Communicating with Parents and Referring Clinicians
S. Ted Treves, MD

1. Compared to contrast agents used in CT and MRI, the administered volume and mass of 99mTc-MDP solution is
   A. 99mTc-MDP volume is approximately equal to CT and MRI contrast agents
   B. 99mTc-MDP volume is 2 times greater than CT and MRI contrast agents
   C. 99mTc-MDP volume is 20-200 fold less than CT and MRI contrast agents
   D. The masses of material injected are equivalent among 99mTc-MDP, CT and MRI contrast agents
   E. The mass of 99mTc-MDP administered material is greater than the mass from CT and MRI contrast agents

Correct Answer: C

References

Rationales
A. Is incorrect since there is a significant difference in the volume of material injected into the patient. Clearly and 99mTc-MDP solution has a much smaller volume that the CT and MRI contrast agents.
B. Is incorrect as the volume of injected 99mTc-MDP solution is much lower than the other two agents.
C. Correct answer
D. Incorrect answer. The masses among the three agents are vastly different. The mass of 99mTc-MDP is orders of magnitude lower than those of CT and MRI contrast agents.
E. Incorrect answer. The mass of administered 99mTc-MDP is not greater than the masses of CT and MRI contrast agents.

2. Administration of radiopharmaceuticals in children results in which of the following?
   A. No pharmacologic effect
   B. Hemodynamic effect
   C. Hyperosmotic effect
   D. Toxic effect
   E. Frequent allergic reactions

Correct Answer: A

References
Rationales
A. Correct answer. Radiopharmaceuticals are given in trace amounts that do not produce a pharmacologic effect.
B. Incorrect. The volume of injected tracer is very low (usually <0.5 mL) and will not trigger a hemodynamic effect.
C. Incorrect. No hyperosmotic effect is triggered by the intravenous administration of radiopharmaceuticals.
D. Incorrect. There are no obvious toxic effects following the administration of radiopharmaceuticals.
E. The amount of mass injected is very tiny and is below the threshold necessary to trigger and allergic reaction. For example, patients that are known to be allergic to iodine can be safely injected with radiopharmaceuticals containing iodine such as iodine-123 or iodine-131.

Bone Scintigraphy-State of the Art
Helen R. Nadel, MD

3. Tc-99m MDP SPECT-CT bone imaging in children is proving most helpful in the diagnosis of?
   A. Metastatic neuroblastoma.
   B. Occult bone injury in nonverbal children.
   C. Chronic regional pain syndrome.
   D. Chronic recurrent nonbacterial osteomyelitis.

Correct Answer: B

References
   Shammas A. Nuclear medicine imaging of the pediatric musculoskeletal system. Semin Musculoskelet Radiol. 2009 Sep;13(3):159-80. Review.

Rationales
B is the correct answer. MDP bone scintigraphy can localize with sensitivity bony abnormality but SPECT/CT will improve specificity for diagnosis of occult fracture or myositis ossificans in nonverbal or handicapped children in whom localization of pain is not always clinically possible. A, C, and D. Bone scintigraphy may be abnormal in the other diagnoses but SPECT/CT will not increase the specificity of diagnosis in the other diagnoses listed.
4. Which of the following is true regarding the use of F-18 PET bone scans in children and young adults?
   A. F-18 PET requires anatomic correlation with diagnostic CT for evaluation of sports injuries.
   B. F-18 PET has a much higher radiation dose than 99mTc-MDP SPECT.
   C. F-18 PET is useful to assess skeletal metastases, but not benign bone disease.
   D. F-18 PET provides faster patient throughput than 99mTc-MDP SPECT.

Correct Answer: D

References

Rationales
A is incorrect – diagnostic CT is not required for identification of pars stress injury in the spine or stress injuries of the extremities.
B is incorrect – The effective dose of F-18 PET is similar or minimally higher than the effective dose of 99mTc-MDP SPECT.
C is incorrect – F-18 PET is particularly useful for the assessment of benign bone processes.
D is the correct answer. The short uptake period (30-60 minutes) for F-18 PET bone scans shortens the overall time from dose administration to completion of scan.

Pediatric Diuresis Renography
Massoud Majd, MD, FACR

5. Diuresis Renogram in an 8-month-old boy with prenatal diagnosis of left hydronephrosis demonstrates normal function, and a post-diuresis drainage half-time of 40 minutes. Which of the following statements best describes your interpretation of the study and the next step recommendation for this patient?
A. The study is finished. The washout half-time of 40 minutes is diagnostic of high grade ureteropelvic junction (UPJ) obstruction and you refer the patient to Urology for pyeloplasty.
B. The study is finished. There is high probability for UPJ obstruction and you recommend a follow-up diuresis renogram in 6 months time to reassess drainage.

C. You are concerned about UPJ obstruction and you ask the technologist to obtain a 3-hour delayed image.

D. You consider the study unfinished and ask the technologist to obtain static images before and after the patient is kept in upright position for 15 minutes to assess gravity-assisted drainage, prior to final interpretation of the scan.

Correct Answer: D

References

Rationales
A. This is an incorrect answer because although post-diuresis drainage half-time is an important parameter in quantitative analysis of diuresis renogram curve, it should not be used in isolation. Poor drainage in supine may be positional and may improve after upright positioning. In addition, the natural history of neonatal hydronephrosis is variable and most of the time, the definitive diagnosis cannot be made on just the initial study, as the drainage may change over time. Therefore, poor post-diuresis drainage in supine position as seen in this infant should not be interpreted as definite evidence of obstruction and an indication for pyeloplasty. Quantitative evaluation of post-upright clearance of the high residual tracer activity at the end of 30 minutes imaging is very important in planning the follow-up imaging evaluation and the patient’s management. Poor drainage in upright position usually increases the likelihood of gradual worsening of obstruction, while in most cases with markedly improved drainage in upright position the follow-up studies show improved hydronephrosis and post-diuresis drainage as demonstrated by the examples demonstrated in the Figures 2,3,4,and 5.

Answer b is also incorrect. Although a post-diuresis drainage half-time of 40 minutes is worrisome for UPJ obstruction and certainly indicates the need for follow-up imaging studies such as renal sonography and/or diuresis renography, this initial study should not be considered as complete without evaluating gravity-assisted drainage as described in the explanation given for answer a.

Answer c is also incorrect. The post-diuresis drainage in the supine position is prolonged and there is certainly concern for UPJ obstruction. However, a delayed image will merely give you a visual inspection of further drainage from the collecting system without the ability to do a quantitative analysis of the drainage. Furthermore, standardization of the technique of gravity-assisted drainage (10 minutes or 15 minutes of upright positioning) is important in comparing multiple studies in the same patient to assess for improvement or worsening of drainage on the follow-up exams.

D. This is the correct answer. Patient’s supine position during diuresis renography can affect the post-diuresis drainage of the tracer from the dilated system. It has been shown that the presence or lack of significant improvement of drainage after upright positioning is helpful in distinguishing obstructed from non-obstructed systems. This may affect management of the patient as demonstrated in the initial and follow-up diuresis renogram curves of two infants with
prolonged post-diuresis washout half-times, one with good post-upright drainage (Figures 2 and 3) and one with poor post-upright drainage (Figures 4, 5 and 6).

**Fig 2.** Initial study at 8 months of age. The post-upright clearance in this patient with a washout half-time 40 minutes was 65%. 

**Fig 3.** Follow-up study at 20 months of age showed markedly improved post-diuresis drainage with a washout half-time of 6 minutes.
**Fig 4.** The initial study in another infant at 4 months of age demonstrated a washout half-time of 27 minutes and a post-upright drainage of only 4%.

**Fig 5.** The followup study at 7 months of age showed marked worsening of the post-diuresis washout half-time (flat time-activity curve). Patient underwent pyeloplasty.
6. A 5-year-old boy with intermittent abdominal pain and sonographic diagnosis of mild left hydronephrosis underwent diuresis renography 6 weeks after an episode of pain to rule out left UPJ obstruction. The study demonstrated normal left renal function with a post-diuresis washout half-time of 9 minutes and 11% residual at 30 minutes. Which of the following statements best describes your interpretation of the study and the next step recommendation for this patient?

A. The study is normal. UPJ obstruction is ruled out as the cause of abdominal pain. GI evaluation is recommended.

B. The study is normal. But intermittent UPJ obstruction cannot be excluded. Repeat diuresis renography during or within 24 hours of pain episode is recommended.

C. The study is normal. But intermittent UPJ obstruction cannot be excluded. Repeat diuresis renography 1-2 weeks after abdominal pain episode is recommended.
Correct Answer: B

References

Rationales
a is incorrect answer. The post-diuresis drainage seen in this study can be interpreted as normal (no evidence of UPJ obstruction) in a 5-year-old child with hydronephrosis who is asymptomatic. But it does not exclude intermittent UPJ obstruction in patients with history of intermittent episodes of abdominal pain particularly when the pain is associated with nausea/vomiting (Dietl’s crisis).
b is the correct answer. Dietl’s crises in children and adolescents with known or unknown hydronephrosis are due to episodes of transient acute UPJ obstruction of varying severity and duration. Acute obstruction causes decreased renal perfusion and severe decrease in the glomerular filtration rate (GFR). While the acute obstruction and pain symptoms are transient, the recovery of the GFR is gradual and may take a week to return to normal. MAG-3 is a tubular agent but its clearance from the cortex is dependent on glomerular filtration and urine flow through the tubules. Therefore, the renal scan and diuresis renogram findings vary depending on when the study is done in relation to the pain episode. If the study is done during or shortly after an episode of pain, the MAG 3 renal scan will often show decreased uptake but with complete or severe cortical retention of the tracer as seen on the renal scan done in this patient while he was in pain (Fig 7). If the study is done within a few days after the transient obstruction, it may show better renal function and good post-diuresis clearance of the tracer from the renal pelvis, but with varying degrees of cortical retention. Unilateral cortical retention of MAG3 in patients with intermittent abdominal pain is pathognomonic of ongoing or recent acute obstruction and a clear indication for pyeloplasty.
c is incorrect answer because GFR eventually returns to normal level resulting in normal cortical clearance of the tracer and most likely no evidence of obstruction.

Fig 8. MAG3 renal scan of the same patient who had a normal diuresis renogram 2 days before. This study was done when the patient had flank. It shows complete cortical retention of MAG3 in the left hydronephritic kidney and no evidence of tracer accumulation in the renal pelvis. The study is finished. Furosemide should not be injected.
7. You are shown early and delayed images from a neonatal hepatobiliary imaging study. Which one of the following statements is true regarding hepatobiliary imaging in a neonate with elevated conjugated hyperbilirubinemia?

A. Neonatal hepatitis and biliary atresia have distinctly different clinical, biochemical and histologic features
B. Sensitivity and specificity for diagnosis of extrahepatic biliary atresia is approximately 52% and 44%, respectively
C. Biliary atresia is excluded if the radiopharmaceutical progresses into the small bowel
D. Pretreatment with phenobarbital for 5 days prior to imaging is not useful in distinguishing biliary atresia from other causes of neonatal cholestasis

Correct Answer: C

References

Rationales
A. is not correct. Hepatitis and biliary atresia have similar clinical presentations, as well as similar biochemical and histologic features. It has been hypothesized that neonatal hepatitis, biliary atresia and choledochal cyst represent variable outcomes of a single process termed: “infantile obstructive cholangiopathy”. Hepatobiliary imaging is the most reliable non-surgical means of distinguishing the two entities.
B. is not correct. The sensitivity and specificity for diagnosis of biliary atresia are much higher. In a recent study of 186 infants by Kwatra et al, sensitivity, specificity, and accuracy were 100%, 93%, and 94.6%, respectively, in children who underwent phenobarbital-enhanced hepatobiliary scintigraphy.
C. is correct. Biliary atresia can be reliably excluded with hepatobiliary imaging when there is passage of the radiopharmaceutical from the biliary system into the small bowel.
D. Is not correct. Pretreatment with phenobarbital (5mg/kg/day) for 5 days prior to imaging is recommended to optimize hepatic uptake and excretion of the radiopharmaceutical. A serum phenobarbital level of 15 mcg/ml should be achieved prior to imaging.

Ventilation/Perfusion Scans
Lisa J. States, MD

8. A perfusion scan shows uptake in the brain, kidneys and thyroid. Choose the single best answer
   A. Free Technetium
   B. Left to Right shunt
   C. Right to Left shunt
   D. Metastatic neuroblastoma
   E. Chronic lung disease

Correct Answer: C

Reference

NM Evaluation of CSF Shunts
Hedieh K. Eslamy, MD

9. Images from a NM shuntogram performed in a patient with shunted hydrocephalus and a ventriculoperitoneal shunt are shown. What is the MOST LIKELY diagnosis?
   A. Occlusion of the proximal catheter
   B. Occlusion of the distal catheter
   C. Fracture of the distal catheter
   D. Extravasation of radiotracer at injection
   E. Valve malfunction

Correct Answer: D

References
10. Lymphoscintigraphy cannot be performed with which radiotracer?
   A. 99m Tc-antimony trisulfide colloid.
   B. 99m Tc-dextran
   C. 99m Tc-sulfur colloid
   D. 99m Tc-serum albumin

Correct Answer: C (Has to be triple filtered.)

References

Oncologic Imaging
Michael J. Gelfand, MD and Susan E. Sharp, MD

11. In regard to [F-18]FDG PET/CT imaging in lymphoma:
   A. Imaging of the lower extremities may be omitted on follow-up studies, if the lower extremities were normal on the initial PET/CT study at presentation prior to therapy.
   B. FDG PET/CT imaging in lymphoma is often falsely negative when residual masses remain after chemotherapy.
   C. At early follow-up, after one or two cycles of chemotherapy, FDG PET/CT imaging in lymphoma is predictive of outcome.
   D. Measurements of standardized uptake value (SUV) are routinely used to evaluate response to therapy.
   E. A and C.

Correct Answer: E

References

12. What is the first line functional imaging agent used in neuroblastoma?
   A. F-18-FDG
   B. I-131-MIBG
   C. I-123-MIBG
   D. Tc-99m-MDP
   E. In-111-Octreotide

Correct Answer: C
Rationales
I-123-MIBG is the first line functional imaging agent used in neuroblastoma due to its high sensitivity and specificity for disease detection. I-123-MIBG is preferred over I-131-MIBG as it gives higher quality images at a lower radiation dose. Use of F-18-FDG for neuroblastoma imaging is increasing, especially in patients with non-MIBG avid disease. Tc-99m-MDP bone scans may be used to assess cortical bone metastases at diagnosis, but provide little or no additional information during follow-up of patients with MIBG-avid disease. In-111-Octreotide is not commonly used for neuroblastoma imaging.

References

NM Infection Imaging in Children
Marguerite T. Parisi, MD, MS Ed

13. Advantages of F-18 FDG PET or PET/CT in the evaluation of infection include all of the following EXCEPT:
   A. Delayed normalization of FDG-uptake in post-traumatic or post-surgical sites.
   B. High spacial and contrast resolution
   C. High sensitivity for chronic infections
   D. Ability to quickly obtain results compared to gallium or radio-labelled white cell scans

Correct Answer: A

Rationales
Correct answer is A. As opposed to the radionuclide bone scan, FDG uptake rapidly normalizes following traumatic or surgical fractures as fibroblasts predominate during normal healing. More over FDG accumulation quickly subsides within 3-4 months following surgery. Choices B-D are all advantages of FDG-PET or PET/CT compared to the other radiotracers used for evaluation of infections

14. All of the following regarding the role of F-18 FDG PET or PET/CT in musculoskeletal infections are true EXCEPT:
   A. Highly sensitive for diagnosis of acute and subacute bone and soft tissue infections.
   B. Not adversely affected by the presence of metallic hardware.
   C. Cannot reliably distinguish infection from non-infectious inflammation or malignancy
   D. Imaging procedure of choice for diagnosis of uncomplicated osteomyelitis.

Correct Answer: D
Rationales
Correct answer is D. F-18 FDG PET or PET/CT is of limited value in diagnosing uncomplicated osteomyelitis compared with the combination of physical examination, evaluation of biochemical marker alteration, and 3-phase bone scan (Tc-99m MDP). This is particularly true in children given the frequent need for sedation and higher patient radiation dose of F-18 FDG compared to Tc 99m MDP bone scan. Choices A-C are all true regarding the role of FDG-PET or PET/CT in children and adults with musculoskeletal infections.

References

15. The most common presentation for ischemic stroke in newborn infants is:
   A. increased irritability, inconsolability
   B. headache and confusion
   C. seizures
   D. focal neurologic deficit e.g. hemiparesis
   E. all of the above

Correct Answer: C

Rationale
The correct answer is c). Seizures alone are characteristic of neonates with arterial or venous ischemic stroke. The neonatal brain is immature and is less likely to show a focal deficit e.g. hemiparesis than older infants and children.

References

FDG PET: Neurologic Applications
A. Luana Stanescu, MD

16. Normal FDG PET brain uptake pattern can show hypermetabolism in all of the following brain areas except:
   A. Basal ganglia
   B. Frontal eye fields
   C. Posterior cingulate gyrus
   D. Frontal and parietal association cortex in infants
   E. Wernicke areas
Correct Answer: D

Rationale
Options A, B, C and E: Incorrect. The basal ganglia normally demonstrate hypermetabolism compared with the white matter on FDG PET images. More focal hypermetabolism has also been described in certain cortical areas, such as the posterior cingulate gyrus, the Wernicke region, and the frontal eye fields. Option D; Correct. The brain glucose metabolic pattern in infants reflects the functional brain maturation, with the frontal and parietal association cortex demonstrating lower FDG uptake, in a pattern similar to that in patients with Alzheimer disease, and progressively increasing until 1 year of age, when the pattern becomes similar to that in adults.

References

PET/MR: Implementing a Clinical Program
Victor Seghers, MD, PhD

17. Which of the following is true regarding current MR Attenuation Correction 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. Create fewer artifacts relative to CT Attenuation Correction
E. Still utilizes ionizing radiation

Correct Answer: C

Rationale
Option A is NOT correct: The current MR Attenuation Correction Algorithms were FDA approved in 2010. Option B is Not correct: PET/MR is clinically validated by the FDA for use without restriction to body part. Option C is CORRECT: The current commercially available attenuation corrections methods include: Philips three segment (air, soft tissue, and lungs) and Siemens four segment (air, soft tissue, fat, and lungs). Bone is not differentiated from soft tissue in either of these 2 methods which may lead to quantitative errors compared to CT-based attenuation correction methods. Option D is NOT correct: Both CTAC and MRAC methods can cause imaging artifacts. Option E is NOT correct: MRAC does not utilize ionizing radiation.

References