STANDARDIZING THE USE OF FDG-PET IN RADIOTHERAPY FOR CONSISTENCY IN IMAGING, TREATMENT PLANNING AND TREATMENT ASSESSMENT

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FDG-PET in Radiology and Radiation Oncology:

Priorities for FDG-PET in Radiology and Radiation Oncology are somewhat different, but getting closer because of initiatives such as QIBA (Quantitative Imaging Biomarkers alliance).

For example:

- Identify PET avid region (Radiology) vs. Identify extents/boundaries of PET-defined tumor (Radiation Oncology)
- Indicate persistence/disappearance of tumor after therapy (Radiology) vs. Quantify change in PET uptake during/after course of therapy (Radiation Oncology)

FDG-PET in Radiation Oncology:

- No consensus on a standard protocol for the clinical use of [^{18}F]FDG-PET in the context of RT
- PET measurements are not consistent between scanners (even with same manufacturer equipment) .
- PET scanning protocols are not consistent between institutions
- Implications:
  - Cannot scan patient on scanner A, at later time point scan on scanner B, then compare PET measurements between scans.
  - May not be able to do so even on the same scanner if the scanner is not QA'd regularly to ensure consistent performance.
  - Replicating trial results from another institution is hampered by differences in scanning equipment and scanning protocols between institutions.

AAPM Task Group 174 Report: Utilization of [^{18}F]Fluorodeoxyglucose Positron Emission Tomography ([^{18}F]FDG-PET) in Radiation Therapy

Task Group Charge:

"To recommend guidelines/protocols for consistent imaging, consistent treatment planning and consistent treatment assessment using FDG-PET in radiotherapy. This report is envisioned as laying the foundation for standardizing the use of FDG-PET in radiotherapy. The guidelines/protocols will facilitate interpretability of results and inter-institutional translatability of radiotherapy techniques involving FDG-PET. Towards this goal, this task group will deal with the issues of methods of hypermetabolic target delineation, quality assurance/assessment of FDG-PET scans in phantoms, future FDG-PET software tools required within radiotherapy treatment planning systems, and patient preparation and imaging parameters."

AAPM Task Group 174 Report: Utilization of [^{18}F]Fluorodeoxyglucose Positron Emission Tomography ([^{18}F]FDG-PET) in Radiation Therapy

Task Group Goals:

- The report provides background and education on current PET imaging systems, PET tracers, intensity quantification, and current utilization in RT (staging, segmentation, image registration, treatment planning and therapy response assessment).

- Recommendations are provided on acceptance testing, annual and monthly quality assurance, scanning protocols to ensure consistency between inter-patient scans and intra-patient longitudinal scans, reporting of patient and scan parameters in literature, requirements for incorporation of [^{18}F]FDG-PET in treatment planning systems, and image registration. The recommendations provided here are not meant to replace procedures established at individual institutions that go above and beyond the recommendations.

Background: FDG-PET Priorities in Radiation Oncology:

- Staging
- Segmentation
- Image Registration
- Treatment Planning
- Therapy Response Assessment

Standardization of FDG-PET in Radiation Oncology:

- PET compliance and QA for Radiation Oncology
- Patient Scanning Protocol
- Reporting in Literature

Staging

FDG-PET for staging:

- Head and neck, lung, colorectal, and malignant melanoma
- Average sensitivity and specificity of PET for disease identification estimated as 84% and 88%, respectively, with overall accuracy of 87-90%.
- Use of PET has been shown to change patient stage/management in several cancers - treatment intent changed from curative to palliative, or vice versa.

Segmentation

Categories:

- Manual segmentation
- Automatic and semi-automatic segmentation:
  - Validated mostly on phantoms
  - Sometimes validated in patient datasets against multi-observer manual delineation
    - no real ground truth
  - Sometimes validated against histopathology ground truth
    - not easy to account for sample deformation

Caveat: Automatic and semi-automatic segmentation algorithm results (if employed):

- May be used for guidance
- Should always be adjusted/corrected with expert input.

Segmentation

Automatic segmentation algorithms (per AAPM TG 211 report):

- Fixed and adaptive threshold algorithms
- Advanced algorithms
  - Gradient-based segmentation
  - Region growing and adaptive region growing
  - Statistical
  - Learning and texture-based segmentation
  - Segmentation of multi-modality images
  - Combinations of algorithms (not mentioned as a category in TG 211)

* TG 211: Classification and evaluation strategies of auto-segmentation for PET.

Segmentation

Fixed threshold algorithms (e.g., 42% of max SUV [1]) rely on:

- Well defined uptake boundary
- Uniform background
- Object and background noise are small compared to intensity change at tumor edge

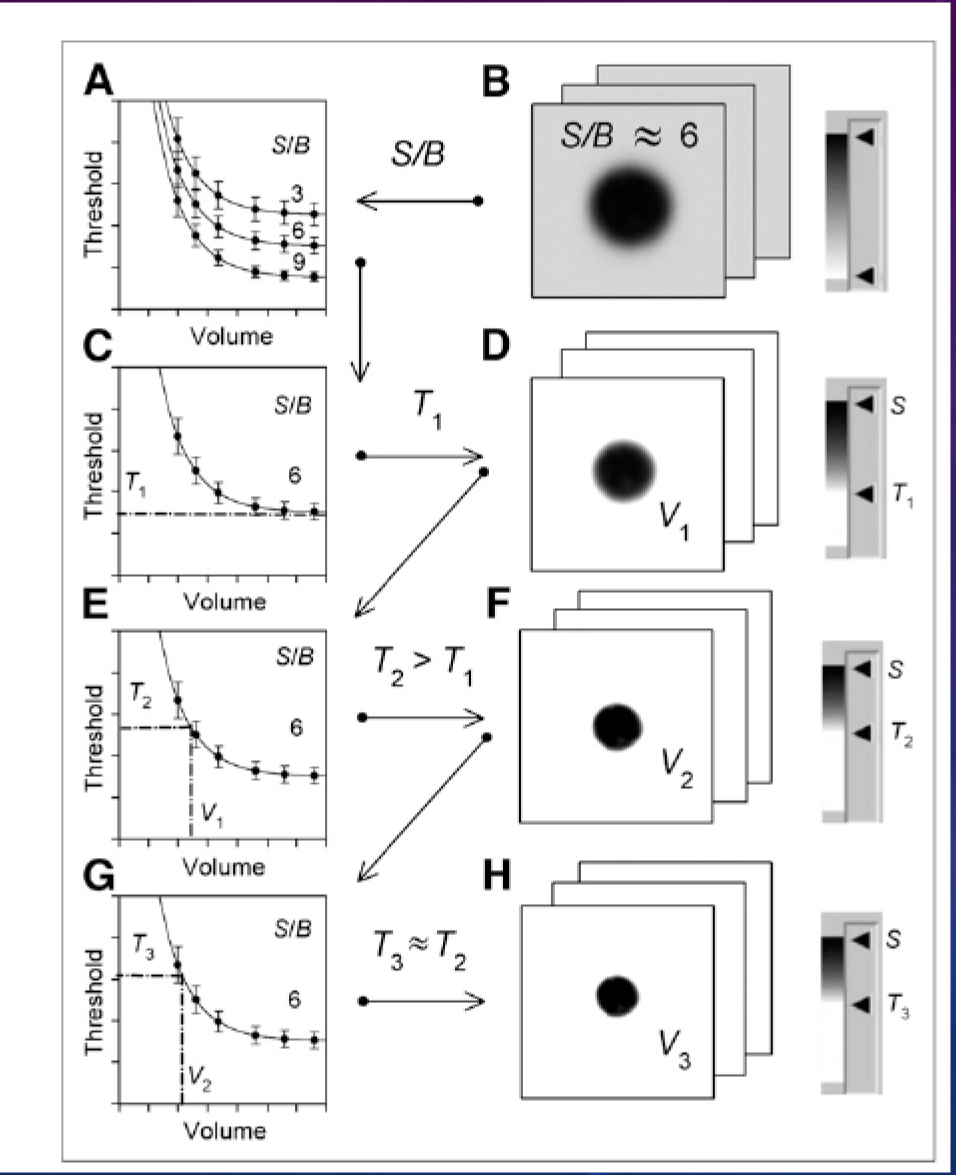
However, above assumptions rarely hold for actual clinical situations.

Adaptive threshold algorithms:

Adapts to properties of tumor and background

1 Y. E. Erdi, O. Mawlawi, S. M. Larson et al., "Segmentation of lung lesion volume by adaptive positron emission tomography image thresholding", Cancer **80**, S2505–S2509 (1997).

Segmentation



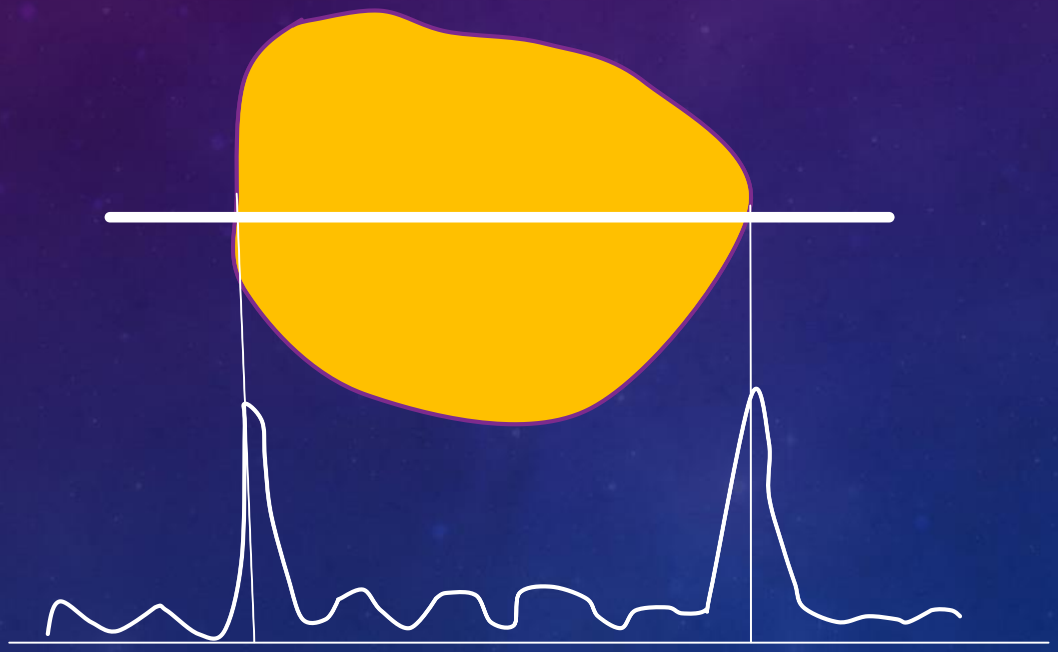
Example of adaptive thresholding

Segmentation of PET volumes by iterative image thresholding, Jentzen, Walter; Freudenberg, Lutz; Eising, Ernst G.; et al. Journal of Nuclear Medicine, Volume: 48 Issue: 1 Pages: 108-114 Published: Jan 2007

Segmentation

Advanced algorithms: Gradient-based segmentation:

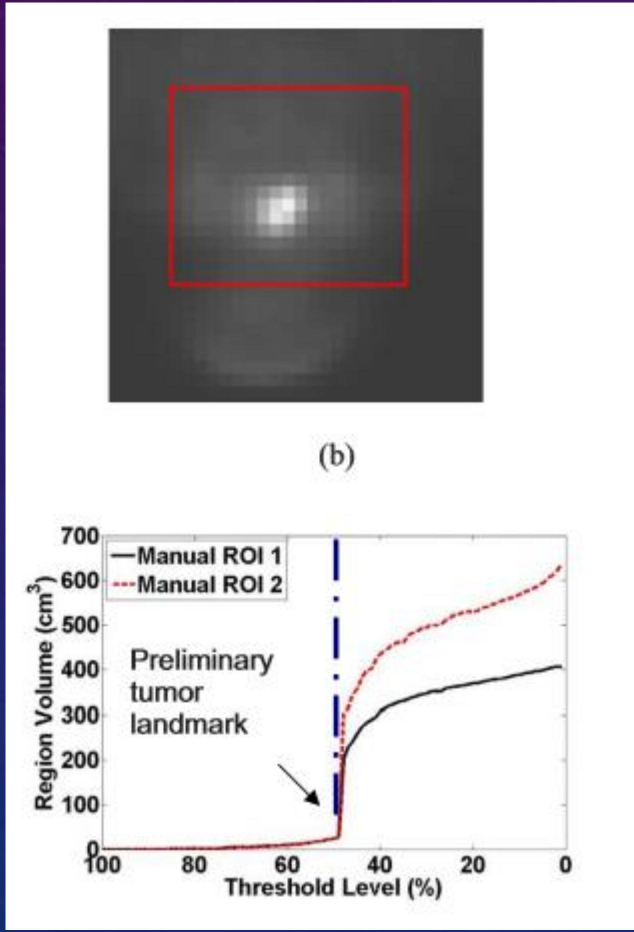
- Creates a map of the PET intensity gradient at every voxel
- Picks the maximum gradient "crests" using adaptive contours or watershed transform



Segmentation

Advanced algorithms: Region growing:

- Maximum voxel value in 3D region of interest identified.
- Start with seed at maximum voxel value
- Add surrounding voxels with threshold > T * mean value (T varies from 100% to 0%)
- Choose threshold at which region volume has sharp transition



A novel PET tumor delineation method based on adaptive region-growing and dual-front active contours
By: Li, Hua; Thorstad, Wade L.; Biehl, Kenneth J.; et al.
Medical Physics, Volume: 35 Issue: 8 Pages: 3711-3721
Published: Aug 2008

Segmentation

Advanced algorithms: statistical:

- Assigning voxels to classes based on probability (e.g., FLAB[1] – Fuzzy locally adaptive Bayesian segmentation)

Advanced algorithms: learning and texture-based segmentation:

- Learning algorithms use features from training set images to classify tumor vs. background
- Features can include texture

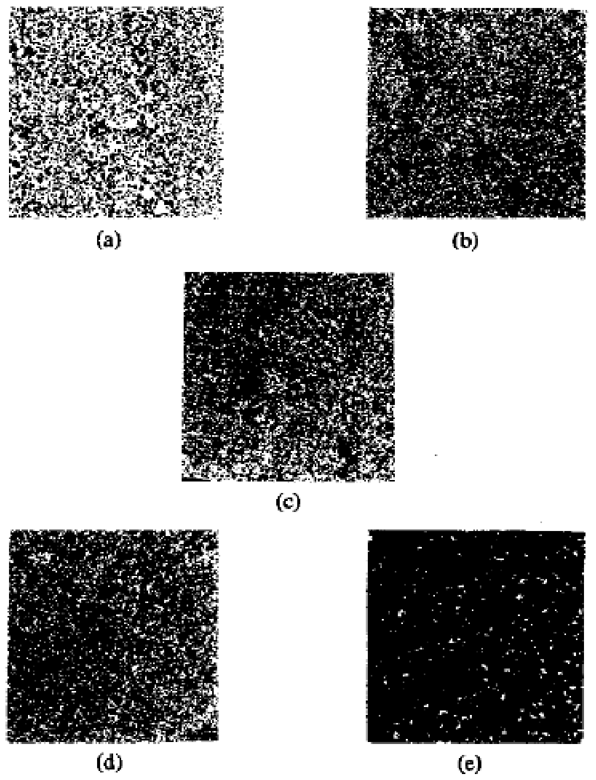


Fig. 5. Samples of photomicrographs of sandstones. (a) Dexter-L. (b) Dexter-H. (c) St. Peter. (d) Upper Muddy. (e) Gaskel.

[1] A Fuzzy Locally Adaptive Bayesian Segmentation Approach for Volume Determination in PET
By: Hatt, Mathieu; le Rest, Catherine Cheze; Turzo, Alexandre; et al. IEEE Transactions on Medical Imaging Volume: 28 Issue: 6 Pages: 881-893 Published: Jun 2009

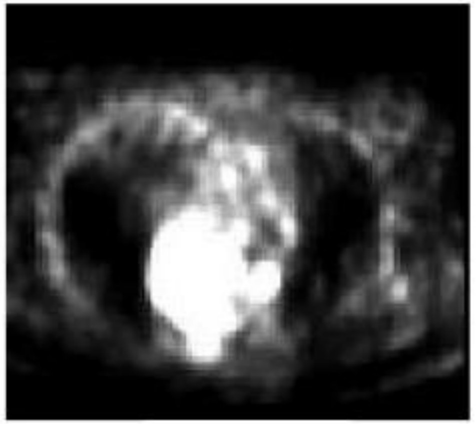
Textural Features for Image Classification
By: Haralick, RM; Shanmuga.K; Dinstein, I
IEEE Transactions on System Man Cybernitics
Volume: SMC3 Issue: 6 Pages: 610-621, 1973.

Segmentation

Advanced algorithms: segmentation of multi-modality images:

- Information supplied by different modalities can better help delineate tumor- union of complementary regions, intersection of agreement regions.

(a)



(b)

Optimal Co-Segmentation of Tumor in PET-CT Images With Context Information, Song, Qi; Bai, Junjie; Han, Dongfeng; et al. IEEE transactions on Medical Imaging, Volume: 32 Issue: 9 Pages: 1685-1697 Published: Sep 2013

Image Registration

Registration accuracy (i.e., translating PET defined segmentation to Planning CT):

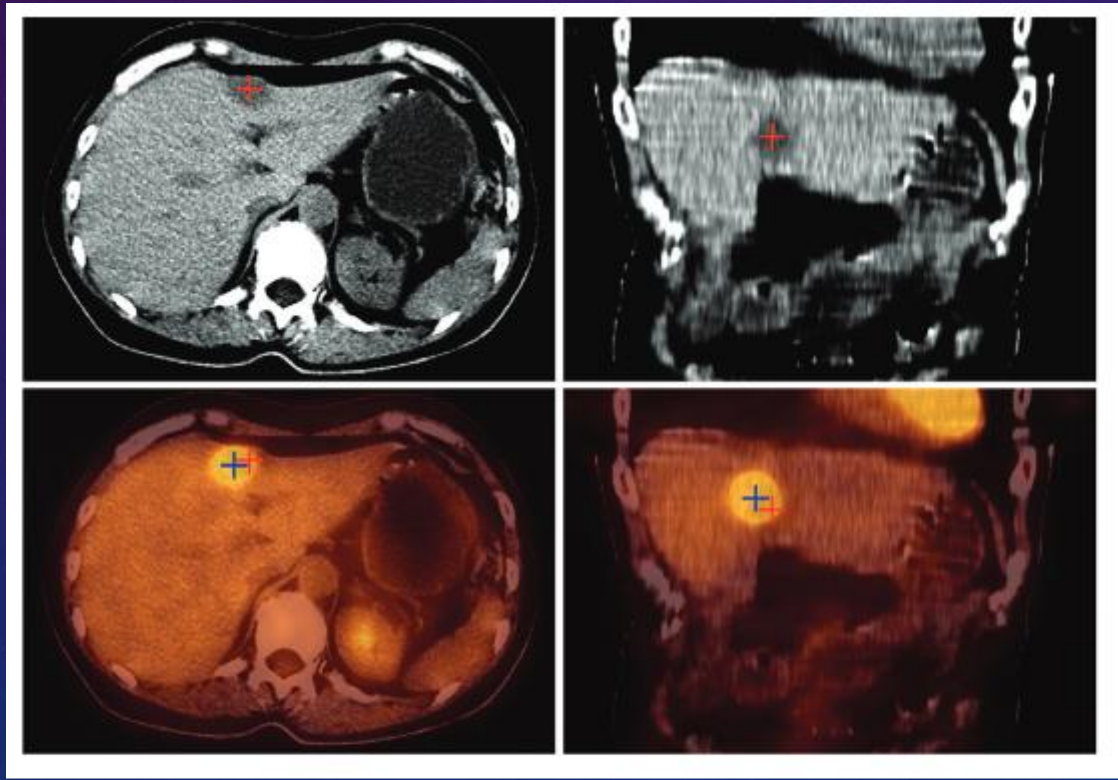
Planning CT ⇔ [low dose CT ⇔ PET] – how good is this registration?

[low dose CT ⇔ PET] – how good is this registration?

CT is acquired prior/after lengthy PET acquisition - perfect registration is not guaranteed

We look for:

- Anatomical landmark coincidences (e.g., nodes in HN)
- CT lesion (if visible) coincidence with PET-avid region
- Respiration induced mismatch, e.g., CT from end expiration and PET from entire breathing



Evaluation of image registration in PET/CT of the liver and recommendations for optimized imaging, Vogel, Wouter V.; van Dalent, Jorn A.; Wiering, Bas; et al. Journal of Nuclear Medicine, Volume: 48 Issue: 6 Pages: 910-919 Published: Jun 2007

Image Registration

Reducing mismatch:

Proper immobilization:

- Planning CT vs. CT-PET: same immobilization on flat couch top
- CT-PET: Patient has minimal motion during long procedure (effective immobilization: mask, vacuum bag, etc.)
- Reduce discomfort from immobilization system to minimize patient moving to get more comfortable

Respiratory motion:

- Use gated PET, but can result in poorer signal because of limited duty cycle
- Use abdominal compression to reduce motion
- Accumulate signal to one phase with deformable registration (deformable registration has its own problems)

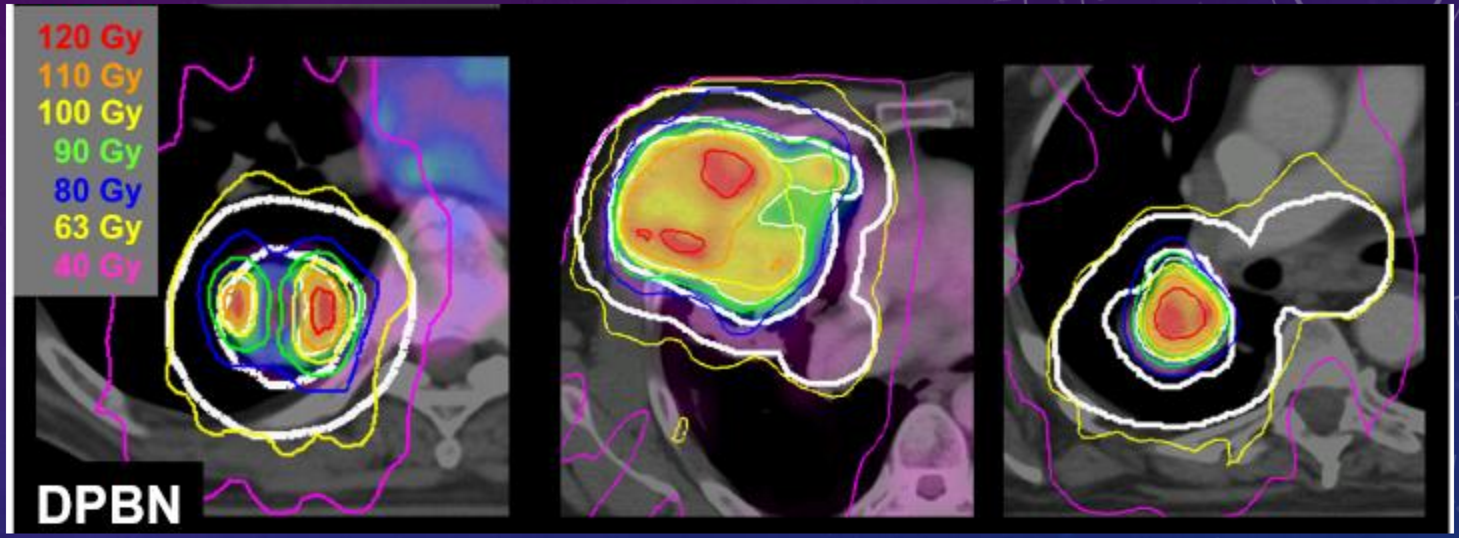
In event of mismatch of CT-PET images:

- Break DICOM link (frame of reference UID)
- Adjust registration (small shifts are usually sufficient)

Treatment planning

Typically:

Segment PET-based GTV
Segment CT-based GTV
GTV = union of CT-based and PET-based GTVs
CTV = GTV + expansion
PTV = CTV + expansion



Future directions: Dose painting?

Confounding factors:

- Stability of high intensity areas during treatment
- Inflammatory effects during treatment

Dose painting by contours versus dose painting by numbers for stage II/III lung cancer: Practical implications of using a broad or sharp brush, Meijer, Gert; Steenhuijsen, Jacco; Bal, Matthieu; et al. Radiotherapy and Oncology, Volume: 100 Issue: 3 Special Issue: SI Pages: 396-401 Published: Sep 2011

Therapy response assessment

Pre-therapy or Post-therapy:

- HN SCC patients with avg pre-therapy SUV > median SUV value had worse 2 yr disease-free survival (Higgins et al, IJROBP, 2012)
- HN SCC patients post-therapy PET image vs. pathologolical/clinical response showed high positive and negative predictive value for nodes (Gupta et al, Radiotherapy & Oncology, 2010)

Pre-therapy vs. Post-therapy:

- Anal SCC 2 yr and 5 yr survival better for complete metabolic responders (Day et al, BJC, 2011)
- Locally advanced rectal adenocarcinoma mean and max SUV significantly correlated to RT responders correlated at time of surgery (Everaert et al, IJROBP, 2011)
- Locally advanced HN SCC 2 yr survival significantly correlated to PET response (Passero et al, Annals of Oncology, 2010)

Therapy response assessment

Pre-therapy vs. Intra-therapy:

- Advanced NSCLC, mean/max SUV change after 40 Gy showed high sensitivity to responders (Huang et al, EJNMMI, 2011)
- Stage 1-3 SCLC metabolic tumor volume change after chemo (before RT) was predictive of survival (Loon et al, Radiotherapy and Oncology, 2011)
- Locally advanced rectal cancer tumor regression grading correlated to max SUV change 15 days into RT (Janssen, IJROBP, 2010)

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY

Need for standardization of FDG-PET in Radiation Oncology:

- Segmentation (repeatability): inconsistent PET acquisition/reconstruction parameters can yield different results.
- Therapy assessment (longitudinal): inconsistent PET acquisition/reconstruction parameters could, at worst, falsely indicate that the patient is responding/not responding to therapy.

Standardization of FDG-PET in Radiation Oncology:

- PET compliance and QA for Radiation Oncology
- Patient Scanning Protocol
- Reporting in literature to allow study duplication

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: QA

At time of Acceptance Testing – NEMA NU 2-2012 tests for performance measures:

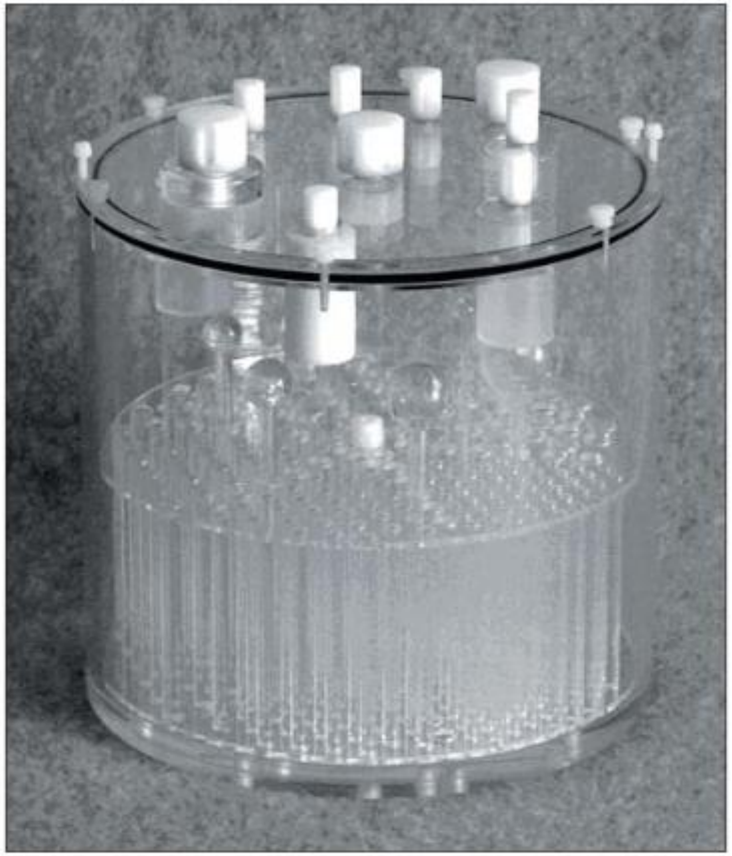
- 3 phantoms
- spatial resolution
- sensitivity
- scatter fraction
- count rate performance
- count rate correction accuracy
- image quality

Recommended to be compliant with ACR Nuclear Medicine & PET accreditation program (http://www.acr.org/Quality-Safety/Accreditation/Nuclear-Med-PET)

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: QA

Annual QA: Repeat portion of ACR accreditation measurements:

- ACR Flangeless PET phantom
- Tests:
  - Absolute SUV
  - SUV ratios
  - Resolution tests



ACR Flangeless PET Phantom™
ACR PET/FL/P

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: QA

Annual QA

Table 1. Phantom Scan Parameters (Data Spectrum's ACR flangeless PET Phantom) and Results

I. Scan Parameters	
Transmission Scan Processing	☐ CT KV ______ mAs______ pitch______ metal/high density artifact correction______ truncation correction________ ☐ Segmentation ☐ Segmentation+emission subtraction ☐ Other__________________
PET scan parameters	Number of bed positions ______________ Time/bed position (min) __________ bed overlap (# slices/mm/%)__________ Emission start time (hh:mm:ss) __________ Activity at emission start time (Bq) __________ Emission mode ☐ 2D ☐ 3D Matrix size ________________ Zoom/FOV (mm)________________
Reconstruction method (FBP, OSEM, etc.)	☐ FBP ☐ OSEM ☐ RAMLA ☐ other If OSEM: iterations __________ subsets _________ PSF/resolution modeling ____________ TOF (yes/no)_________ Pixel size _________
Processing Filter	Filter type _______________ Setting ___________
Slice thickness (mm)	

II. Phantom Scan Results (according to ACR standards)	
Mean SUV of background (central 6 cm diameter region on axial slice) (slice at longitudinal center of cylinders)	________ Pass/Fail (Pass: SUV 0.85 – 1.15) Baseline value ________ % deviation ________ (Pass: < 10%)
Max SUV of 25 mm cylinder (slice at longitudinal center of cylinders)	________ Pass/Fail (Pass: SUV > 1.8 to < 2.8) Baseline value ________ % deviation ________ (Pass: < 10%)
Ratio of max SUVs 16mm/25mm (slice at longitudinal center of cylinders)	________Pass/Fail (Pass: ratio > 0.7) Baseline value ________ % deviation ________ (Pass: < 10%)
PET/CT alignment check: Visually examine alignment between CT and PET images for the cylinders (4 "hot", 1 "cold", 1 empty, 1 Teflon rod). Manually align the PET and CT images using visual inspection and report the alignment distance along X, Y, and Z direction. Limits: +/- 2mm in any direction.	________Pass/Fail (Pass: within ±2 mm in any direction[62].)

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: QA

Monthly QA

- ACR Flangeless PET phantom
- Tests:
    - Quantification and Uniformity
    - Scatter and Randoms correction
    - Resolution
    - Alignment of CT and PET

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Overall Process

Patient workup for PET scanning of RT patients takes about 2 hours. Typical steps taken during those 2 hours:

- Prior to arrival patient is instructed to fast a minimum of 4 hours.
- Patient arrives.
- Height and weight measured.
- Serum glucose level measured (may need to reschedule patient if blood glucose level is greater than some set value, e.g., 150 mg/dL).
- Radiopharmacy notified of patient arrival.
- Patient radiopharmaceutical prepared in the radiopharmacy (activity and assay time noted).
- Immobilization device fabricated in PET/CT (schedule permitting), or fabricated in radiation oncology CT simulator for transport to PET/CT.
- Patient radiopharmaceutical transported to injection area.
- Patient injected and time of injection noted. Residual activity and associated assay time noted.
- Patient waits 45-60 min in a quiet room. In many facilities, the patient drinks (diluted positive or negative) oral contrast, if applicable. Note that the schedule should be adjusted for certain oral contrast agents that need to be taken 2 – 4 hours prior to scanning.

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Overall Process

- Technologist arrives and requests the patient to go to the bathroom to empty bladder.
- Immediately before proceeding to the scanner room, the patient may drink another cup of oral contrast.
- Technologist mounts flat carbon fiber indexable table for RT simulation and planning in place of cushioned diagnostic couch.
- Patient goes to the imaging room.
- Setup on the table, indexing of immobilization, and patient alignment to external wall-mounted lasers - ~15 min.
- Patient info entered into the system.
- Scout view - 1 min.
- CT scan - 2 min (low dose for attenuation correction).
- PET scan - this is highly variable and depends on the local protocol, field of view, and number of bed positions. Each bed position is about 15 cm (3-6 min/bed position, taking a total of about 40 minutes).
- Diagnostic CT with/without intravenous contrast.

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Factors affecting consistency

Factors affecting PET quantitative measurements:

- Patient parameters in time period (hours/days) prior to administration of radiopharmaceutical: Food intake, physical activity, glucose level.
- Activity administration parameters: Radiopharmaceutical activity administered, route of administration, patient weight, other drugs (muscle relaxants, pain medication, etc.).
- Patient parameters in time period immediately post administration of radiopharmaceutical: Length of time period between radiopharmaceutical administration and scanning, waiting room temperature, physical activity.
- Imaging parameters: scanner type, attenuation correction, image acquisition time, motion correction/ respiratory gating, image processing parameters (algorithm, filtering).
- Parameters in registration of PET images to planning CT image: Immobilization (preferably same as for RT treatment)

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Consistent parameters for imaging

Table 2. Patient Specific Preparation and Imaging Parameters

(Template column to be filled out by Radiation Therapy Medical Physicist)

Patient specific parameters should match Template parameters (grey-shaded boxes need only be filled if not in compliance with the corresponding template parameters). In the event of possible mismatch, the Radiation Therapy Medical Physicist should be consulted prior to scanning.

	Template Parameters	Patient-Specific Parameters
Technologist	N/A	
Patient name		
Date (month/ day/ year)	N/A	
Scanner used (relevant for institutions with multiple scanners)		
Patient weight (Kg)		
Patient height (cm)		
Exercise in 24 hrs prior to [^{18}F]FDG injection	none	
Duration of patient fasting pre-RT imaging (hours)	4 hours	
Patient voided bladder prior to injection of [^{18}F]FDG	yes	☐ no (notes) ________________
Blood glucose in 1- 2 hours prior to [^{18}F]FDG injection (mg/dL)	Allowed range:	

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Consistent parameters for imaging

Pre-injection activity assay (Bq)	Allowed range:	
Time of activity assay (hh:mm:ss)	N/A	
Time of injection (hh:mm:ss)	N/A	
Post injection activity assay (Bq)	N/A	
Location of injection site (use 21 gauge needle; injection should be anatomically remote to tumor site)	☐ right antecubital ☐ right wrist ☐ left antecubital ☐ left wrist ☐ right foot ☐ left foot ☐ Other ________________	☐ right antecubital ☐ right wrist ☐ left antecubital ☐ left wrist ☐ right foot ☐ left foot ☐ Other ________________
Waiting area parameters	Temperature (°F/°C) > 75°F/ 22°C Position: ☐ sitting ____________ ☐ lying _____________ Instruct to minimize talking	Temperature (°F/°C)__________ Position: ☐ sitting ____________ ☐ lying _____________
Water consumed following injection (> 500 ml (16 oz))	Range allowed:	
Administration of diuretic/sedative	Details________________________	Details________________________
Patient voided bladder immediately prior to scanning	yes	☐ no (notes) ________________

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Consistent parameters for imaging

Immobilization parameters (as in RT treatment, to best extent possible)	Head-neck immobilization ____________________ Body immobilization & knee support ____________________ Arm position ____________________	Head-neck immobilization ____________________ Body immobilization & knee support ____________________ Arm position ____________________
Time between [^{18}F]FDG injection and start of scan	Range allowed: ________________ min	________________ min
Transmission Scan	☐ low dose CT (for attenuation correction only) ☐ before PET scan ☐ after PET scan ☐ helical__________ ☐ 4D__________ Scan direction: ☐ craniocaudal ☐ caudocranial ☐ diagnostic quality planning CT ☐ before PET scan ☐ after PET scan ☐ before low dose CT ☐ after low dose CT ☐ oral contrast__________ ☐ IV contrast__________ ☐ helical__________ ☐ 4D__________ Scan direction: ☐ craniocaudal ☐ caudocranial	☐ low dose CT (for attenuation correction only) ☐ before PET scan ☐ after PET scan ☐ helical__________ ☐ 4D__________ Scan direction: ☐ craniocaudal ☐ caudocranial ☐ diagnostic quality planning CT ☐ before PET scan ☐ after PET scan ☐ before low dose CT ☐ after low dose CT ☐ oral contrast__________ ☐ IV contrast__________ ☐ helical__________ ☐ 4D__________ Scan direction: ☐ craniocaudal ☐ caudocranial

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Consistent parameters for imaging

PET scan/reconstruction parameters	No. of bed positions______ % bed overlap _________ Time/bed position (min)___ Scan range description ____________________ Emission mode ☐ 2D ☐ 3D Gating ☐ Phase #bins__________ ☐ Amplitude #bins________ ☐ Other __________ ☐ FBP* ☐ OSEM* ☐RAMLA* ☐ other_______ Filter type______________ Filter Setting ____________ If OSEM: iterations _____________ subsets __________ Transverse smoothing ______ Axial smoothing _____ PSF*/resolution modeling in reconstruction_____________ TOF* (yes/no)__________ FOV* _________ Pixel size __________	No. of bed positions ______ % bed overlap _________ Time/bed position (min)___ Scan range description ____________________ Emission mode ☐ 2D ☐ 3D Gating ☐ Phase #bins__________ ☐ Amplitude #bins________ ☐ Other __________ ☐ FBP ☐ OSEM ☐RAMLA ☐ other_______ Filter type______________ Filter Setting ____________ If OSEM: iterations _____________ subsets __________ Transverse smoothing ______ Axial smoothing _____ PSF/resolution modeling in reconstruction_____________ TOF (yes/no)__________ FOV _________ Pixel size __________

STANDARDIZATION OF FDG-PET IN RADIATION ONCOLOGY: PATIENT SCANNING

Reporting in Literature

Table 3. Patient and Scan Parameters

Item	Description
I. Scanner Specifications	
Scanner used - Make, Model.	
Scanner software version (list updates if patients were imaged with different versions)	
Protocol for scanner calibration	
II. Patient Specifications	
Fasting status	
Blood glucose level prior to [^{18}F]FDG injection	
Injected activity (Bq)	
Location of injection site (right/left wrist, right/left antecubital, right/left foot)	
Water consumed after [^{18}F]FDG injection (ml/oz)	
Time between [^{18}F]FDG injection and start of scan	
PET scanning and processing	2D/3D mode ________ Number of bed positions ________ Time/bed position __________ Gating __________ (phase, amplitude, # bins, etc.) Attenuation correction with CT ____ other ____ Reconstruction method: FBP__, OSEM__, RAMLA___other___ If OSEM: iterations ________, subsets ________ PSF ___________, TOF (yes/no)________, Filter ____________, Slice thickness ________(cm), pixel size________(cm)

III. Phantom Scan Parameters *Acquired from scans of Data Spectrum's ACR flangeless PET phantom*	
Mean SUV of background (central 6 cm diameter region on axial slice) (slice at longitudinal center of cylinders)	
Max SUV of 25 mm cylinder (slice at longitudinal center of cylinders)	
Ratio of max SUVs 16 mm/25 mm (slice at longitudinal center of cylinders)	

TREATMENT PLANNING SYSTEM [^{18}F]FDG-PET-SPECIFIC REQUIREMENTS

- Conversion of PET image to SUV
- Delineation of tumor using SUV cutoff/thresholding or robust segmentation algorithms, plotting of variation in PET tumor volume as a function of cutoff or threshold value, and mapping PET voxel SUV to non-uniform radiation dose prescription distributions as part of the treatment planning objectives.
- Support for simultaneous fusing of (and contouring on) multiple [^{18}F]FDG-PET image datasets (e.g., datasets from pre-, during-, and post-treatment).

SUMMARY

FDG-PET Priorities in Radiation Oncology:

Staging – valuable for staging/upstaging/downstaging

Segmentation – automatic segmentation helpful, but must be validated by human expert

Image Registration – careful to check inherent CT/PET registration

Treatment Planning – identifying PET-avid region, dose painting

Therapy Response Assessment – pre-tx, pre-tx vs. intra-tx, pre-tx vs. post-tx

Standardization of FDG-PET in Radiation Oncology:

PET compliance and QA for Radiation Oncology

Patient Scanning Protocol – consistency!

Reporting in literature – enable duplication

THANK YOU!