SESSION 1: APPLIED PHYSICS AND MRI TECHNIQUES

When to Use What Sequences
Govind B. Chavhan, MD, DNB, DABR

1. Which of the following sequences will NOT be suitable for bowel imaging?
   A. Single-shot FSE
   B. Balanced SSFP
   C. T1-3D GRE
   D. T1-Fast spin-echo

   Correct Answer: D

   Reference

   Rationale
   T1 FSE takes long time and will not able to suppress motion artifacts from peristalsis. Other 3 sequences are fast.

2. Which of the following sequences will NOT be suitable for marrow imaging?
   A. T2-fast spin-echo
   B. T2-FFE/MPGR
   C. STIR
   D. T1- fast spin-echo

   Correct Answer: B

   Reference

   Rationale
   Marrow signal abnormality can be suppressed on gradient-echo images due to susceptibility artifacts. Other sequences are spin-echo sequences and can be used for marrow imaging.
How We Do It: Body MR Angiography
Rajesh Krishnamurthy, MD

3. Challenges for performance of time resolved CE-MRA in children when compared to adults include all the following except:
   A. Higher heart rates
   B. Transient first-pass of the contrast bolus within the target vascular anatomy
   C. Inability of children to hold their breath during acquisition
   D. Lesser complexity of target anatomy

Correct Answer: D

Reference

Rationale
Visualizing vascular structures in the pediatric population using contrast enhanced magnetic resonance angiography (CE-MRA) raises several specific challenges such as:

a) Higher and more variable heart rates inherent to the pediatric patient population result in faster and more variable arterial-to-venous transit times.

b) Pediatric patients weigh less. The volume of contrast bolus administered is, therefore, proportionately smaller, and first-pass transit of the contrast bolus within the target vascular anatomy is even more transient than in adults.

c) Many infants and children are sedated and cannot hold their breath during the acquisition, making it necessary to acquire data during free breathing.

The combination of small bolus volume, rapid bolus passage through the target vasculature, and variable circulation rates makes it difficult to accurately capture the arterial phase of the contrast bolus in pediatric patients. Thus, there is a clinical need for a rapid CE-MRA technique capable of separating the arterial and venous phases of the bolus passage within the human body in a sedated pediatric patient breathing freely during the course of the examination.

Due to the diversity of congenital and acquired diseases involving the cardiovascular system, pediatric patients tend to have a similar or greater complexity of target anatomy when compared to adults.
4. An advantage of time-resolved MRA using TRICKS, TWIST or keyhole techniques in the pediatric population would be:
   A. Eliminating temporal blurring of information
   B. Capturing the contrast bolus without the need for timing bolus or contrast arrival monitoring
   C. Visualization and characterization of small vessels
   D. Enabling free-breathing acquisition of CE-MRA

Correct Answer: B

Reference

Rationale
By combining parallel imaging methods such as SENSE with the temporal under-sampling methods such as ‘keyhole’, it is possible to obtain 3D CE-MRA acquisitions that reduce the scan time by a net factor of 8-12, without significantly compromising spatial resolution. Bolus timing becomes unnecessary using these rapid CE-MRA sequences, a significant advantage in the case of young patients with rapid circulatory rates, and a small volume of available contrast. Multiple rapid CEMRA sequences (dynamics) can be programmed to run consecutively and a near-real-time effect can be achieved. As with any CE-MRA, the trade off in 4D-MRA is between temporal resolution and spatial resolution. Parameters for spatial resolution are determined by the age of the patient, size of the target vessel, and the clinical indication. Parameters for temporal resolution are determined by the hemodynamic factors (heart rate, cardiac function), the characteristics of the target vasculature, and the clinical indication.

If the key-hole fraction that is chosen too small, then the contrast signal in very small vessels may not be captured during the first pass, and this may obscure visualization and characterization of smaller structures.

As the k-space data used for final image reconstruction consists of data acquired at disparate time points, temporal blurring of the data is an integral part of the technique. For the same reason, respiratory motion that occurs during this time frame is a source of concern. Therefore, breath-holding is important for time resolved CE-MRA acquisitions that use temporal undersampling.

5. One of the following is not an appropriate indication for the use of contrast enhanced MRA in the liver in children:
   A. Characterization of benign versus malignant masses
   B. Determining the presence and extent of portosystemic varices
   C. Determining the patency of surgically created portosystemic shunts
   D. Screening for hepatic artery or portal vein thrombosis after hepatic transplantation.

Correct Answer: A
Rationale
When diffuse liver disease and portal hypertension are diagnosed, MR angiography is used frequently in a problem-solving role to evaluate the status of the hepatic vasculature after a Doppler ultrasound has been performed. Common indications include suboptimal ultrasound studies due to patient body habitus, characterization of portal vein thrombosis, to determine the presence and extent of portosystemic varices (especially around the gastroesophageal junction which may predict the risk for life-threatening hematemesis), to screen for the presence and adequacy of a spontaneous splenorenal shunt, to map the portal circulation to determine feasibility of bypass procedures, and to determine patency of portal bypass procedures or surgically created portosystemic shunts. It has also been used in the preoperative evaluation of liver transplant recipients to determine patency of the portal venous system, IVC anatomy and variations in hepatic arterial anatomy. In the post-operative period after hepatic transplantation, MRA is helpful to screen for hepatic artery thrombosis or stenosis, or for portal vein thrombosis, especially when ultrasound is indeterminate. Time resolved CE-MRA is an ideal technique for these applications, and provides reliable separation of hepatic arterial, portal venous and hepatic venous phases.

Optimization and Artifact Reduction in Abdominal MRI
Taylor Chung, MD

6. Single-shot Fast (Turbo) Spin Echo or HASTE is used quite often clinically for abdominal imaging. How does the addition of parallel imaging (such as SENSE or iPAT or ASSET) typically with acceleration factor of 2, improve or degrade the quality of the single-shot image?

A. There is no improvement
B. There is degradation of the image as the single shot image is more blurry with parallel imaging
C. With parallel imaging, the echo train length is shorten thereby improving the inherent blurriness due to long echo train length typically found in single shot imaging
D. With parallel imaging, the echo train length is increased thereby improving SNR of the image

Correct Answer: C

Reference
This signal modulation broadens the point-spread function (PSF) of the acquisition and causes image blurring. By shortening this T2 decay by 50% will result in sharpening the image as the PSF will be much narrower. See reference.

7. Which of the following MR technique is NOT frequently used to compensate for respiratory motion artifacts in a sedated, freely-breathing 5-year-old child undergoing an abdominal MR examination?
   A. Respiratory triggering using bellows placed over the upper abdomen
   B. Use multiple signal averaging to minimize ghosting artifacts
   C. Play out a RF saturation band across the anterior abdominal wall to minimize the high signal from the subcutaneous fatty tissue
   D. Use ECG or peripheral pulse gating to decrease pulsation artifacts from the abdominal aorta

Correct Answer: D

Reference

Rationale
Answers A, B, C, are fairly standard accepted techniques of compensation for respiratory motion and work well especially in a sedated child who is freely breathing in a very periodic motion. See reference. Pulsation motion from large arterial vessels such as the aorta is not considered as respiration motion and will not be compensated by the above methods. ECG or peripheral pulse gating are methods to compensate for the cardiovascular pulsation artifacts although the efficiency of data acquisition can be poor.

SESSION 3: GENITOURINARY

Clinical Perspective: MR Urography
Walid Farhat, MD

8. Which of the following is also administered in addition to intravenous gadolinium when performing excretory MR urography?
   A. Intravenous saline
   B. Furosemide 15 minutes prior to the MRI
   C. Intravenous saline and furosemide
   D. Oral water with or without furosemide

Correct Answer: C

Reference
**Rationale**
Continuous intravenous saline and furosemide help improve upper tract distention, increase homogeneity of opacification, and minimize artifacts. Saline alone is not sufficient. Furosemide should be withheld if there are contraindications.

9. **Which of the following is poorly demonstrated on MRI?**
   A. Urine  
   B. Blood  
   C. Calcium  
   D. Renal medulla and cortex

**Correct Answer: C**

**Reference**

**Rationale**
Calcium (such as in renal calculi) contains no water and therefore does not have protons that are easily influenced by magnetic fields, and as such, it returns almost no signal (signal void) on all sequences and is difficult to detect.

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**Functional MR Urography Protocol Optimization: Tips & Tricks**
*Kassa Darge, MD, PhD*

10. **Prone positioning of the patient for functional MR urography has the following advantages except one of the following:**
   A. Facilitate contrast washout from dilated pelvicalyces  
   B. Shorten functional MR urography examination time  
   C. Eliminate need for bladder catheterization  
   D. Reduce mix-up between delayed washout and possible pelviureteral obstruction

**Correct Answer: C**

**References**


**Rationale**
Placing the patient in prone position does not eliminate the need for bladder catheter. The main reasons for catheterizing the bladder for functional MR urography are a) to reduce distention and consequently lessen the urge to void; b) to decrease the chance of vesicoureteric reflux and c) to lessen potential negative effect on urine flow from the
pelvicalyces to the bladder. None of these are affected in a significant way by placing the patient in prone. Thus the indications for placing a bladder catheter remain the same whether the patient is supine or prone.

Prone positioning counteracts the effect created by the Gadolinium contrast agent with higher specific gravity than urine, namely, contrast layering in the dependent position. The ureteropelvic junction is in 98% of patients anterior. Thus with the dorsal layering effect it takes a longer time for the contrast to reach the ureter. Putting the patient in prone allows the contrast layering in the region of the ureteropelvic junction facilitating the washout and thus speeding up the study. Particularly in a dilated system the confusion between possible ureteropelvic junction obstruction and delay just due supine positioning can be avoided by prone positioning.

11. The intravenous administration of furosemide in functional MR urography is primarily necessary for what purpose?

A. To conduct a diuretic stress test in a potential case of ureteropelvic junction obstruction  
B. To shorten the functional MR urography examination duration  
C. To eliminate the confounding effect of possible vesicoureteric reflux  
D. To avoid examination with the patient in prone position.

Correct Answer: A

References


Rationale
Diuretic enhanced excretory MR urography is primarily carried out to maximally distend the pelvicalyces and evaluate the washout of contrast, particularly in cases with suspected ureteropelvic junction obstruction. It does improve the overall image quality, too, and thus morphological evaluation.

By increasing the urine flow it may result in a shorter examination. However, this is not the primary reason for administering furosemide. It is not know that furosemide per se will reduce the occurrence of vesicoureteric reflux. Even if, this cannot be the indication for using furosemide. Positioning has nothing to do with the decision to use furosemide or not.
12. Which of the following is a common MR urography finding in children with intermittent hydronephrosis and flank pain?
   E. UPJ narrowing from a crossing vessel
   F. Distal ureter narrowing
   G. Mid ureteric stricture (valve)
   H. Severe renal parenchymal thinning

Correct Answer: A

Reference

Rationale
Intermittent hydronephrosis and associated ipsilateral flank pain are commonly due to UPJ narrowing from a crossing vessel. This clinical presentation generally is not commonly associated with distal ureter narrowings/obstructions, mid ureteric strictures, or severe renal parenchymal thinning.

13. Which MRI finding(s) suggest renal dysplasia in the setting of an ectopic ureter?
   A. Parenchymal thinning with subcapsular cysts
   B. Exaggerated corticomedullary differentiation
   C. Kidney enlargement
   D. Parenchymal hyperenhancement

Correct Answer: A

Reference

Rationale
Renal parenchymal thinning/volume loss with subcapsular cysts suggest dysplasia in the setting of an ectopic ureter. There is also commonly diminished corticomedullary differentiation and postcontrast hypoenhancement.
Female Pelvis: Congenital Anomalies

Jesse Courtier, MD

14. All of the following structures arise from the paired Mullerian ducts except?
   A. Lower 1/3rd of the vagina
   B. Cervix
   C. Fallopian tubes
   D. Uterus

Correct Answer: A

Reference

Rationale
The lower 1/3rd of the vagina originates from the urogenital sinus. The upper 2/3rd of the vagina originates from the paired Mullerian ducts. Choices B, C, and D all arise from the paired Mullerian ducts.

15. In a septate uterus, the T2-weighted MRI signal intensity of the fibrous portion of the septae is typically:
   A. Heterogenous
   B. Hyper-intense relative to myometrium
   C. Hypo-intense relative to myometrium
   D. Hyper-intense relative to skeletal muscle

Correct Answer: C

References


Rationale
The fibrous component of the septation in a septate uterus is typically very low signal intensity on T2-weighted images (lower in signal intensity than skeletal muscle). The myometrial component of the septation is typically high signal intensity on T2-weighted imaging. Distinguishing these components is important as it can impact clinical decision making. A fibrous septation can be addressed with a less invasive hysteroscopic resection, while a muscular/myometrial septation must be addressed via a trans-abdominal approach.
Female Pelvis: Acquired Abnormalities Including Tumors

Monica Epelman

16. The most specific finding in ovarian torsion in pediatric patients is:
   A. Absence of signal on Doppler evaluation of the affected ovary
   B. Midline position of the affected ovary
   C. Ovarian volume asymmetry with the torsed side being 12-15 times larger than that of the normal side
   D. Presence of small peripheral cysts

Correct Answer: C

References


Rationale
An enlarged ovary is the most common finding of ovarian torsion in pediatric patients and massive adnexal asymmetry (ratio >12-15) is highly specific for ovarian torsion. Despite the findings listed as options A, B, and D may be encountered in ovarian torsion, these are not as specific as option C.

17. An adolescent female presents with new neuropsychiatric symptoms, paraneoplastic limbic encephalitis and the lesion shown at the arrows. Which of the following tumors is not associated with this patient's paraneoplastic syndrome?
   A. Mature teratoma
   B. Immature teratoma
   C. Dermoid cyst
   D. Mucinous cystadenoma

Correct Answer: D

References


Rationale
Anti-NMDAR (N-methyl-D-aspartate receptor) encephalitis is a paraneoplastic syndrome that may be found in patients with ovarian neoplasms. Ovarian tumors associated with anti-NMDAR encephalitis include mainly mature teratomas (option A), also known as dermoid cyst (option C), but this association has also been reported, although less commonly, with immature teratomas (option B) and sex cord-stromal tumors. NMDAR subunits reacting with patients’ antibodies may be found even with small ovarian teratomas containing nervous tissue and may trigger anti-NMDAR encephalitis primarily affecting the hippocampus/forebrain regions. Recognition of this association is important, as in these situations tumor resection and immunotherapy may result in significant improvement or complete cure. No known association between epithelial ovarian neoplasms (mucinous cystadenoma – option D) and anti-NMDAR encephalitis has been reported to date.

SESSION 6: Advanced MRI Techniques

Diffusion Weighted Imaging
Govind B. Chavhan, MD, DNB, DABR

18. Which of the following normal abdominal structure is NOT restricted on diffusion?
   A. Spleen
   B. Ovary
   C. Testis
   D. Kidney

Correct Answer: D

Reference

19. Which of the following tumors is NOT restricted on diffusion?
   A. Hepatoblastoma
   B. Hemangioma
   C. Neuroblastoma
   D. Wilms tumor

Correct Answer: B

Reference
20. Which specific type of elasticity is measured during MR elastography?
   A. Young’s modulus
   B. Shear modulus
   C. Bulk modulus
   D. Dynamic modulus

Correct Answer: B

References


Rationale
MR elastography measures tissue elasticity by evaluating the speed of applied propagating shear waves in the targeted tissue. Tissue elasticity can be measured in a variety of ways. In MR elastography, the specific physical property that is being measured is the shear modulus, which is defined as the ratio of shear stress to the shear strain. The Pascal (Pa) is the unit of shear modulus.

Option A is not correct. Young’s modulus is measured during ultrasound elastography. It is defined as the force required to stretch (or compress) a material along one axis. It is also measured in Pascals (Pa). Options B and C are not correct. Bulk modulus and dynamic modulus are physical properties which currently do not have medical imaging applicability clinically.

21. Advantages of MR elastography over US elastography in the evaluation of liver stiffness include all of the following except:
   A. Larger volume of parenchyma evaluated
   B. Higher reproducibility
   C. Cheaper
   D. Higher technical success rate

Correct Answer: C

References
Rationale
While MR elastography has numerous advantages over US elastography, the cost of an MR elastography exam is generally more expensive than an US elastography exam. Option A is not correct. MR elastography samples a much larger volume of liver parenchyma than does US elastography or biopsy. Option B is not correct. Numerous studies have confirmed that MR elastography is more reproducible than US elastography. Option D is not correct. Studies have confirmed a higher technical success rate with MR elastography than with US elastography as MR elastography is not affected by ascites or obesity.

Whole Body MRI in Children
Geetika Khanna, MD, MS

22. Which of the following sequences is used for attenuation correction in PET-MR?
   A. STIR (short tau inversion recovery)
   B. Low b value diffusion weighted
   C. High b value diffusion weighted
   D. Dixon

Correct Answer: D

Reference

Rationale
The Dixon sequence results provides 4 sets of images (fat only, water only, in-phase, and out of phase) which are used to generate a \(\mu\)-map. The \(\mu\)-map is used for attenuation correction of the PET data. STIR and diffusion weighted imaging have been shown to be very useful in lesion detection in whole body MRI for oncologic and non-oncologic indications. While low b value images are good for lesion detection, high b value images are useful for lesion characterization due to lack of T2- shine through. However, these sequences cannot be used for attenuation correction.

23. Clinical indications for whole body MRI include all of the following, EXCEPT:
   A. Loeys Dietz syndrome
   B. Polyarteritis Nodosa
   C. Chronic recurrent multifocal osteomyelitis
   D. Li-Fraumeni syndrome

Correct Answer: B

References

**Rationale**

Whole body MRI has become a useful screening, diagnostic, and surveillance tool for pathologies that are multifocal in location. Examples include chronic recurrent multifocal osteomyelitis and enthesitis related arthritis, where patients may have evidence of active inflammation in sites that are clinically silent. This has important diagnostic and therapeutic implications. Due to radiation sensitivity and increased risk of malignancies, whole body MRI has become a useful screening tool in patients with Li-Fraumeni syndrome. Loeys Dietz syndrome is an autosomal dominant connective tissue disorder resulting in vasculopathy. Patients undergo surveillance imaging (every 1-2 years) with whole body MR angiography to evaluate for dissections/aneurysms. Polyarteritis Nodosa (PAN) is a small/medium vessel vasculopathy. Though it can involve multiple organs, the spatial resolution of whole body MRI is not sufficient to evaluate the small vessels and end-organ damage seen in PAN.

**SESSION 9: Potpourri**

**Minimizing Sedation for MRI: Alternative Techniques**
*Michael S. Gee, MD, PhD*

24. **Which one of the following is not a typical role for child life specialists?**
   A. Help the patient and parents become familiar with the MRI environment.
   B. Use play therapy to increase cooperation and decrease anxiety.
   C. Maintain effective communication with the patient and parents before, during, and after the MRI.
   D. Determine the optimal sedative agent based on the patient’s level of anxiety and the expected duration of the scan, and participate in its administration.

**Correct Answer: D**

**References**


**Rationale**

Determination of optimal sedative agent and sedative administration are typically performed by physicians and/or nurses.
25. Which of the following is true regarding respiratory triggered FSE T2-weighted imaging with radial k-space sampling compared with traditional Cartesian sampling?
   
   A. It decreases the effect of motion by increasing the number of signal averages.
   B. It accelerates acquisition by undersampling k-space.
   C. It reduces motion artifact by oversampling the periphery of k-space.
   D. It reduces motion artifact by oversampling the center of k-space.

Correct Answer: D

Reference

Rationale
A) Increasing the number of signal averages is a different technique for reducing motion related artifacts. B) While undersampling of k-space does allow for shortening scan time, radial acquisition techniques rely on redundant sampling as a strategy to reduce decrease motion. This can result in a small increase in the duration of the acquisition. C) and D) Radial acquisition of k-space results in radial sampling of the center of k-space, not the periphery.

MRI for Appendicitis
Michael M. Moore, MD

26. Which of the following sequences would best be eliminated to reduce imaging time?
   
   A. Axial SS-TSE
   B. Axial balanced SSFP
   C. Coronal SS-TSE
   D. Coronal T1 post gadolinium

Correct Answer: B

Reference
AJR 2014; 203:543â€“548  
Pediatr Radiol 2014; 44:605â€“612

Rationale
Streamlined protocols are critical for emergent MRI clinical feasibility. Balanced SSFP is less helpful than both T1 post gadolinium and T2 SS-TSE. Therefore bSSFP may be eliminated to shorten appendicitis MRI protocol.
27. How often will pediatric appendicitis MRI discover alternative diagnoses that may be missed on focused appendicitis ultrasound?
   A. 5%
   B. 10%
   C. 20%
   D. 33%

   Correct Answer: C

Reference
Pediatr Radiol 2014; 44:948â€“955
Clinical Radiology 2015; 70: 881-889

Rationale
Two separate studies both demonstrate that alternative causes of abdominal pain are discovered 20% on pediatric appendix MRI (Ref 1 20.6%; Ref 2 19.2%). The three most common are adnexal-ovarian cysts; enteritis -colitis; and mesenteric adenitis. Additional alternative diagnoses such as pyelonephritis, ovarian torsion and malignancy are also described.

MRI of Anorectal Malformation
Daniel J. Podberesky, MD

28. The overall incidence of an associated anomaly in anorectal malformation patients is approximately ____?
   A. 20%
   B. 40%
   C. 50%
   D. 75%

   Correct Answer: C

References


Rationale
The overall incidence of an associated anomaly in a patient with an anorectal malformation is approximately 50%. This is an important point for the radiologist interpreting an imaging study in this patient population to keep in mind, as it is critical to meticulously search for other associated anomalies, many of which may be unknown to the caring physicians.
29. All of the following associated anomalies are commonly encountered when interpreting anorectal malformation MRIs, except ___?

A. Urinary system anomalies  
B. Cryptorchidism  
C. Biliary anomalies  
D. Spine anomalies  

Correct Answer: C

References


Rationale
Biliary anomalies are not one of the common abnormalities associated with anorectal malformations. Option A is not correct. Urinary system anomalies are encountered in 30-40% of anorectal malformation patients. Option B is not correct. Cryptorchidism is encountered in 10-40% of male anorectal malformation patients. Option D is not correct. Spine abnormalities are encountered in 15-55% of anorectal malformation patients.

Case Based Review
Taylor Chung, MD

30. Refer to Figure 1A and 1B: What is the contrast agent used in this Abdominal MR examination?

A. MultiHance (Gadobenate Dimeglumine)  
B. Eovist (Gadoxetate disodium)  
C. ProHance (Gadoteridol)  
D. Dotarem (Gadoterate Meglumine)  
E. Ablavar (Gadofoveset trisodium)

Answer: B

Rationale
Contrast is noted in the intrahepatic biliary duct on the 25 min delayed image after contrast administration. With such long delay time, unless it is an intravascular agent such as Ablavar, the 1st pass effect of the extracellular contrast agents is gone and therefore the enhancing tubular structure is not a vessel and therefore a biliary duct. Also, no other vessel contain contrast. The contrast agent is therefore a hepatobiliary agent or excreted by the liver into the bile ducts. Both Multihance and Eovist are hepatobiliary agents. Since only 4% of the
total excretion for MultiHance is through the hepatobiliary route, the delay necessary to visualize contrast in the bile ducts will be much longer than 25 minutes. Therefore, the correct answer is Eovist. Eovist is cleared by the liver (50%) and kidneys (50%). Assuming normal hepatic function, contrast can be visualized 15 - 20 min post intravenous injection in the biliary ducts.

Reference

31. Refer to the movie clip shown in the case based review or to the series of 10 images (below). What is most appropriate diagnosis?

A. Gallstone causing obstruction of the biliary tree
B. Complication from pancreatic divisum surgery
C. Choledochal cyst type IV
D. Duplication cyst

Answer: C

Rationale
Most appropriate diagnosis is choledochal cyst. One can argue about the type or even consider Caroli’s disease. The entire biliary tree system is dilated and there are areas focal narrowing and dilatation in the intrahepatic biliary system. Note the long and dilated common channel with stones and the normal calibre pancreatic duct arising from this dilated common channel. This pathologic anatomy was proven at surgery.

References
32. Regarding the contiguous gene syndrome of tuberous sclerosis complex (TSC) and autosomal dominant polycystic kidney (ADPKD) one of the following is not correct:

A. Renal cysts are more predominant than angiomyolipomas
B. Patients with this syndrome have more frequently hypertension and chronic renal failure compared to those with either TSC or ADPKD alone.
C. The renal cysts are smaller compared to the ones with TSC alone.
D. Significant renal enlargement and development of macrocysts is noted in infancy.

Answer: C

Reference:
33. The following imaging features are commonly depicted in xanthogranulomatous pyelonephritis except:

   A. Staghorn calculus
   B. Hydronephrosis
   C. Non-functioning kidney
   D. Renal polyps

Answer: D

References