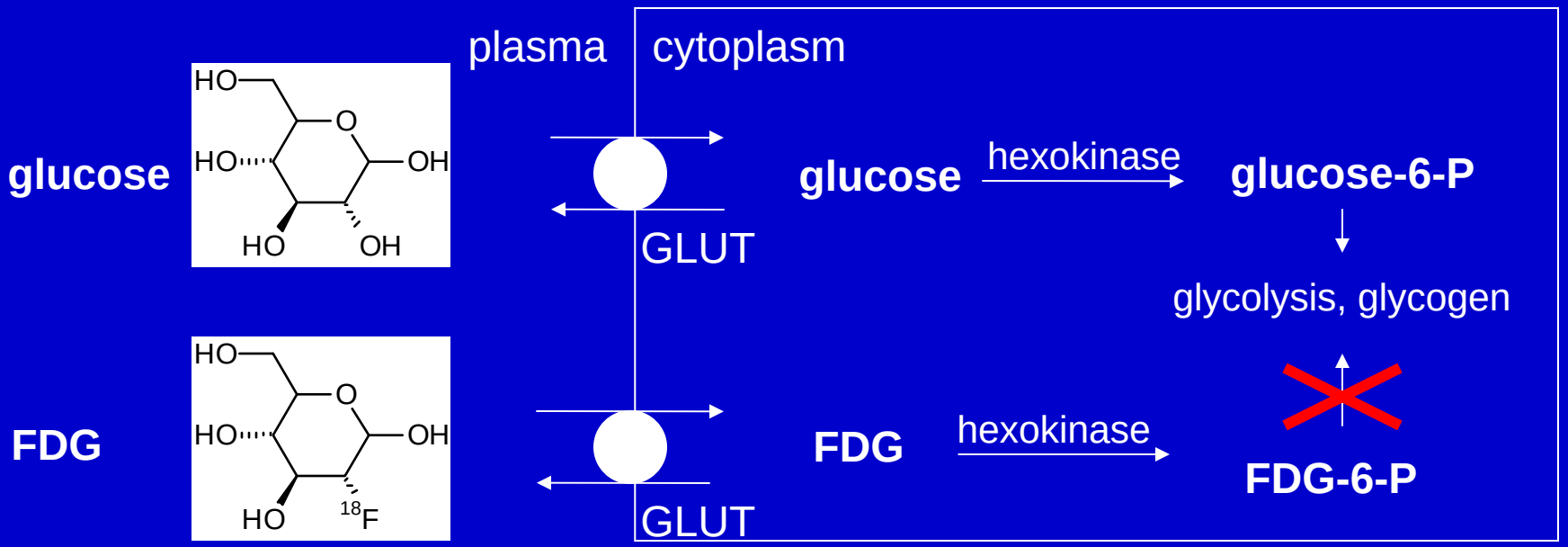
Metabolic Trapping of FDG



- FDG-6-P unable to undergo glycolysis/glycogen formation
- FDG-6-P too polar to diffuse out of cell
- Thus becomes “metabolically trapped”

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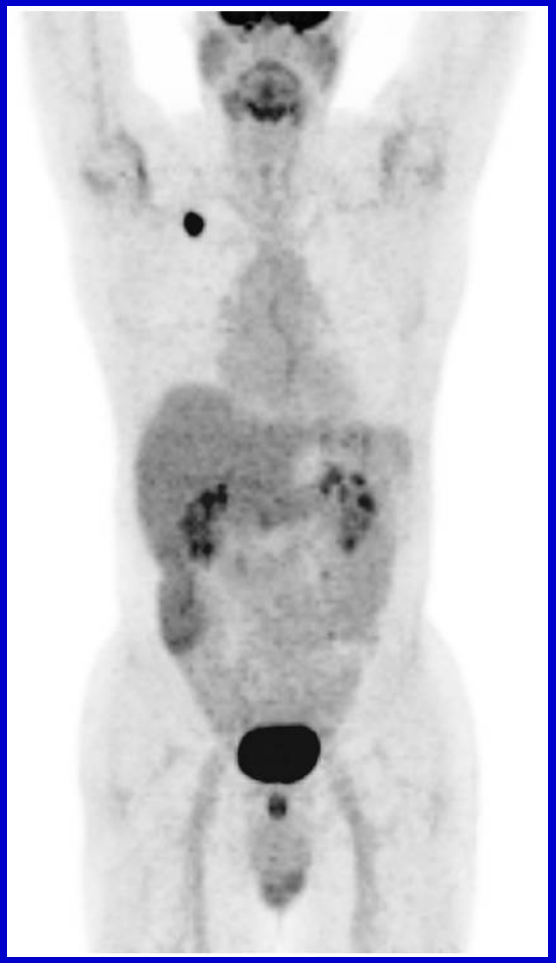
FDG uptake in Normal Tissues

- Brain
- Heart
- Skeletal muscle
- Larynx
- GI tract:
  - Stomach, Colon, Liver
- GU tract:
  - Kidneys, Ureter, Bladder
  - Uterus during menstruation
- Bone marrow
- Thyroid
- Spleen
- Salivary gland
- Brown fat

Patient #1



Coronal PET scan

Courtesy of Maryellen Sun, MD

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FDG Localizes Tumors

- Increased uptake FDG in tumor
  - Elevated levels of GLUT
  - Elevated levels of hexokinase
  - Increased rates glycolysis
- Area of hypermetabolism- “hot spot”
- Useful for cancer staging
  - lung, colorectal, esophageal, stomach, head and neck, cervical, breast, melanoma, lymphoma

Patient #1

Coronal PET scan

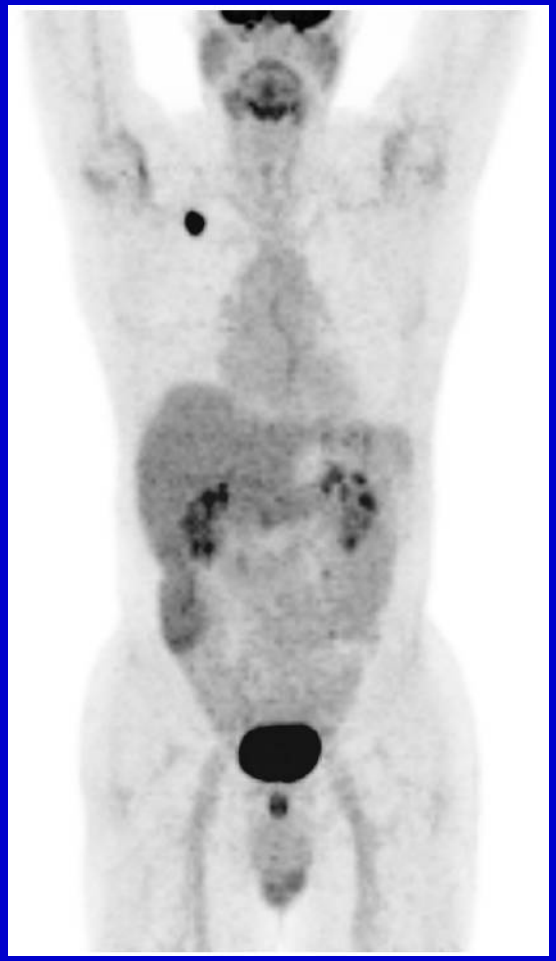
Courtesy of Maryellen Sun, MD

Mabel Djang, HMS III
Gillian Lieberman, MD

Limitations of PET

- Not all malignancies are FDG avid
  - Prostate cancer
- Not all FDG avid tissue is malignant
  - Normal tissue uptake can vary
  - Inflammation→ infection, post-rad/surg, granulomas, arthritis
- Poor resolution of images
- Lack of anatomic landmarks

Patient #1



Coronal PET scan

Courtesy of Maryellen Sun, MD

Emergence of PET/CT

- PET and CT provide complementary information
  - PET provides functional information but little anatomic detail
  - CT provides anatomic and morphologic information (size, shape, density of lesions) but provides little physiologic insight into tissues

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Emergence of PET/CT

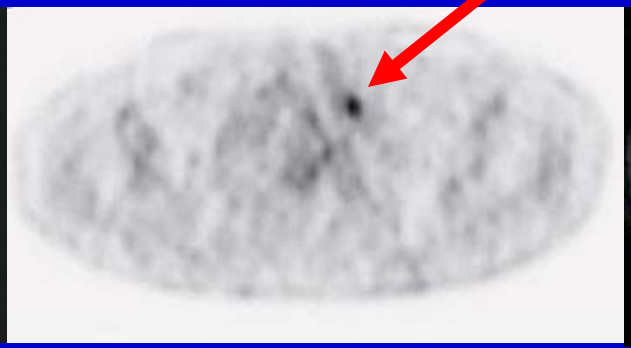
- Early attempts at synthesizing information suboptimal
  - Attempts at viewing images side-by-side problematic

Patient had non-small cell lung cancer with axial CT, PET, and PET/CT images through the apex of thorax shown below. Focal area of hypermetabolism found on PET; however, exact localization of lesion proved difficult. PET/CT allowed for exact localization- node was removed of the node, metastatic disease was found, and patient was started on chemotherapy.

Normal sized lymph nodes

Yet focus of hypermetabolism

Axial CT through apex of thorax



Axial PET through apex of thorax

Fused PET/CT axial image

Lardinois, D. et al. N Engl J Med 2003;348:2500-2507

Emergence of PET/CT

- Attempts at software fusion: synchronization problems
- Solution: PET & CT in 1 scanner
  - Simultaneous data collection in 1 gantry optimizes data integration
  - Invented in 2000 by Dr. David Townsend
  - 2003: BIDMC first hospital in Massachusetts to install PET/CT

Advantages of PET/CT

- Better localization of FDG-avid tissue
  - Both malignant and benign
- Evidence of increased diagnostic accuracy
- Overall decreased scan time compared with PET
  - 30 minutes rather than 60 minutes = increased pt comfort

Challenges in PET/CT

- CT of PET/CT not of diagnostic quality
  - CT performed at lower radiation to minimize exposure
    - Decreased image quality
  - Current protocol: Breathing motion throughout scan
    - Degrades image quality
  - Oral/IV contrast problematic → image artifacts
    - But without contrast, delineation of anatomic detail not as good in CT

Applications of PET/CT in Oncology

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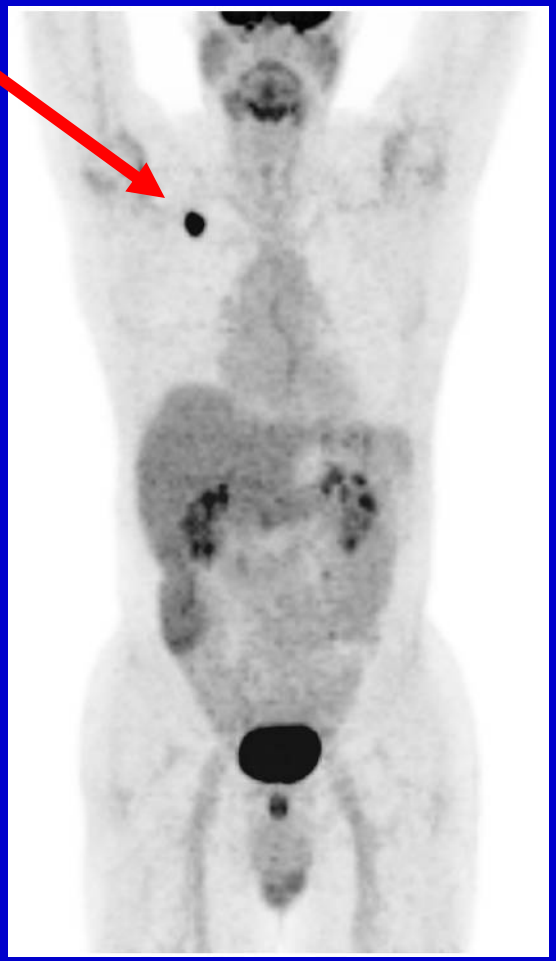
Application #1: Cancer Staging and Restaging in our patient, 58M with lymphoma



Before chemotherapy

After chemotherapy

Patient #1

- Area of hypermetabolism regresses after therapy
- Circled areas showed tissues demonstrating variability in normal uptake – NOT spread of lesion

Courtesy of Maryellen Sun, MD

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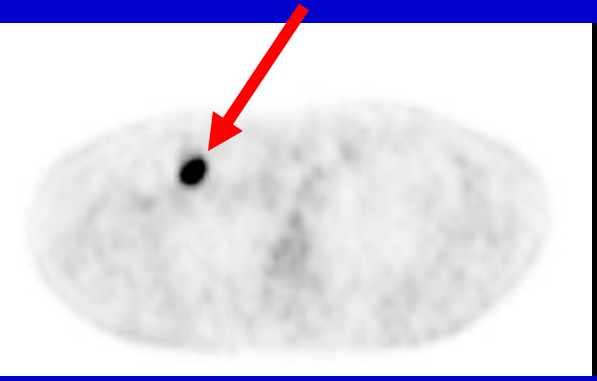
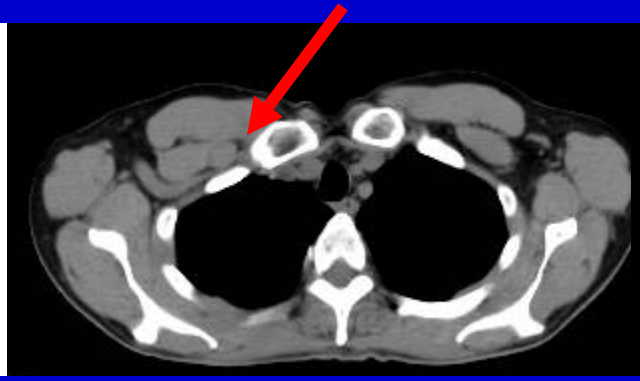
Our patient's PET/CT before and after Tx

FDG-avid area

Enlarged node

FDG-avid lymph node





Axial PET

Axial CT

Axial PET/CT

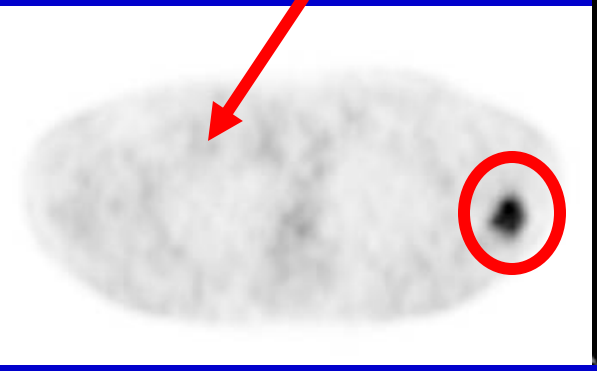
Before chemotherapy

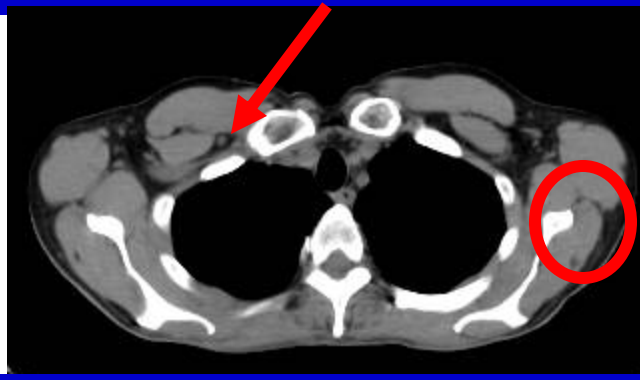
Benign: FDG uptake in active muscle

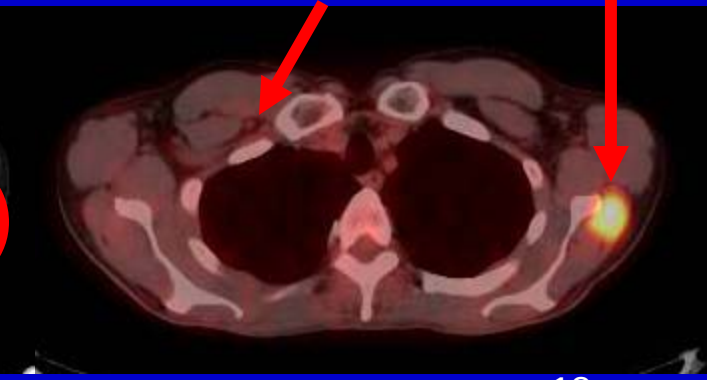
No longer FDG-avid

Normal node

Node has no residual tumor







Axial PET

Courtesy of Maryellen Sun, MD

Axial CT

Axial PET/CT

After chemotherapy

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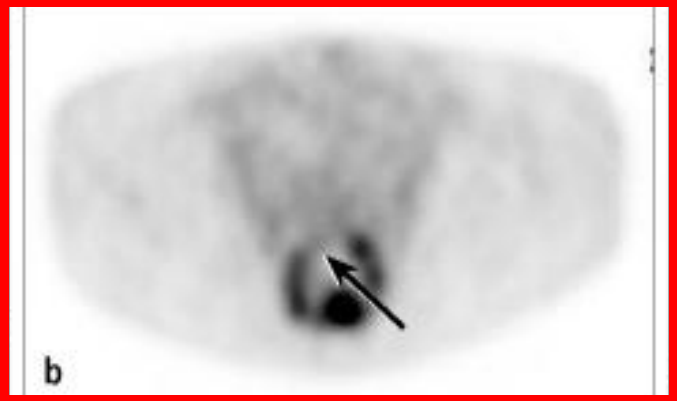
Application #2: Assistance with Biopsy - Companion Patient

Axial CT through sacrum



Axial PET scan through sacrum

Axial PET/CT through sacrum

- CT shows presacral mass
- CT-guided biopsy negative (arrow=biopsy route)
- PET and PET/CT show biopsy bypassed tumor
- Repeat biopsy based on PET/CT revealed tumor

Griffeth LK BUMC Proceedings 2005;18:321-330.

Summary

- Principles of PET
  - Label a biologically important molecule
  - Track its position in the body with a PET scanner
  - Provides metabolic information
- PET in Oncology
  - FDG: Non-specific uptake yet excellent tumor localizer
  - Major limitation: Poor resolution and Lack of anatomic detail
- PET/CT
  - Localizes FDG avid tissue, both malignant and benign
  - Major limitations: Lower CT quality - Breathing motion, Issues with contrast

Summary

- Applications of PET/CT in oncology:
  - Cancer Staging and Restaging
  - Assistance with biopsies
  - Many others…

Thanks to:

- Kalpana Mani, MD
- Maryellen Sun, MD
- J. Anthony Parker, MD, PhD
- Aaron Grant, PhD
- Aaron Thurston
- Pamela Lepkowski
- Gillian Lieberman, MD

http://www.petscaninfo.com/zportal/shared/images/pekingwb.gif

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