SPR 2015 Nuclear Session
May 1, 2015
SAM Questionnaire

Dose Reduction Strategies for SPECT/CT and PET/CT
Adam M. Alessio, PhD

1. **Technology dose savings can be achieved in SPECT imaging through all the following except:**
   A. Improved collimator designs
   B. Higher resolution detectors made from materials such as CzT
   C. Improved data processing and reconstruction algorithms
   D. Faster rotation of detector heads
   E. Greater solid angle coverage

   Correct Answer: D

Reference
1. DePuey, EG. "Advances in SPECT Camera Software and Hardware: Currently Available and New on the Horizon." *J Nucl Cardiol* 19.3 (2012): 551-81

Rationale
Rotating the detector heads faster will not lead to more detected counts at any moment in time. Therefore, this does not improve sensitivity and will not lead to potential dose savings.

2. **Diagnostic Reference Levels (DRLs) can be used in clinical practice to:**
   A. Provide legal justification in event of malpractice law suit
   B. Set standards to identify normal, average doses
   C. Set standards to identify unusually low doses
   D. Compare local practice with peer institutions and national levels
   E. Provide required protocol settings for local practice

   Correct Answer: D

Reference
1. NCRP, Report 172: Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States (National Council on Radiation Protection and Measurements, 2012).

Rationale
Compare local practice with peer institutions and national levels.

Explanation: The Diagnostic Reference Level is set at the 75% dose level of all like exams. Diagnostic reference levels are just supplements to professional judgment and do not provide a dividing line between good and bad medicine. DRLs should not be viewed as absolute determinants of appropriate use of medical radiation. DRLs are not intended

for regulatory or commercial purposes or to establish legal standards of care. Optimization must take into account both patient dose and clinical utility, based on image quality. For Nuclear Medicine, this is usually set at the 75% injected activity for all similar studies. This 75% level can be used to identify unusually high dose levels and to promote (not dictate) good practice for a more specific medical imaging task.

SPECT/CT: Musculoskeletal Applications
Andrew Trout, MD

3. **Which of the following is shown in the figure and is one of the more common causes of pediatric low back pain not related to the spectrum of pars abnormalities?**

   A. Diskitis/osteomyelitis
   B. Metastatic disease
   C. Abnormal articulation of a transitional vertebra
   D. Transverse process fracture
   E. Sacral fracture

   Correct Answer: C

References

1. Connolly LP, et al. Clin Nucl Med. 2004 Nov;29(11):689-93
2. Gelfand MJ, et al. Eur J Nucl Med Mol Imaging. 2010; 37:S211

Rationale
The fused SPECT/CT image shows abnormal uptake at the articulation of a transitional vertebra with the sacrum.

4. **Which of the following is correct regarding the addition of SPECT/CT imaging to whole body bone scanning?**
   A. An additional dose of radiotracer is required for SPECT imaging
   B. SPECT imaging does not add value without a simultaneously performed localization CT
   C. Localization CT should be performed at diagnostic dose settings
   D. SPECT imaging results in additional radiation exposure to the patient
   E. CT may identify abnormalities without radiotracer uptake

   Correct Answer: E

References

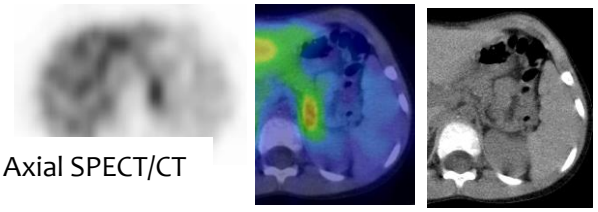
1. Gregory PL, et al. Eur Spine J. 2004; 13(6):503
2. Sharp SE, et al. J. Nucl Med. 2012; 53(S1):262

Rationale

CT helps to localize abnormal radiotracer uptake, helps to define the underlying musculoskeletal abnormality and may add value in the assessment of abnormalities without radiotracer uptake.

SPECT/CT: Oncologic Applications

Susan E. Sharp, MD



Axial SPECT/CT

Images modified from Sharp et al. *Semin Nucl Med*. 2011;41(5):345-353

5. **A 4-year-old undergoes I-123-MIBG imaging after therapy. What is the left retroperitoneal uptake seen on SPECT/CT due to?**
   A. residual retroperitoneal tumor
   B. skeletal metastatic disease
   C. physiologic renal activity
   D. physiologic adrenal activity
   E. physiologic bowel activity

   Correct Answer: D

Rationale

The SPECT/CT images show that the left retroperitoneal uptake is due to physiogic adrenal activity.

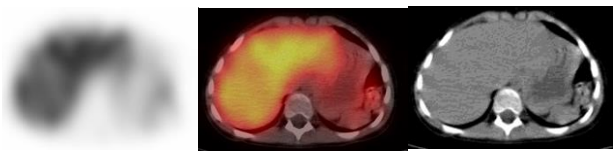
The CT scan shows a normal adrenal gland at the site of MIBG uptake. No residual tumor is seen in this region. The uptake is anterior to the kidney and therefore cannot be renal activity. The uptake is medial and posterior to bowel and is therefore not bowel activity. The uptake does not correspond to the spine or another bony structure and is therefore not a skeletal metastasis.

Reference

1. S. Ted Treves, editor. Pediatric Nuclear Medicine and Molecular Imaging. Fourth Edition.
   New York, NY. Springer 2014. Chapter 19; pages 429-45.

6. **A 6-year-old undergoes I-123-MIBG imaging after therapy. What does the pattern of liver uptake shown most often reflect?**
   A. normal hepatic activity
   B. liver metastases
   C. cirrhosis
   D. biliary obstruction
   E. hepatitis

   Correct Answer: A



Axial SPECT/CT

Images modified from Treves ed. Nuclear Medicine and Molecular Imaging. 4th ed. New York. Springer (2014).

References

1. S. Ted Treves, editor. Pediatric Nuclear Medicine and Molecular Imaging. Fourth Edition.
   New York, NY. Springer 2014. Chapter 19; pages 429-45.
2. Jacobsson et al. Clin Nucl Med. 2007;32:24-8.
3. Rufini et al. J Nucl Med. 1996;37:1464-8.

Rationale

The SPECT/CT images show relatively increased uptake within the left hepatic lobe, a common normal finding.

The right and left hepatic lobes normally demonstrate significant differences in I-123-MIBG uptake with relatively higher uptake in the left hepatic lobe. Physiologic uptake in the liver is often heterogeneous, especially on SPECT images. No definite focal areas of uptake are seen to indicate a liver metastasis. Cirrhosis, biliary obstruction, and hepatitis are uncommon and would not be expected causes of this pattern of liver uptake.

SPECT/CT: Oncologic Applications

Michael J. Gelfand MD

7. When SPECT/CT is added to standard protocols for thyroid cancer imaging with radioactive iodine,

A. SPECT/CT results are clearly improved with use of I-123 instead of I-131.
B. Remnant normal thyroid tissue can consistently be differentiated from local metastases of thyroid cancer.
C. Midline radioiodine uptake anterior to the trachea is likely due to uptake in a benign thyroglossal duct remnant.
D. The SPECT/CT imaging seldom provide information that affect radiotherapy.

Correct Answer: C

References

1. Wong KK, Zarzhevsky N, Cahill JM, et al. Incremental value of diagnostic 131I SPECT/CT fusion imaging in the evaluation of differentiated thyroid carcinoma. AJR Am J Roentgenol. 2008;191:1785-94.
2. Valdés Olmos RA, Rietbergen DD, Vidal-Sicart S, et al. Contribution of SPECT/CT imaging to radioguided sentinel lymph node biopsy in breast cancer, melanoma, and other solid cancers: from "open and see" to "see and open". Contribution of SPECT/CT imaging to radioguided sentinel lymph node biopsy in breast cancer, melanoma, and other solid cancers: from "open and see" to "see and open". Q J Nucl Med Mol Imaging. 2014; 58:127-39.

8. When SPECT/CT is added to standard lymphoscintigraphy protocols,

A. Use of an intraoperative gamma probe is no longer needed for sentinel lymph node localization.
B. Use of blue dye is no longer needed for sentinel lymph node localization.

C. In pediatric patients, activity at the injection site frequently interferes with imaging of the sentinel node.
D. The SPECT/CT imaging aid the surgeon in planning incisions and locating the sentinel nod e.

Correct Answer: D

References

1. Wong KK, Zarzhevsky N, Cahill JM, et al. Incremental value of diagnostic 131I SPECT/CT fusion imaging in the evaluation of differentiated thyroid carcinoma. AJR Am J Roentgenol. 2008;191:1785-94.
2. Valdés Olmos RA, Rietbergen DD, Vidal-Sicart S, et al. Contribution of SPECT/CT imaging to radioguided sentinel lymph node biopsy in breast cancer, melanoma, and other solid cancers: from "open and see" to "see and open". Contribution of SPECT/CT imaging to radioguided sentinel lymph node biopsy in breast cancer, melanoma, and other solid cancers: from "open and see" to "see and open". Q J Nucl Med Mol Imaging. 2014; 58:127-39.

3.

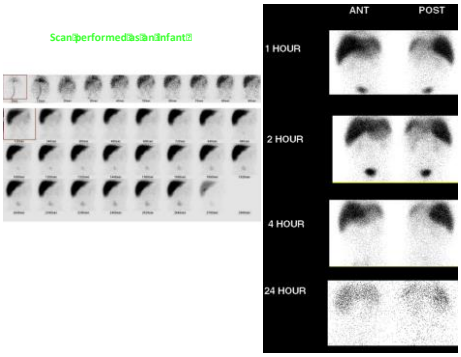
PET/CT in Oncology: Usual and Unusual Tumors

Helen Nadel, MD

9. A 27 year old who had the following scan as an infant presents with new lymph nodes in the neck and a PET/CT study is performed.

Based on the scan findings the likely diagnosis is:

A. Sarcoidosis
B. Tuberculosis
C. Post transplant lymphoproliferative disease
D. Neuroendocrine tumor



Correct Answer: C

References

1. Von Falck, C., et al. "Post transplant lymphoproliferative disease in pediatric solid organ transplant patients: A possible role for [18F]-FDG-PET (/CT) in initial staging and therapy monitoring." European journal of radiology 63.3 (2007): 427-435.
2. Bitzan, Martin, et al. "Cryptogenic organizing pneumonia after rituximab therapy for presumed post-kidney transplant lymphoproliferative disease." Pediatric Nephrology 25.6 (2010): 1163-1167

Rationale

The scan performed as an infant is a biliary scan that did not show any excretion to 24 hours. The presumed diagnosis was biliary atresia confirmed with biopsy and he underwent liver transplantation as a child. He was successfully treated at age 10 for PTLD and was off all immunosuppressive therapy for more than 10 years when he recently presented with new swelling in neck. The PET/CT shows extensive, left neck,

mediastinal and left axillary lymphadenopathy in keeping with PTLD and transformation to lymphoma.

- *A is incorrect as there is no symmetrical hilar adenopathy and would not be predisposed to this after diagnosis of biliary atresia.*
- *B is incorrect as again given history not likely predisposed and no direct contact. Scan does not show lung involvement.*
- *D is incorrect as not classic position for neuroendocrine tumor as nodal disease*
- *PTLD*
- *Patient having organ transplant at risk second malignancy*
- *Most commonly develop skin neoplasms and post-transplant lymphoproliferative disorder (1-2%)*
- *PTLD acts like an aggressive lymphoma*
- *Linked to presence of Epstein-Barr virus*
- *80% are B-cell lymphomas, 20% T-cell lymphomas*
- *Most occur within 1 year of transplant and are EBV positive*
- *Those occurring later are more aggressive and often EBV negative*
- *PTLD and PET/CT*
- *83% of PTLD patients had extranodal involvement on PET/CT.*
- *In 57% ^{18}F-FDG PET/CT detected occult lesions not identified on other imaging modalities or suggested PTLD in equivocal lesions.*
- *More aggressive PTLD histological subtypes demonstrated higher SUV_{max} compared with less aggressive subtypes.*

10. Post therapy SUVmax of less than 2.5 on FDG PET/CT imaging can predict good responder in:

A. Adrenocortical carcinoma
B. Ewing sarcoma
C. Hepatocellular carcinoma
D. Osteogenic sarcoma

Correct Answer: B

References

1. Hawkins DS, Rajendran JG, Conrad EU, 3rd, Bruckner JD, Eary JF. Evaluation of chemotherapy response in pediatric bone sarcomas by [F-18]-fluorodeoxy-D-glucose positron emission tomography. *Cancer.* Jun 15 2002;94(12):3277-3284.
2. Hawkins DS, Schuetze SM, Butrynski JE, et al. [18F]Fluorodeoxyglucose positron emission tomography predicts outcome for Ewing sarcoma family of tumors. *J Clin Oncol.* Dec 1 2005;23(34):8828-8834.

Rationale

There is no definitive SUV cut-off that correlates with ultimate prognosis. However, in the Ewing Family of tumors FDG PET CT tumor response with reduction of SUV of greater than 40% and with SUVmax of less than 2.5 post chemotherapy is predictive of

progression free survival and is independent of initial stage. There is no cutoff for the other tumors listed so answers A, C,D are incorrect.

PET in Epilepsy: The Value of Multimodality Imaging
Jason N. Nixon, MD

11. In the images provided, what is the most likely etiology of the abnormal distribution of cortically-thresholded FDG-PET activity?

A. Periventricular nodular heterotopia
B. Limbic encephalitis
C. Rasmussen encephalitis
D. Depth-of-sulcus FCD
E. Active seizure

Correct Answer: D

Rationale

Cortically-thresholded FDG-PET fused to MR allows improved analysis of the distribution of cortical FDG-PET activity and facilitates identification of focal areas of hypometabolism at the depth of sulci, commonly seen with type II FCD, that are easily missed on visual PET inspection alone. Periventricular nodular heterotopia will appear in a periventricular distribution, but are also easily missed on visual inspection of FDG-PET. Limbic encephalitis often presents with a characteristic pattern of bilateral mesial temporal hypermetabolism; the associated swelling of the mesial temporal structures on MR can be easily overlooked. Rasmussen encephalitis typical presents with a widely-distributed area of hypometabolism with admixed hypermetabolic foci. Active seizures are expected to be hypermetabolic on FDG-PET.

Reference

1. Rubi S, et al. Epilepsia 2011; 52(12):2216-24.

12. In patients with tuberous sclerosis, which imaging feature on FDG-PET is indicative of a potentially active lesion?

A. Temporal location
B. Disproportionately widespread hypometabolism relative to tuber size on MR
C. Degree of hypometabolism
D. Subcortical location
E. Proximity to adjacent lesions

Correct Answer: B

Rationale

Patients with tuberous sclerosis and drug resistant epilepsy can be considered for epilepsy surgery if one or a few active lesions can be identified and targeted for removal or ablation. Lesions with widely-distributed hypometabolism on FDG-PET compared to the size of the anatomic lesion on MR are more likely to be epileptogenically active lesions. Other features of the tubers on FDG-PET, including location, degree of hypometabolism, and proximity to adjacent lesions, have not be shown to be predictive of

epileptogenicity. Of note, brain imaging with C11-alpha-methyl-L-tryptophan (AMT) PET is another potentially useful imaging modality for this indication.

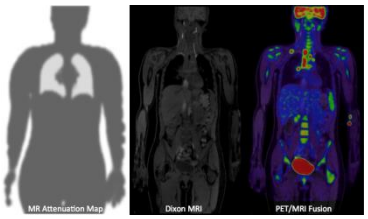
Reference

1. Chandra PS, et al. Epilepsia 2006;47(9):1543-49.

MR Protocols

Matthew J. Goette, PhD

13. In the following PET/MR exam of a patient diagnosed with Hodgkin lymphoma, what image artifact is most clearly observed?



A. Mischaracterization of lung tissue in MR attenuation map
B. Truncation artifact in MR attenuation map and Dixon MRI
C. Misregistration of PET and MR images from patient motion
D. Metallic implant leading to signal loss in Dixon MRI
E. Cardiac motion artifact causing ghosting in Dixon MRI

Correct Answer: B

Rationale

A is <u>not</u> correct: This 3-segment MR attenuation map shows typical lung tissue characterization, denoted by light gray color, as opposed to white color that denotes air.

B is CORRECT: The MR signal is truncated in the patient's arms in both the MR attenuation map and Dixon MR image, which is a result of the inhomogeneity of the magnetic field toward the edges of the bore.

C is <u>not</u> correct: Due to patient cooperation throughout the exam, particularly during the breath-held Dixon sequence, the PET and MR images are coregistered very well.

D is <u>not</u> correct: Metallic implants and other devices like injection ports typically yield large MR signal losses, which result in voids in Dixon MR images and MR attenuation maps, which are not seen here.

E is <u>not</u> correct: Although cardiac motion is always present in non-cardiac-gated sequences like this Dixon exam, obvious ghosting artifacts are not seen here.

References

1. Vargas MI, Becker M, Garibotto V, Heinzer S, Loubeyre P, Gariani J, Lovblad K, Vallée JP, Ratib O. Approaches for the optimization of MR protocols in clinical hybrid PET/MRI studies. Magn Reson Mater Phy 2013;26:57-69.
2. Martinez-Möller A, Eiber M, Nekolla S, Souvatzoglou M, Drzezga A, Ziegler S, Rummeny E, Schwaiger M, Beer A. Workflow and scan protocol considerations for integrated whole-body PET/MRI in oncology. J Nucl Med 2012;53(9):1415-26.

14. Which of the following is true regarding current MR Attenuation Correction (MRAC) algorithms used in PET/MR?

A. Not yet FDA-approved
B. Currently only validated for Brain PET/MR
C. Does not differentiate bone from soft tissue
D. Creates fewer artifacts relative to CT Attenuation Correction (CTAC)
E. Still uses ionizing radiation

Correct Answer: C

Rationale

A is not correct: The current MR Attenuation Correction algorithms were FDA approved in 2010.

B is not correct: PET/MR is clinically validated by the FDA for use without restriction to body part.

C is CORRECT: The current commercially available attenuation corrections methods include: Philips three segment (air, soft tissue, and lungs), Siemens four segment (air, soft tissue, fat, and lungs), and GE four segment (air, soft tissue, fat, and lungs). Bone is not differentiated from soft tissue in any of these methods, which may lead to quantitative errors compared to CT-based attenuation correction methods.

D is not correct: Both CTAC and MRAC methods can cause imaging artifacts.

E is not correct: MRAC does not utilize ionizing radiation.

References

1. Keereman V, Mollet P, Berker Y, Schulz V, Vandenberghe S. Challenges and current methods for attenuation correction in PET/MR. Mag Reson Mater Phy 2013;26(1):81-98.
2. Partovi S, Kohan A, Gaeta C, Rubbert C, Vercher-Conejero J, Jones R, O'Donnell J, Wojtylak P, Faulhaber P. Image quality assessment of automatic three-segment MR attenuation correction vs CT attenuation correction. Am J Nucl Med Mol Imag;3(3):291-99.
3. Catalano O, Rosen B, Sahani D, Hahn P, Guimaraes A, Vangel M, Nicolai E, Soricelli A, Salvatore M. Clinical impact of PET/MR imaging in patients with cancer undergoing same-day PET/CT: initial experience in 134 patients—a hypothesis-generating exploratory study. Radiology 2013;269(3):857-69.

PET/MR: Pediatric Solid Tumors

Victor J. Seghers, MD, PhD

15. What is a likely benefit of PET/MR over PET/CT scanners?

A. Superior PET resolution
B. Faster Image Acquisition

C. Improved Anatomic Resolution of Cortical Bone
D. Decreased Patient Radiation Exposure

Correct Answer: D

Rationale

A is not correct as on the Philips PET/MR the PET detectors on PET/MR and PET/CT are the same. The Siemens PET detectors on PET/MR also have lower resolution than their corresponding PET/CT.

B is not correct as even simple performance of MRAC takes longer than CTAC. This is most relevant for the tandem configuration of the Philips PET/MR scanner. For integrated PET/MR scanners in theory PET/MR can equal imaging times for PET/CT as there is simultaneous acquisition of both PET and MR.

C is not correct as CT is superior to MR for imaging of cortical bone. It is hoped that superior MR imaging of bone marrow relative to CT will prove clinically useful in PET/MR.

D is the correct answer. CT can contribute 45% or more of the total effective dose of PET/CT, making reduced radiation exposure in a PET/MR an attractive attribute. This is offset by improvements in both software and hardware such as iterative reconstruction techniques and new PET detectors (Digital PET) on newer PET/CT scanners.

References

1. Simultaneous Whole-Body PET/MR Imaging in Comparison to PET/CT in Pediatric Oncology: Initial Results; Schafer et al; Radiology, October 2014
2. PET/MR Imaging: Technical Aspects and Potential Clinical Applications; Torigian et al; Radiology April 2013
3. Competitive advantage of PET/MRI; Jadvar and Colletti; European Journal of Radiology; January 2014

16. What is an accurate statement comparing Germanium and CT-based transmission attenuation correction methods?

A. No difference
B. CTAC requires a Germanium conversion factor
C. CTAC and Germanium-based AC are comparable
D. CTAC produces much lower calculated SUV

Correct Answer: C

Rationale

A is not correct as they are 2 different methods of calculation of attenuation of photons.

B is not correct as no Germanium conversion factor has been widely accepted for clinical use.

C is correct. The quantitative radioactivity values are comparable although CT-based AC produces radioactivity concentration values significantly higher than germanium-based corrected values. This is important as it emphasized not mixing a patients scans on PET-only and PET/CT scanners and is historically relevant in the current discussion of MRAC vs CTAC.

D is <u>not</u> correct. Please see answer for C above.

References

1. Essentials of Nuclear Medicine Imaging, 5th edition, Chapter 13, Mettler and Guiberteau
2. Journal of Nuclear Medicine, 2002; 43:1137-1143