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Practice and prospects of PET/CT guided interventions

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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

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Interventional radiology procedures

Interventional Radiology
Edt. R. Uberoi, 2009

PET/CT guided

- Tumor Biopsies
- Tumor Ablations

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Intra-procedural PET/CT guidance

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

Lesion not seen in CT image

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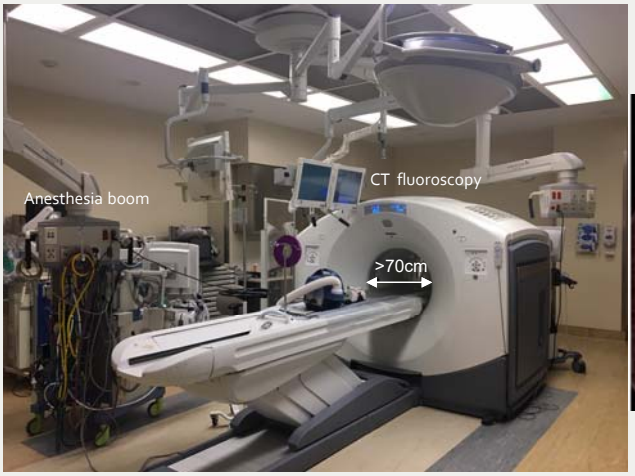
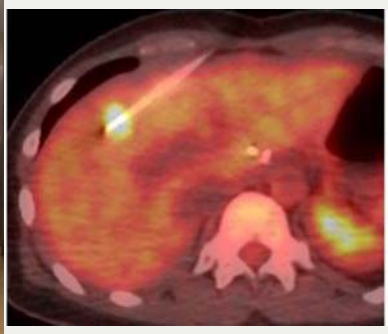
Intra-procedural PET/CT guidance



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



Fused PET/CT with
the needle in place

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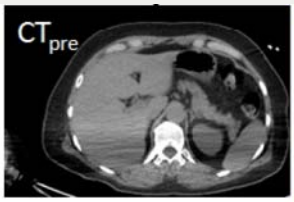
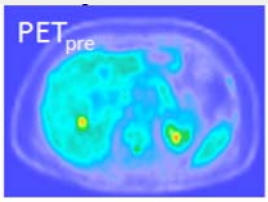
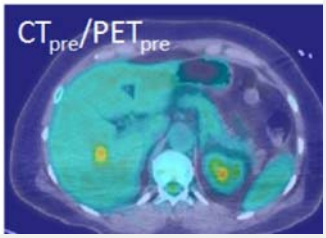
Imaging flow of a PET/CT guided biopsy

PET/CT scan before needle insertion





^{18}F-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

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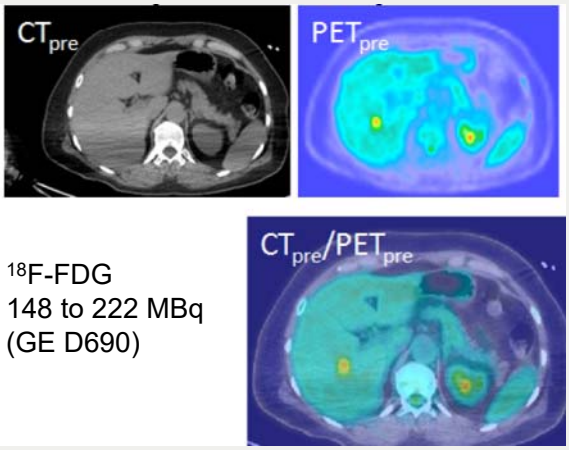
Imaging flow of a PET/CT guided biopsy

PET/CT scan before needle insertion



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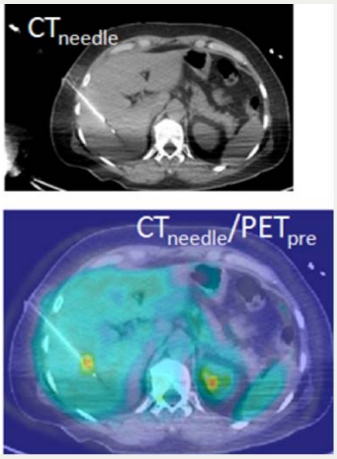

Fanchon et al, Med. Phys, 2017

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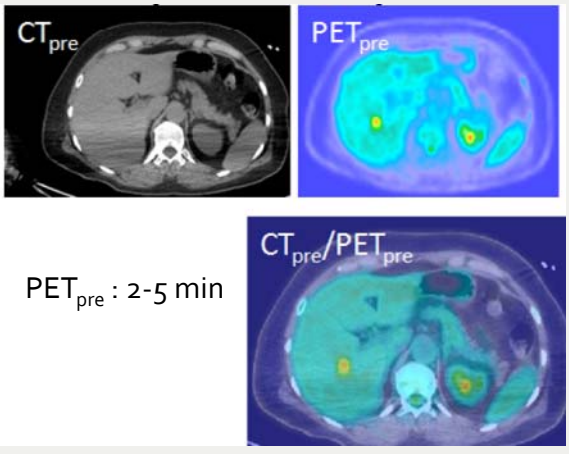
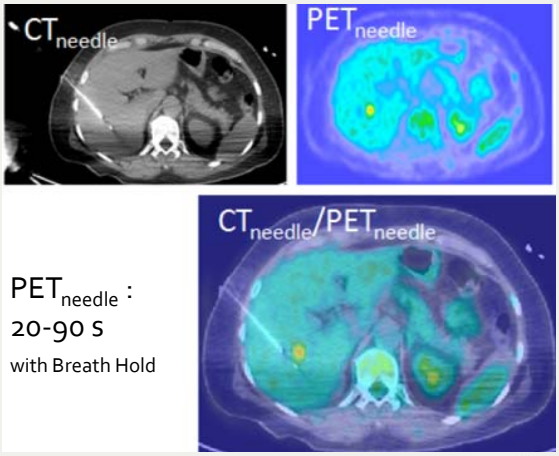
Imaging flow of a PET/CT guided biopsy

One PET scan before needle insertion



PET_{pre} : 2-5 min

Second PET scan after needle insertion



PET_{needle} :
20-90 s
with Breath Hold

Fanchon et al, Med. Phys, 2017

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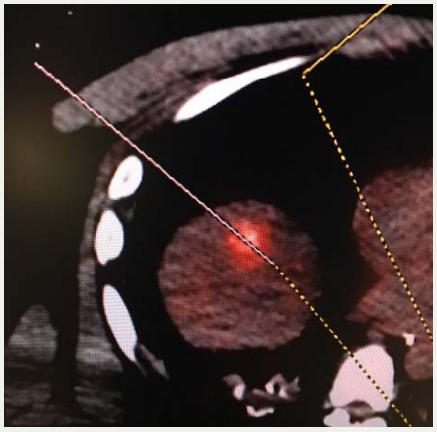
PET/CT guided ablations

Planning on fused PET/CT

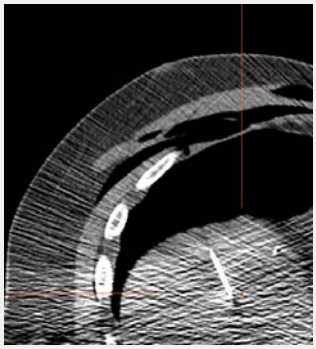


^{18}F-FDG
148 MBq pre-ablation
(GE D690)

Ablation probe placement

Short CT with BB grid

Insertion in CT fluoroscopy mode



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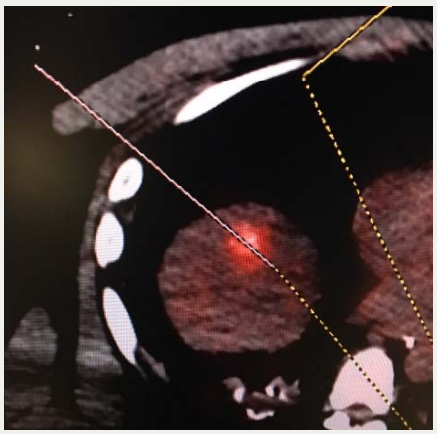
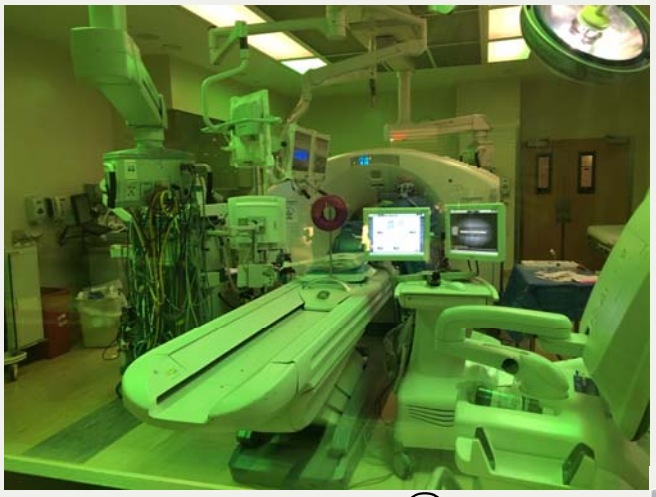
PET/CT guided ablations

Planning on fused PET/CT



RF probe placement



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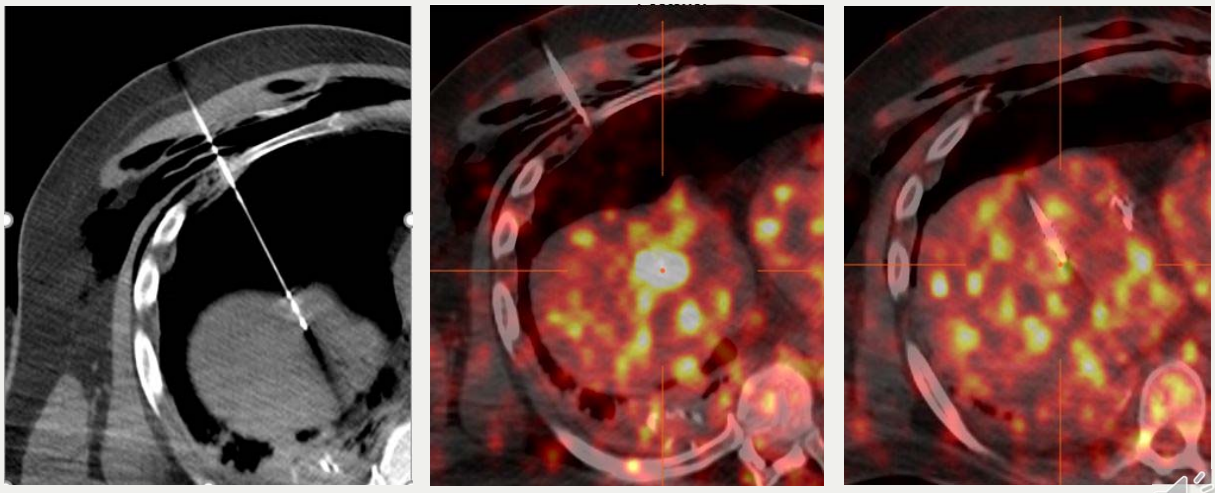
PET/CT guided ablations

Probe placement verification on CT and 1 min breath hold PET



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Ablations: 2nd FDG injection for verification

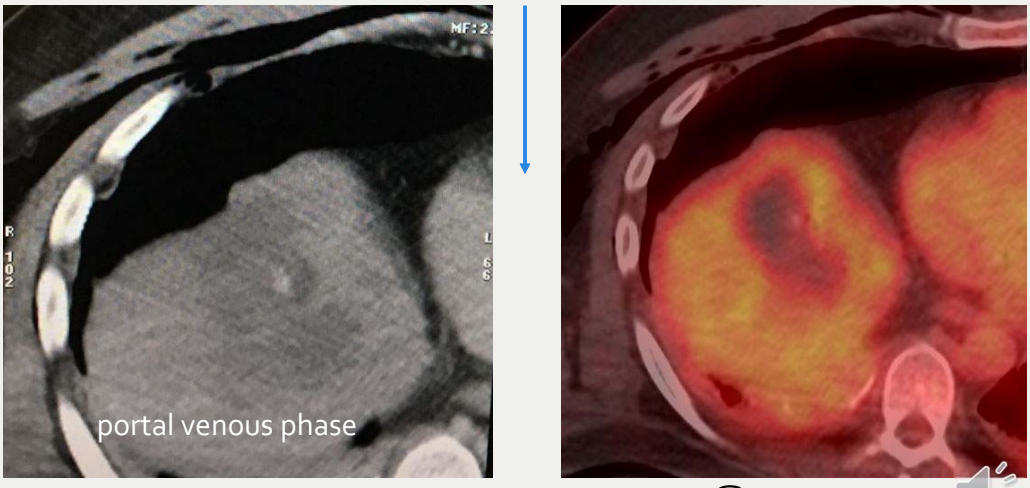
Post ablation:

1) 296 MBq ^{18}F-FDG

2) Thee phase CE-CT

3) Second ablation

4) post ablation PET/CT



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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

Cancer Center

Radiation safety: ^{18}F-FDG guided

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

Median Effective Dose from **448 MBq**

0.02 mSv - operator
0.01 mSv - nurse anesthetist
0.02 mSv - radiology technologist

0.32 mSv - extremity dose equivalent for operator

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
vs. 2.4 mSv/a nat. bkg

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

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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 MBq x 0.019 mSv/MBq ~ 8.4 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

Hu et al, J Vasc Interv Radiol 2020; 31:1052–1059

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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 & Cornelis, JNM 2016
Gazzato et al, Min. Inv Ther & Allied tech, 2018
Kaye et al, Eur. Rad, 2019

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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

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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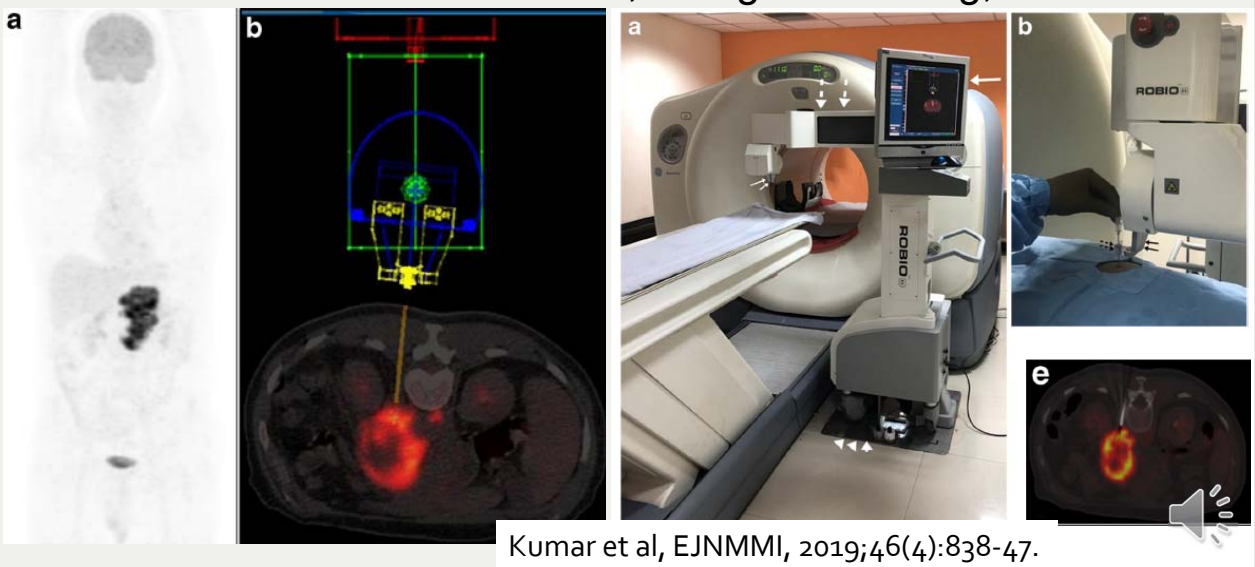
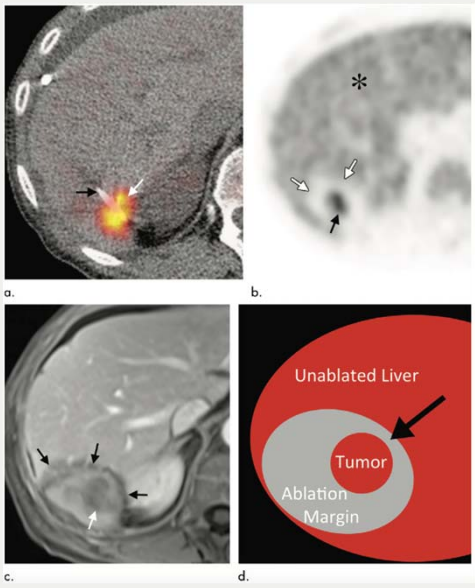
Robotic arm assisted PET/CT guided biopsy

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



Kumar et al, EJNMMI, 2019;46(4):838-47.

^{13}N-ammonia perfusion imaging of ablation margin

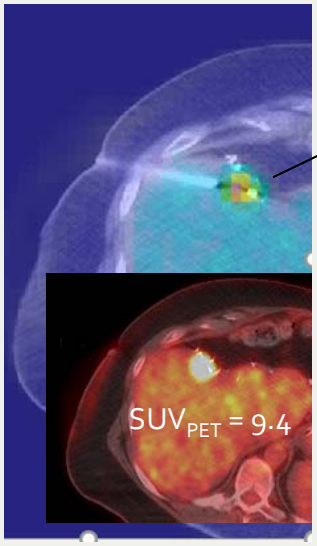


- ~ 374 MBq ^{18}F-FDG 45-60 min before first PET/CT
- ablation
- ~ 338 MBq ^{13}N-ammonia 5-15 min post ablation
- Width of photopenic anulus –> measure of ablation margin

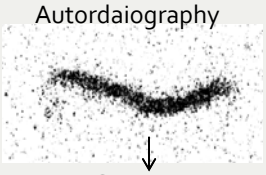
Shyn et al, Radiology ,288 138-145 2018

Biopsy adequacy evaluation: Colorectal cancer liver metastases

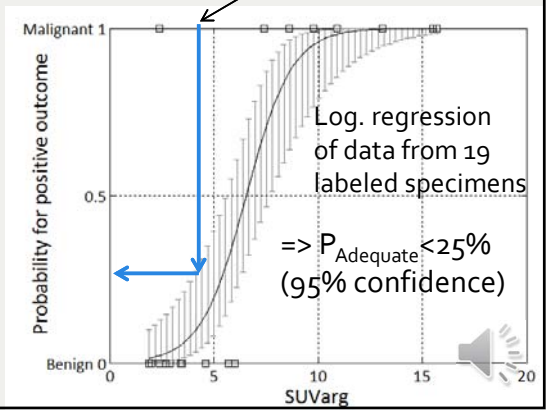
Complications: pneumothorax



Autordaiography



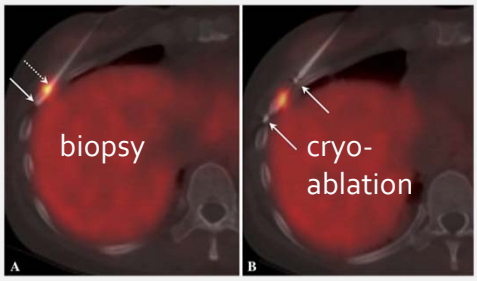
SUV_{ARG} = 3·9

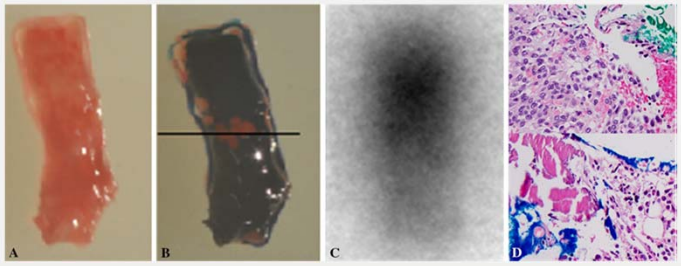


Fanchon L *et al*, JNM, v 56, 4, p538, 2015

In situ validation of new tracers

Fig. 2 A Ga-68 DOTATOC PET/CT-guided biopsy. The arrows depict the first biopsy specimen within the needle. The specimen ends were stained green (dotted arrow) and blue (solid arrow) to retain orientation between this image, autoradiography, and surgical pathology. B Ga-68 DOTATOC PET/CT-guided cryoablation. A new PET acquisition is used for this fused image. The arrows depict the markers at both ends of active tip of cryoapplicator. The ice ball properly covered the lesion and intended margin during both freeze cycles (not shown)





Cardiovasc Intervent Radiol
DOI 10.1007/s00270-016-1350-1

CASE REPORT

Ga-68 DOTATOC PET/CT-Guided Biopsy and Cryoablation with Autoradiography of Biopsy Specimen for Treatment of Tumor-Induced Osteomalacia

Majid Maybody[1] · Ravinder K. Grewal[2] · John H. Healey[3] · Cristina R. Antonescu[4] · Louise Fanchon[5] · Sinchun Hwang[6] · Jorge A. Carrasquillo[2] · Assen Kirov[5] · Azeez Farooki[7]

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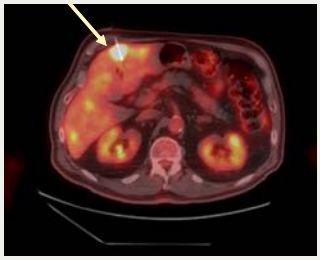
Benefit of PET/CT g. bx for Radiogenomics

=> Correlation of uptake with genomic profile of same lesion

KRAS+ : SUV_{max} = 17.5



other lesions SUV_{max} < 12.2

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, SUR_{max}

Student's T-test p< 0.001

SUR_{MAX} AUC=0.76

Popovich, Talarico, van den Hoff ,…Kirov, submitted
Kirov et al, SNMMI 2019

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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

- Shyn PB. Interventional positron emission tomography/computed tomography: state-of-the-art. Tech Vasc Interv Radiol. 2013;16(3):182-90.
- Solomon SB, Cornelis F. Interventional Molecular Imaging. J Nucl Med. 2016;57(4):493-6.
- Fei B, Schuster DM. PET Molecular Imaging-Directed Biopsy: A Review. AJR Am J Roentgenol. 2017;209(2):255-69.
- Cazzato RL, Garnon J, Shaygi B, Koch G, Tsoumakidou G, Caudrelier J, et al. PET/CT-guided interventions: Indications, advantages, disadvantages and the state of the art. 2018;27(1):27-32.
- Book: "Oncological PET/CT with Histological Confirmation" J. Cerci, S.Fanti, D. Delbeqe editors, Springer, 2016

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Interventional Radiology team

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Contributors

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