Practice and prospects of PET/CT guided interventions

Assen S. Kirov, Ph.D.
Associate Attending Physicist
Department of Medical Physics
Memorial Sloan-Kettering Cancer Center, New York, NY

Outline: PET/CT guided interventions

Real-time, intra-procedural PET/CT guided

1. General procedure flow
2. Advantages and limitations
3. Radiation safety
4. Developments and research opportunities
**Interventional radiology procedures**

Interventional Radiology
Edt. R. Uberoi, 2009

- Tumor Biopsies
- Tumor Ablations

**PET/CT guided**

- Arterial access for angiography and intervention
- Arterial thrombolysis and mechanical thrombectomy
- Angioplasty and stenting
- Methods of arterial closure
- Stenting
- Interventional radiology in transplantation
- Interventional uro-radiology
- Haemodialysis fistula
- Hepatobiliary intervention
- Gastro-intestinal intervention
- Venous intervention
- Interventional radiology in management of gynaecological disease
- Embolization techniques
- Tumour ablation
- Biopsy and drainage
- Salivary and lacrimal ducts intervention
- Foreign body retrieval/repositioning: arterial, venous, soft tissue
- Musculoskeletal intervention
- Interventions in the chest

**Intra-procedural PET/CT guidance**

PET/CT in the Interventional Radiology Suite Center for Image Guided Interventions, MSKCC

Lesion not seen in CT image
**Intra-procedural PET/CT guidance**

PET/CT in the Interventional Radiology Suite Center for Image Guided Interventions, MSKCC

Fused PET/CT with the needle in place

**Imaging flow of a PET/CT guided biopsy**

PET/CT scan before needle insertion

18F-FDG
148 to 222 MBq (GE D690)

Initial PET/CT scan:
- 1 or 2 bed positions PET scan
- scan time: 2-5 min
- 148-222 MBq (~4 to 6 mCi) injection
- injection to scan times: 30 min to 4 h

Fanchon et al, Med. Phys, 2017
**Imaging flow of a PET/CT guided biopsy**

**PET/CT scan before needle insertion**

\[ ^{18}\text{F-FDG} \]

148 to 222 MBq (GE D690)

Fanchon et al, Med. Phys, 2017

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**Imaging flow of a PET/CT guided biopsy**

**One PET scan** before needle insertion

**Second PET scan** after needle insertion

\[ \text{PET}_{\text{pre}} : 2-5 \text{ min} \]

\[ \text{PET}_{\text{needle}} : 20-90 \text{ s} \]

with Breath Hold

Fanchon et al, Med. Phys, 2017
PET/CT guided ablations

Planning on fused PET/CT

Ablation probe placement

Short CT with BB grid

Insertion in CT fluoroscopy mode

18F-FDG
148 MBq pre-ablation
(GE D690)

PET/CT guided ablations

Planning on fused PET/CT

RF probe placement

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**PET/CT guided ablations**

Probe placement verification on CT and 1 min breath hold PET

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**Ablations: 2nd FDG injection for verification**

2) Thee phase CE-CT  
3) Second ablation  
4) post ablation PET/CT

Post ablation:
1) 296 MBq $^{18}$F-FDG

portal venous phase
On-line PET/CT guidance vs Previous PET/CT

- Issues with using a previous PET/CT:
  - Misregistration (different body & organ position)
  - Tumor evolution from the time of the PET
  - Can’t use in-OR post-ablation PET for ablation verification

- Intra-procedural PET/CT
  - Registered PET and CT at time of procedure
  - Account for tumor displacement by the needle
  - Reduce breathing artifacts (breath hold PET)
  - Allows ablation verification by second FDG injection

Radiation safety: $^{18}$F-FDG guided

Personnel: Ryan et al, CIR 2013: from 12 cases, detector: OSL under Pb apron,

<table>
<thead>
<tr>
<th>Median Effective Dose</th>
<th>From 448 MBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02 mSv - operator</td>
<td>0.02 mSv</td>
</tr>
<tr>
<td>0.01 mSv - nurse anesthetist</td>
<td>0.01 mSv</td>
</tr>
<tr>
<td>0.02 mSv - radiology technologist</td>
<td>0.02 mSv</td>
</tr>
<tr>
<td>0.32 mSv - extremity dose equivalent for operator</td>
<td>0.32 mSv</td>
</tr>
</tbody>
</table>

Current injections: 148 to 222 MBq

Gazzato et al 2016 (386 MBq split dose): operator’s right hand max ~ 0.15 mSv

Patient ED: From 6 mCi inj.: 222 MBq x 0.019 mSv/MBq = 4.2 mSv

CT guidance: 24.0 mSv (Leng et al, 2011)
PET/CT guidance(222 MBq): 28.2 mSv

vs. 2.4 mSv/a nat. bkg
**Radiation safety: $^{18}$F-FDG guided ablations**

Current injections for ablations: ~ **270 to 444 MBq**

- **Personnel ED:** only from pre-ablation injection if no ablation after second inj.
- **Patient ED:**
  - **Estimate for 444 MBq (12 mCi) total injected (split dose):**
    \[
    444 \text{ MBq} \times 0.019 \text{ mSv/MBq} \approx 8.4 \text{ mSv}
    \]
  - CT guidance: 24.0 mSv *(Leng et al, 2011)*
  - PET/CT guided (444 MBq): 32.4 mSv

- **Estimate for 270 MBq (189-357 MBq range) in 117 procedures, Hu et al, 2020:**
  - Added dose for same radiologist: 7.8 ± 2.8 mSv
  - Corrected for confounding factors: 6.2 ± 2.9 mSv
  - Mean patient dose from PET/CT guidance: 41.9 ± 21.5 mSv

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**Benefits of PET/CT guidance**

**Biopsies:**
- Visibility of PET tracer avid lesions not seen otherwise
- Allows to target the most metabolically active area
- Resolve previously inconclusive biopsies
- Detect cancer recurrence - post surgery, ablation or radiation therapy
- Not limited to FDG: $^{18}$F-FDOPA (NETs), $^{68}$Ga-DOTATOC

**Ablations:**
- Prolonged visualization of the lesions
- Verification of ablation and prediction of local recurrence

Solomon & Comelis, JNM 2016
Gazzato et al, Min. Inv Ther & Allied tech, 2018
Kaye et al, Eur. Rad, 2019
Limitations for $^{18}$F-FDG PET/CT guided Int.

**Limitations:**

- Availability of an interventional PET/CT
- Very small lesions not seen in PET due to PVE
- Slightly longer procedure times
- Increased patient doses
- Tumors not avid with $^{18}$F-FDG PET

**Not a limitation**

- Benign inflammatory lesions – PET guides for accurate biopsy

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Solomon & Cornelis, JNM 2016
Gazzato et al, Min. Inv Ther & Allied tech, 2018
Hu et al, J Vasc Interv Radiol 2020; 31:1052–1059

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Robotic arm assisted PET/CT guided biopsy

Kumar et al: EJNMMI 2019; Diag Interv Imag; 2020

Kumar et al, EJNMMI, 2019;46(4):838-47.
**13N-ammonia perfusion imaging of ablation margin**

- ~374 MBq 18F-FDG 45-60 min before first PET/CT
- ablation
- ~338 MBq 13N-ammonia 5-15 min post ablation
- Width of photopenic anulus → measure of ablation margin

Shyn et al, Radiology, 288, 138-145, 2018

**Biopsy adequacy evaluation: Colorectal cancer liver metastases**

Complications: pneumothorax

SUV\text{ARG} = 3.9

\text{SUV_{PET}} = 9.4

Log. regression of data from 19 labeled specimens

\Rightarrow P_{\text{Adequate}} < 25\%

(95\% confidence)

Fanchon L et al, JNM, v 56, 4, p538, 2015
**In situ validation of new tracers**

**Benefit of PET/CT g. bx for Radiogenomics**

=> Correlation of uptake with genomic profile of same lesion

**KRAS+ :**  \( \text{SUV}_{\text{max}} = 17.5 \)

Colorectal adenocarcinoma liver metastases
60 lesions of which 31 with “on the spot” gen. profile

Predicting CRC **KRAS+** missense mutations using the PVE and uptake time corrected tumor-to-blood ratio, \( \text{SUR}_{\text{max}} \)

other lesions \( \text{SUV}_{\text{max}} < 12.2 \)

Student’s T-test  \( p < 0.001 \)

\( \text{SUR}_{\text{MAX}} \text{ AUC}=0.76 \)

Popovich, Talarico, van den Hoff, …Kirov, submitted
Kirov et al, SNMMI 2019
Intra-procedural PET/CT guidance

Biopsies
- MGH, Boston – Tatli, Shyn et al, 2011: breath hold (BH)
- Curitiba, Brasil – Cerci, Bogoni et al, 2013: 126 pancreatic ca. cases
- New York – Ryan, Solomon et al, lung, liver, bone, soft tissue
- Bologna, Italy – Nanni, Tabacchi, Zanoni et al, bone, soft tissue, lymphoma
- Chandigarh, India – Kumar et al robotic arm, $^{18}$F, $^{68}$Ga labeled tr.
- Xiamen, China – Nana et al, 2018, FDG avid prostate lesions

Ablations
- BWH, Boston – Shyn et al 2017-18: BH image reg.; $^{13}$N perfusion: abl. margin
- New York – Ryan, Sofocleous et al: split dose technique
- Strasbourg – Gazzato, Gangi et al: $^{18}$F-FDOPA liver ablations of NETs
- JH, Baltimore – Pasciak et al: $^{90}$Y PET/CT for post-RE percutaneous RFA

Summary: Intra-proc. PET/CT guidance

- A well equipped interventional suite is needed
- PET/CT guided biopsies
  - Promise to improve diagnostic success rate and reduce complications
  - Quantifying radioactivity in biopsy specimens:
    - allows high res. in situ validation of new radiopharmaceuticals
    - promising for evaluation of biopsy adequacy
- PET/CT guided ablations
  - Split dose technique: pre- ablation and post- ablation tracer injections
  - Allow targeting, treatment assessment and recurrence prediction
- The doses added to personnel and patients are low
Published reviews


Interventional Radiology team
Contributors