RADIATION THERAPY
PLANNING:
WHY PET/CT

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SISTER PATRICIA LYNCH REGIONAL CANCERCTR

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RADIATION

THE GOOD
THE BAD
THE UGLY

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RADIATION THERAPY

- PLANNING
- DELIVERY
TUMOR STAGE IS ONE OF THE MOST IMPORTANT PREDICTORS OF OUTCOME
LOCOREGIONAL RECURRENCE IS THE LEADING CAUSE OF DEATH AFTER PRIMARY RADIATION

LINKED TO INADEQUATE ERADICATION OF CLONOGENIC CELLS
BASIC CONCEPTS: RT

- Radiation induced lethal events – random
- Higher the dose – better results
- Higher dose = more collateral damage
- Dose to tumor – limited by dose to normal tissues
ALL TECHNICAL ADVANCES IN RT HAVE BEEN DIRECTED AT REDUCING THE VOLUME OF IRRADIATED NORMAL TISSUE.
**SMALLER** TREATMENT VOLUME ALLOWS **HIGHER** DOSE TO TUMOR TARGET
“Today’s lesson is about targets of opportunity.”
TARGET VOLUME DEFINITIONS

- **GTV**: GROSS TUMOR VOLUME – VISIBLE EXTENT & LOCATION
- **CTV**: CLINICAL TARGET VOLUME – CORRECT FOR MICROSCOPIC SPREAD
- **PTV**: PLANNING TARGET VOLUME – CORRECT FOR MOTION & OTHER INACCURACIES
Innovative Modalities for Reducing Normal Tissue Exposure

- IMRT – Intensity Modulated RT
- Brachytherapy
  - Mammosite
  - Gliasite
  - Prostate Seed Implantation
- Radiosurgery
- Respiratory Gating
IMRT

- Intensity Modulated Radiation Therapy
- Controls shape of radiation fields for maximum conformal pattern
  - “Shrink-wraps the tumor with the radiation field”
- Controls intensity of the radiation beam across the target to accomplish:
  - Uniformity across tumor
  - Minimal exposure to normal tissue
Benefits of IMRT

- Delivery of a higher tumor dose
- Delivery of a lower dose to surrounding tissue/organs
- 30% increase in dose with decreasing toxicity by 66%
- Improvement in the patient’s quality of life
PRECISE DELIVERY OF RADIOTHERAPY AND ABILITY TO MODULATE DOSE WITHIN A GIVEN VOLUME DEMANDS:

ACCURATE STAGING AND TUMOR IMAGING
IMAGING CHALLENGES

- ACCURATE LOCALIZATION
  - TUMOR vs ATELECTASIS/POST-OP & POST-RT FIBROSIS

- ACCURATE STAGING
  - EXTENT OF PRIMARY, NODAL & DISTANT METASTASES

- IMAGE IN TREATMENT POSITION

- ESTIMATE MICROSCOPIC SPREAD
CT RT SIM

- ACCURATE ANATOMIC LANDMARKS FOR RT BEAM TARGETING
- 3-D VIRTUAL PATIENT
- ELECTRON DENSITY MAP FOR DOSE CALCULATIONS
ANATOMIC IMAGING LIMITATIONS

- Diagnosis based on alteration in anatomy.
- 50% - 80% of patients have residual masses after treatment.
- 30% of recurrences occur in sites of prior disease.
- Tumor recurrence without size change or in normal size nodes.
NSCLC WITH LEFT LOWER LOBE ATELECTASIS
Radiation Treatment Planning

Biologic Target Volume vs. Planning Target Volume
Functional Imaging

- Tumor Burden
  - MRI
  - MRS (choline/citrate)

- Tumor Growth
  - PET (IUDR)

- Hypoxia
  - PET (F-miso)

June 2000 Issue of “Red Journal”
"Please, Ms. Sweeney, may I ask where you're going with all this?"
Radiation treatment planning with an integrated positron emission and computer tomography (PET/CT): A feasibility study

- 39 patients
- GTV changed in 56%
- Therapy changed from curative to palliative in 16%
PET/CT DIRECTED RT PLANNING

BENEFITS

- IDENTIFY AND ACCURATELY LOCALIZE BIOLOGICALLY ACTIVE TUMOR
- SENSITIVITY OF PET>CT IN MOST CANCERS
- WHOLE BODY IMAGING FACILITATES IDENTIFICATION OF DISTANT/OCCULT METS
- DISTINGUISH TUMOR FROM POST-OP, POST-RT CHANGES, ATELECTATIC LUNG
PET/CT DIRECTED RT PLANNING BENEFITS

- HIGH RESOLUTION IMAGING
  - 3-D VIRTUAL PATIENT MODEL
  - ACCURATELY EXCLUDE NON-TUMOR BEARING ORGANS/TISSUES
- MAINTAIN CT DENSITY MAPS FOR DOSE CALCULATIONS
PET/CT DIRECTED RT PLANNING

BENEFITS

- PROGNOSTIC INFORMATION BASED ON PET SUV MEASUREMENTS
- MONITOR/QUANTIFY THERAPY EFFECTS
  - Changes in SUV/tumor size
NSCLC: NODAL EXTENT
OCCULT SECOND PRIMARY:
76 YO MALE H&N CA

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PET/CT DIRECTED RT PLANNING

BENEFITS

- IMPROVED TARGET DELINNIATION

RESULTS IN LESS VARIABILITY IN CONTOUR DEFINITION.
SUBJECTIVE TARGET DEFINITION

- Variability of target volume definition in cervical esophageal cancer.

- Conformal radiotherapy for lung cancer: different delineation of gross tumor volume (GTV) by radiologists and radiation oncologists.

- Clinical variability of target volume description in conformal radiotherapy.
Observer variation in contouring gross tumor volume in patients with poorly defined non-small-cell lung tumors on CT: the impact of 18FDG-hybrid fusion.


“High observer variability in CT-based definition of GTV can occur. A more consistent definition of GTV can often be obtained if coregistered FDG-hybrid PET images are used.”
PET/CT RT SIM Candidates

- Head & Neck
- NSCLC
- Cervical
- Rectal
- Breast – Chest wall
- Lymphoma
- Esophageal
PET/CT SIM Protocol

- FDG Injection – 30 min uptake (total 60 min)
- Part 1 SIM – Fluoroscopic/Radiographic isocenter placement and immobilization creation – 30 min
- RT team positions patient on Exact Couch with proper immobilization: 5 – 20 min
- Whole-body PET/CT: 30 – 36 min
- Limited PET/CT Scan: 1-2 bed positions- 4-10 min
TOOLS OF THE TRADE

- COMPATIBILITY
- DEPARTMENTAL
- DICOM
TEAM EFFORT
COMMUNICATIONS

- EXPLAIN PROCESS TO PATIENT
- ASSESS PATIENT AT START
- INJECTION TIME
- TIME FOR COMPLETION OF SIM
- FLEXIBILITY
carbon fiber composite table width – 19”
PET/CT and RT Compatible Devices

Pelvic Immobilization       Head and Neck Immobilization
Contouring is performed on AW workstation

Contours exported via RT DICOM to Varian Eclipse Computer

Contouring is dependent on PET windowing chosen!
NON-SMALL CELL LUNG CA
RECURRENT COLORECTAL CA
Colorectal CA—Para-aortic nodes
Initial Treatment Plan

PET/CT  Head and Neck Primary
IMRT Boost Treatment Plan
PET/CT  Head and Neck Primary
Changes in RT Management

- Improved staging
  - Upstage > Combined chemo/RT
  - Curative to palliative
- Border changes due to nodal coverage
  - Modified target volume in 68%
- *Decrease target volume >> increase tumor boost dose
- Increase in Re-Treats
THE FIRST STEP
WHAT NEXT?

- DEFINE BIOLOGICALLY ACTIVE TUMOR
  - NEW PET AGENTS
    - Cell proliferation (FLT)
    - Hypoxia (MISO)
    - Membrane synthesis (Choline)

- TUMOR MOTION
  - CALYPSO SYSTEM (IMPLANTED BEACONS)
  - CT/LINAC
  - 4DPET/CT
TARGET MOTION

IT'S NOT A GOOD THING
METHODS OF TUMOR TRACKING

- FLUOROSCOPY
- IMPLANTED MARKERS
- ABC (active breathing control)
- DIBH (deep inspiration breath hold)
- RESPIRATORY GATED CT
- RESPIRATORY GATED PET/CT
RESPIRATORY-GATED PET/CT

4DPET/CT
MATERIALS

- GENERAL ELECTRIC DISCOVERY LS PET/CT SCANNER
  - ADVANTAGE WORKSTATION (VERSION 4.0)
- VARIAN LINAC
  - ECLIPSE TREATMENT PLANNING SYSTEM
- RESPIRATORY GATING:
  - 2 VARIAN REAL TIME POSITION MANAGEMENT SYSTEM (RPM) – LINAC AND PET/CT
    - PASSIVE INFRARED MARKER, VIDEO CAMERA INTERFACED TO PC, AUDIO PROMPT
Increase Treatment Time by $\times 4.2$ (24% Duty Cycle)

Inspiration: 2.8 Sec.
Expiration: 3.3 Sec.
Breathing Period: 6.1 Sec.
PATENT 1

- 80YO FEMALE, 5 CM RT HILAR NSCLC, 2 SATELLITE LESIONS
- HX SMOKING, CHRONIC COPD
- RX CHOICE: PALLIATION
- RESPIRATORY GATED RT: TO SPARE ALREADY COMPROMISED LUNG
PATIENT 1: 7 MONTHS POST-GATED RT
CASE 7

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70 yo NSCLC
89 yo female: gastric ca
MARCH 2004

JUNE 2004

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74 YO FEMALE: PANCREATIC CA

Coronal1 source1
E: 913
S: 100
A: 122

FOV 50.0cm
STND Ph: 0%

1.0/
kv: 120
mA: 60
Rot 0.70s/Cl
2.5mm/2.5sp
TILT: 0.0
03:05:10 PM
W = 400 L = 40

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RESPIRATORY GATED RT

- WHICH PATIENTS BENEFIT?
- IS THERE A DECREASE IN RADIATION PNEUMONITIS?
- DOSE ESCALATION?
- IS THERE BETTER LOCAL CONTROL?
- IS OUTCOME IMPROVED?
CONCLUSION

- PET and PET/CT provide significant improvement in radiation therapy planning by providing:
  - More accurate staging & therefore better treatment stratification
  - Improved tumor target delineation
  - Decreased possibility of geographic miss
  - Potentially improved local tumor control resulting from increased target radiation dose
“In the future, everybody will have fifteen minutes of health-care coverage.”