Physics of Common MR Sequences in CHD
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Which of the following statements are true regarding the principle of contrast-enhanced MRA (CEMRA)?

A. To achieve higher CNR (contrast-to-noise ratio) in CEMRA images, one needs to time the arrival of the contrast agent to the target vessels with the filling of data in the center of k-space
B. To achieve higher CNR in CEMRA images, one needs to time the arrival of the contrast agent to the target vessels with the filling of data in the periphery of k-space
C. To achieve high SNR (signal-to-noise ratio) in CEMRA images, one can inject higher volume of contrast at a slower rate
D. 3D T2-weighted fast gradient echo pulse sequence is typically used for CEMRA

Answer: A

CEMRA sequence is typically a 3D T1-weighted fast gradient echo sequence with shortest TE and TR. The Gadolinium(Gd)-based contrast agent shortens the T1 of tissues and therefore when contrast traverses the vessels of interest, there will be very high signal intensity in the vessels compare to the background if the imaging pulse sequence is T1-weighted. The collecting of data is timed with the bolus injection of Gd-based intravenous contrast agent such that the contrast arrives to the vessels of interest at the time received radio-frequency (RF) signal is used to fill the center of k-space. The center of the k-space ‘controls’ the contrast of the image; and the periphery of k-space ‘controls’ the spatial resolution of the image. The signal intensity achieved is proportional to the injection speed in the diluted concentration achieved in the arterial vessels from a peripheral venous injection. Therefore, higher SNR can be achieved if the contrast is injected more rapidly. Note that if the Gd agent is very concentrated (as in renal collecting systems or in venous vessel where the injection is made), the T2 shortening effect is so severe that there will be void of signal.

Reference:
Evaluation of Function and Flow in CHD
Laureen M. Sena, MD

Regarding velocity encoded cine MRI, potential sources of error that can compromise accurate quantification of blood flow include all of the following EXCEPT:

A. Aliasing from a low velocity encoding range
B. Signal loss from higher order dephasing
C. Phase offset
D. Using an imaging plane perpendicular to the vessel of interest
E. Partial volume averaging from inadequate spatial resolution

Answer: D

Rationale:
All of the selections describe sources of error that can result in significant inaccuracies when measuring blood flow with velocity encoded cine MRI except for selection d. Measurements of blood flow are actually the most precise when the imaging plane is perpendicular or orthogonal to the vessel of interest. Deviation of +15 degrees from the orthogonal imaging plane can result in an increase in vessel area that can then increase partial volume effects leading to error in flow measurement.

Reference:
Segmental Approach to Imaging of CHD
Rajesh Krishnamurthy, MD

This patient has a functional single ventricle, status post Fontan completion. Please study this set of axial bright blood images, and pick the best answer regarding segmental cardiac anatomy:

1. \{I,D,D\} normal AV inflow, double outlet RV
2. \{I,L,L\} mitral atresia, hypoplastic left heart syndrome, aortic atresia
3. \{S,D,S\} tricuspid atresia, pulmonary atresia
4. \{S,D,D\} double inlet LV, pulmonary atresia
5. Segmental anatomy cannot be determined using these images

Answer:

3. \{S,D,S\} tricuspid atresia, pulmonary atresia
• **Situs solitus of the atria (S):** The coronary sinus (cs) and IVC enter the right-sided atrium, which therefore represents the morphological right atrium. The pulmonary veins (pv) enter the morphological left atrium (la). The right atrium connects to the right pulmonary artery via an atrio pulmonary anastomosis (F). The SVC also connects to the right pulmonary artery (rpa).

• **AV-connection:** Right AV valve (tricuspid valve) is atretic and fatty replaced. Left AV valve (mitral valve) is normal.

• **D-looping of the ventricles (D):** The large left sided ventricle has a smooth septal surface c/w a morphologic LV. The small blind-ending chamber to the right is the infundibular outlet chamber of the RV which fills via a bulboventricular foramen.
• Ventriculo-arterial connection: RV-PA outflow is atretic (pa). Aortic (ao) outflow from the LV is normal.
• Solitus relationship of the great arteries (S): The aortic valve (av) lies posterior and to the right of the atretic pulmonary valve (pv).

References:


Imaging Protocol After 2 Ventricle Repair
Robert J. Fleck, MD

You are shown two images from a cardiac MRI in a 28-year-old male who had cardiac surgery when he was an infant. Figure 1 is a SSFP image obtained during diastole in mid ventricle short axis orientation and Figure 2 is a SSFP image obtained during diastole in the horizontal long axis plane. What is the most likely diagnosis and the surgical repair that has been performed?

A. Tetralogy of Fallot status post transannular patch with right ventricular outflow tract obstruction.
B. L-transposition status post repair.
C. D-transposition status post arterial switch.
D. Tetralogy of Fallot status post repair with residual VSD.
E. D-transposition status post atrial switch.

Answer: E
Rationale:
Figure 1 is a short axis view that shows a hypertrophied right ventricle with flattening of the intraventricular septum and a left ventricle with a relatively thin wall. Figure 2 shows the same ventricular findings with the addition of a low signal curved structure in the area of the left atrium and absence of a normal interatrial septum. The low signal curved structure in the atrium has its edge attached to the mitral valve and represents an intra-atrial baffle that directs the systemic venous blood to the left ventricle in a patient with D-transposition who has undergone an atrial switch procedure. The two eponyms for atrial switch procedures are Mustard and Senning procedures named for the surgeons that first performed this procedure.

Prior to performing the arterial switch procedure (Jantene procedure) the Mustard and Senning procedure were used to “correct” blood flow in D-transposition. The intra-atrial baffle directs the systemic venous return to the left ventricle which pumps blood to the pulmonary artery. The oxygenated blood returning via the pulmonary veins flows around the baffle into the right ventricle. The right ventricle is thus committed to pumping blood to the systemic circulation and subsequently hypertrophies.

Option A is not correct. However, right ventricle as seen on the short axis images could have this appearance of hypertrophy in a tetralogy of Fallot patient and cause septal flattening in cases with severe RVOT obstruction. The problem is that the low signal curved structure in the atrium and the thin left ventricular wall is not consistent with repaired tetralogy of Fallot.

Option C is not correct. If an arterial switch had been performed there would be no baffle in the atrium and the ventricles may appear nearly normal.
Option B is not correct. L-transposition is often called congenitally corrected transposition because there is discordance at the atrioventricular level and the ventriculoarterial level. Thus systemic venous blood flows via the right atrium into the left ventricle which pumps it to the pulmonary artery. Pulmonary venous blood returns to the left atrium flows into the right ventricle and is pumped to the body. It can be treated with a double switch resulting in the presence of an intra-atrial baffle. However, after the double switch the morphologic right ventricle will pump to the pulmonary artery and would likely not be hypertrophic.

Option D is not correct. The same reasons as above. In addition, there is no jet from a residual VSD seen.

Reference:
Imaging Protocol After Single Ventricle Repair
Lorna P. Browne, MBBS

Following the Fontan Procedure (total cavo-pulmonary anastomosis), which of the following is associated with better outcomes?

A. Tricuspid Atresia
B. Older age (>8 years) at time of repair
C. Increased right atrial pressures
D. Normal systemic venous anatomy

Answer: A

Rationale:
Tricuspid atresia is a better prognostic indicator, because systemic LVs do better than systemic RVs.

Some centers perform Fontans at an earlier age, with the belief that younger children do better. In most places, the extra-cardiac conduit Fontans are done at 3-4 yrs of age, or when they are at least 15 kg. They may be done earlier if they have complicating factors (significant AV valve regurgitation needing repair, progressive cyanosis, etc), so those who get them done earlier may be sicker, but this doesn’t mean that doing them later is better. Fontans that are performed >5 years of age are the exception, rather than the rule.

Increased right atrial pressure after a lateral tunnel or extracardiac conduit Fontan is usually related to atrioventricular valve regurgitation. In a patient with atropulmonary Fontan, it may also be related to high pulmonary artery pressures. In both cases, the outcomes are worse.

Inability to separate systemic from pulmonary venous return may even preclude completion of the Fontan. However, once systemic veins are incorporated into a Fontan pathway, they become less important as a prognosticator for long term outcomes. Therefore, normal systemic venous return does not improve outcome. Of course, systemic venous hypertension from various causes, including abnormalities of the peripheral systemic circulation, may lead to portal venous hypertension, PLE or an otherwise failing Fontan.

References:
CT and MRI of the Coronaries in Children
Cynthia K. Rigsby, MD

A left coronary artery arising from the right sinus of Valsalva has been described to travel in all EXCEPT which of the following locations?

A. Between the aorta and right ventricular outflow tract/main pulmonary artery
B. Dorsal (posterior) to the aorta
C. Ventral (anterior) to the aorta
D. Within the lumen of the right ventricular outflow tract/main pulmonary artery
E. Within the ventricular septum

Answer: D

Rationale:
A left coronary artery arising in an anomalous position from the right sinus of Valsalva has been described to travel between the aorta and RVOT/main pulmonary artery, dorsal to the aorta, ventral to the RVOT/main pulmonary artery, and within the ventricular septum. It has not been described to travel within the lumen of the RVOT/main pulmonary artery. See attached diagram from the above referenced article.

Reference: