1. The difference between the number of spins aligned with rather than against the main magnetic field is approximately what?

A. 1 in a 100
B. 1 in a 100
C. 1 in a 1,000,000
D. 1 in a 1,000,000,000

2. T2 relaxation describes what?

A. Loss of longitudinal magnetization
B. Loss of transverse magnetization
C. Regrowth of longitudinal magnetization
D. Regrowth of transverse magnetization

3. Of the following traditional sequences, which is a common choice for suppressing signal from fat?

A. Spin echo
B. Phase contrast
C. Inversion recovery
D. Gradient echo

4. A spin echo is formed by:

A. Applying a negative magnetic field gradient
B. Flipping magnetization using a second radiofrequency pulse
C. Saturating magnetization from fat
D. Reversing the direction of the B0

5. An advantage of parallel imaging includes:

A. Increasing phase encoding steps
B. Generating more signal while reducing noise
C. Reduction of aliasing artifacts
D. Reduction of susceptibility artifacts

6. Parallel imaging gains speed by:

A. Sacrificing spatial resolution
B. Sacrificing temporal resolution
C. Sacrificing SNR
D. Sacrificing reconstructed field-of-view

7. Your patient complains of chest pain and shortness of breath following the vasodilator stress perfusion sequence. Telemetry is notable for complete heart block. What is the most appropriate next course of action?

A. Immediately move the patient to Zone 4 to begin resuscitation
B. Give oxygen, IV epinephrine and abort study
C. Reassure patient, observe and continue study
D. Give IV aminophylline and reevaluate

8. In what outpatient clinical situation are coronary angiography and stress MRI considered equivalent as appropriate modalities for risk stratification?

A. Symptomatic, high pre-test probability of CAD, interpretable ECG and able to exercise

B. Asymptomatic, high global CAD risk, uninterpretable ECG, unable to exercise
C. Symptomatic, intermediate pre-test probability of CAD, uninterpretable ECG, able to exercise
D. Symptomatic, low pre-test probability of CAD, interpretable ECG, unable to exercise

9. Which is true regarding phase contrast velocity mapping?

A. It involves an equal and opposite phase shift
B. The magnitude image contains useful data on flow
C. In-plane velocity mapping can provide quantification of flow
D. Slower moving blood/protons undergo a greater phase shift then faster moving blood/protons

10. Which of the following is true regarding potential errors in CMR flow assessment?

A. Background phase shift errors occur because of turbulent flow in high velocity jets.
B. Aliasing occurs when the velocity exceeds the chosen velocity range.
C. The velocity of small, very high velocity jets can usually be measured accurately.
D. Partial volume effects/errors occur more frequently with through plane imaging than for in-plane imaging.

11. If parallel imaging is increased to reduce the scan time for cine imaging, what is the effect on the resultant image?

A. Decrease in spatial resolution
B. Decrease in signal to noise ratio
C. Increase in spatial resolution
D. Increase in temporal resolution

12. What is the best strategy to use for cine imaging in a patient with isolated ectopic heartbeats?

A. Retrospective gating
B. Prospective triggering
C. Retrospective gating with arrhythmia rejection
D. Real time imaging

13. A 55 year-old man presents with moderate concentric left ventricular hypertrophy, but normal left ventricular size and ejection fraction 62%. On CMR parametric mapping tissue characterization, the septum showed normal T2 and T2* values, low native T1 values and normal extracellular volume (ECV) values. The most likely diagnosis is:

A. Hypertrophic cardiomyopathy
B. Cardiac Amyloidosis
C. Anderson-Fabry disease
D. Myocardial iron overload

14. A 78 year-old man presents with 8 months of progressive shortness of breath and significant renal failure. CMR reveals small bilateral pleural effusions and a small pericardial effusion. There was moderate-severe concentric left ventricular hypertrophy (septum measuring up to 20 mm) with a left ventricular ejection fraction of 68%. Parametric mapping showed global LV native T1 values of 1100 ms (normal range 960 +/- 25 ms), and global T2 values of 54 ms (normal range 48 +/- 3 ms). No gadolinium-based contrast agent was administered for contrast-enhanced imaging. The most likely diagnosis is:

A. Hypertrophic cardiomyopathy
B. Myocarditis
C. Cardiac Amyloidosis
D. Anderson-Fabry disease

15. What is the threshold percentage of late gadolinium enhancement that has been associated with an increased risk of sudden cardiac death in patients with hypertrophic cardiomyopathy?

A. 50
B. 20
C. 15
D. 5

16. What is the best technique to identify mural thrombus?

A. First pass perfusion imaging
B. Late Gadolinium Enhancement
C. Cine Gradient Echo Imaging
D. T1W imaging

17. What is the whole body SAR (specific absorption rate) limited to if an MRI system is operating in "first level controlled"?

A. 2W/Kg
B. 4W/kg
C. 0.5 degree Celsius temperature rise
D. 2KW/kg

18. In the American College of Radiology Guidelines what does 'Zone 4' within in an MRI Department refer to?

A. The room containing the MRI magnet
B. The area open to the general public outside the MRI environment
C. The equipment room
D. The control room

19. Scanning patients with MRI-conditional implantable cardiac electronic devices does NOT generally require:

A. Knowledge of the pacemaker leads manufacturer and model
B. Device re-programming
C. Chest X ray prior to MRI
D. External defibrillator and CIED programmer to be available
E. Monitoring with continuous ECG and pulse oximetry

20. Artifact in CMR images in CIED patients:

A. Is similar in pacemakers and defibrillators
B. Is similar in MR conditional and non-MR conditional devices
C. Is worse with inspiration
D. Is better with steady state free precession cine imaging compared with spoiled gradient echo cine imaging
E. Can be improved on late gadolinium imaging by reducing the bandwidth of the inversion prepulse

21. Which of the following is TRUE about LGE (late gadolinium enhancement)?

A. The usual reason for LGE is intracellular uptake of Gadolinium
B. Subendocardial diffuse pattern of LGE is pathognomonic for cardiac amyloid
C. LGE in basal septum is pathognomonic for cardiac sarcoid
D. Extent of LGE in HCM provides prognostic information as to the arrhythmic risk of SCD (sudden cardiac death)
E. Fatty metaplasia in the myocardium appears bright due to extensive Gd uptake by fat's T1 properties

22. What is the most common benign tumor of the cardiac valves?

A. Myxoma
B. Fibroelastoma
C. Fibroma
D. Angiosarcoma

23. In the context of the differential diagnosis between athlete's heart and cardiomyopathies, which of the following features is suggestive of cardiomyopathy?

A. Ratio of LV-to-RV end-diastolic volume=1

B. LVH with concomitant LV dilatation
C. Asymmetric LVH
D. Absence of LGE

24. Which of the following features is a physiological cardiac adaptation to regular sport activity?

A. Predominant LV dilatation
B. Predominant RV dilatation
C. Balanced RV and LV dilatation
D. Sub-epicardial LGE

25. What scanner should T2* mapping for iron overload be performed?

A. At 3 Tesla scanner
B. At 1.5 Tesla scanner
C. At 1.5 or 3.0 Tesla scanner
D. At any scanner irrespective of the static field

26. How many echoes should the multi-echo T2* gradient-echo sequence have?

A. At least 8 equally spaced echoes from 2 to 18ms
B. Less than 8 equally spaces echoes
C. At least 8 equally spaced echoes
D. The number of echoes are irrelevant

27. A 25 year old female is referred for further assessment of a patent ductus arteriosus diagnosed on echocardiography after a murmur was noted on physical examination. Phase contrast flow analysis on CMR reveals the following information.

Main pulmonary artery:
HR bpm 50 bpm
Antegrade flow 60 ml/beat, no retrograde flow.

Ascending aorta:
HR bpm 80
Antegrade flow 80 ml/beat, no retrograde flow.

What is the approximate shunt flow across the PDA (Qp:Qs rounded to one decimal place)?

A. Qp:Qs 0.8:1
B. Qp:Qs 1.3:1
C. Qp:Qs 0.5:1
D. Qp:Qs 1.9:1

28. The developmental abnormality that gives rise to a sinus venosus defect is best imaged in the following cine SSFP view:

A. 4-chamber view demonstrating atria and ventricles
B. right ventricular 2 chamber view demonstrating right atrium and right ventricle
C. left ventricular 2 chamber view demonstrating left atrium and left ventricle
D. axial stack covering great vessels (superior vena cava, aorta, pulmonary arteries) and atria

29. Which of the following can be assessed well using CMR in a patient with aortic stenosis?

A. Left ventricular pressure
B. The presence of Infective vegetations on the aortic valve
C. Calcification of the valve and coronary arteries
D. Valve orifice area by direct planimetry

30. Which of the following is true in the CMR assessment of valve disease?

A. Multiple valve lesions cannot be assessed
B. Most prosthetic valves are unsafe in the MR scanner
C. Good visualization and assessment of the pulmonary valve can usually be obtained
D. Pulmonary stenosis cannot be assessed well

31. Acute aortic dissection on SSFP cine images can be identified based on which finding?

A. Direct visualization of the dissection flap

B. Poor enhancement of the false lumen
C. High signal intensity in the aortic wall
D. Abnormal vessel wall distensibility

32. What CMR sequence can establish the diagnosis of an acute aortic intramural hematoma?

A. First pass perfusion imaging
B. T1-weighted black-blood
C. T2-weighted black blood
D. Late gadolinium enhancement
E. Steady state free precession

33. For which of the following applications does CMR not have a clinical indication?

A. Evaluation of anomalous coronary arteries
B. Assessment of coronary stenosis
C. Imaging of coronary artery aneurysms
D. Assessment of aortocoronary bypass grafts

34. For coronary arteries MR imaging in patients with high heart rate (>90 bpm), what would the optimal time for data collection be?

A. 150 ms after the QRS
B. Early-diastole
C. End-systole
D. Mid-diastole

35. An indication for contrast-enhanced peripheral MRA is:

A. Left leg weakness
B. Claudication, plan for revascularization
C. Giant cell arteritis
D. AV graft failure in ESRD

36. A type of non-contrast MRA is:

A. TWIST
B. CEST
C. Bolus-chase
D. QISS

37. What is Swyer-James-MacLeod?

A. Congenital tricuspid atresia associated with pulmonary hypertension
B. Unilateral pulmonary vascular hypoplasia and unilateral bronchiectasis
C. Pulmonary-bronchial fistula
D. Partial anomalous venous return into left atrium

38. What is the reserve halo sign in pulmonary embolism?

A. Crescent shape morphology of a fresh pulmonary thrombus
B. A morphological manifestation of pulmonary infarction
C. Interventricular septal paradoxical motion associated with right ventricular acute overload
D. The presence of 2 adjacent low SI structures in axial plane representing respectively a bronchus and occlusive thrombus

39. Regarding incidental findings on Cardiac MRI

A. Incidental findings are rare (< 1%)
B. Cardiac MR images have a limited field of view therefore visualization of non cardiac pathology is very limited
C. Significant incidental findings can occur in as many 1 in 10 cases
D. The liver is not a common site for incidental findings

40. Regarding detection of incidental findings on Cardiac MRI

A. Review of prior imaging is generally not helpful
B. A systematic checklist is critical when reviewing CMR images for incidental pathology
C. Incidental findings are mostly inconsequential and do not need to be communicated to referring physician

D. CMR images may show an abnormality but are not helpful in characterizing disease

41. In the context of the differential diagnosis between athlete's heart and cardiomyopathies, which of the following features is suggestive of hypertrophic cardiomyopathy?

A. Ratio of LV-to-RV end-diastolic volume=1
B. LVH with concomitant LV dilatation
C. Asymmetric LVH
D. Absence of LGE

42. Which of the following features is a physiological cardiac adaptation to regular sport activity?

A. Predominant LV dilatation
B. Predominant RV dilatation
C. Balanced RV and LV dilatation
D. Sub-epicardial LGE

1. C

Using the Boltzmann distribution at typical clinical field strengths and body temperature - the population difference is approximately 1 in a million spins

2. B

T2 is a decay of magnetisation caused by the dephasing of spin coherence in the transverse plane

3. C

Fat has a short T1 that differs from other tissues, which facilitates its suppression using an inversion recovery approach. By timing subsequent excitation and data acquisition to coincide with the nulling of fat recovery, areas of fat appear dark in the resulting images.

4. B

A 180 degree refocusing pulse is used to flip the magnetization orientation, which continue to precess about the same access. This causes magnetization spinning at different rates to come back into alignment, producing a spin echo.

5. D

6. C

Accelerated imaging using the parallel imaging approach trades-off speed vs SNR, but does not sacrifice resolution.

7. D

The patient developed symptomatic complete heart block following a vasodilator stress agent - a serious side effect. Side effects should resolve before completion of the perfusion sequence. Persistent symptoms should be treated with aminophylline, a nonselective adenosine receptor antagonist.

Answer A is incorrect as Zone 4 is the room with the scanner. Resuscitation efforts should not occur in Zone 4.

Answer B is incorrect as oxygen and epinephrine are used in the treatment plan for anaphylaxis. Heart block is not a symptom of anaphylaxis but a known effect of vasodilator agents.

Answer C is incorrect as the patient has symptomatic heart block after the end of the perfusion sequence, typically 2-3 minutes after the vasodilator agent is

given. Effects of adenosine typically last 15 minutes. The patient's symptoms need to be treated.

8. A

Appropriateness criteria
sCMR=stress CMR, ICA=invasive coronary angiographyA, ICA=A, A=appropriate, M=may be appropriate, R=rarely appropriate

A| sCMR = A, ICA = A
B| sCMR = M, ICA = R
C| sCMR = A, ICA = M
D| sCMR = M, ICA = R

9. A

The equal and opposite phase shift is the fundamental aspect of CMR physics that underpins phase contrast velocity mapping.
It is the phase image (not the magnitude image) that contains the useful flow data.
Through-plane velocity mapping can quantify flow, not in-plane velocity mapping which can only quantify velocity
Faster moving protons undergo a greater phase shift

10. B

Aliasing is due to phase wrap, which is caused by a jet velocity above the maximum selected for the sequence
Background phase errors occur because of field inhomogeneity and Eddy currents but not blood flow turbulence
The velocity of high velocity jets is often difficult to measure accurately
Partial volume effects/errors occur more frequently with in-plane imaging, not through-plane imaging

11. B

The signal to noise ratio is reduced by the square root of the parallel imaging factor but has no effect on resolution.

12. C

Data collected in the r-r intervals containing an ectopic heartbeat will be rejected, resulting in an artefact free image with no reduction in resolution or signal.

13. C

Anderson-Fabry disease (AFD) is an X-linked lysosomal storage disease resulting in alpha-galactosidase deficiency, and multi-system accumulation of glycosphingolipids. Cardiac manifestations include left ventricular hypertrophy, arrhythmias, conduction system disease and heart failure. Fat and glycosphingolipids results in low native T1 values. As the accumulation of glycosphingolipids is an intracellular process, the extracellular volume (ECV) in AFD is typically normal. High T2 values have been observed in AFD, but usually in the area of late gadolinium enhancement in the basal inferolateral wall, and not typically in the hypertrophied septum. Hypertrophic cardiomyopathy is usually reported as having elevated, not low, native T1 values. Cardiac amyloidosis usually results in significantly increased native T1 and ECV values and manifests in older individuals. Myocardial iron overload usually does not usually

present with LVH, has low T1 values, but also low T2* values.

14. C

Cardiac amyloidosis in later stages show moderate-severe concentric LVH, associated with significantly increased native T1 values (in this case 5-6 SD above normal). Associated pleural and pericardial effusion can be seen as supportive features. Myocarditis may also cause significantly elevated native T1, but would also cause significantly elevated T2 values, and the case history is one of subacute SOB, rather than an acute presentation of severe myocarditis. Although hypertrophic cardiomyopathy is typically associated with elevated T1 values, the degree of T1 elevation is milder than that seen in severe cardiac amyloidosis. Anderson-Fabry disease is an X-linked lysosomal storage disease resulting in alpha-galactosidase deficiency, and multi-system accumulation of glycosphingolipids; cardiac involvement is associated with low global native T1 values.

15. C

Greater than or equal to 15% LGE of LV mass associated with composite end point of SCD and/or ICD discharge with HR 3.0.

16. B

The advantage of Late gadolinium enhancement is that it can distinguish thrombus from immediately adjacent myocardium particularly when using longer inversion sequences. It also allows to evaluate if there is adjacent myocardial infarction or scar as most thrombus will appear by the company they keep (wall motion abnormality, myocardial infarction or slow flow).

17. B

The Specific Absorption Rate (SAR) is measured in watts per kilogram (W/kg).Normal mode restricts whole body SAR to 2W/Kg while First level controlled restricts it to 4W/kg..

18. A

Zones I through IV correspond to levels of increasing magnetic field exposure. Zone 1 holds no restrictions and is open to free public access. Zone IV should be demarcated and clearly marked as being potentially hazardous due to the presence of very strong magnetic fields

19. C

According to Heart Rhythm Society guidelines chest X ray is not required prior to scanning in all patients where the device details and history are known.

20. B

Artifact is greater in high energy cardiac devices (defibrillators and cardiac resynchronisation defibrillators) than in pacemakers.

Artifact can be reduced by using GRE cine imaging and breath holding in inspiration, and using broadband/ Wideband inversion pre-pulse on late gadolinium imaging.

21. D

GBCA are interstitial agents and don't cross over into the intracellular space unless the myocyte is necrotic with loss of sarcolemmal integrity. Thus, the usual reason for LGE is expanded ECV due to fibrosis/scar.
Although patterns of LGE are useful in suggesting a disease states, more often than not they are not pathognomonic. For example, subendocardial LGE is often seen in AL cardiac amyloid but may also occur in systemic sclerosis or post-transplant rejection and sometimes even in TTR cardiac amyloid. Similarly, basal septal LGE can occur in myocarditis, dilated cardiomyopathy (usually in a midline septal stripe pattern) or pulmonary hypertension (at RV insertion points) or HCM (often in areas of maximal wall thickness). Thus, the clinical context plus the LGE pattern must both be considered before reporting a likely etiology.
LGE carries an adverse prognosis in many disease states ranging from infiltrative cardiomyopathies to ischemic heart disease to dilated cardiomyopathy and myocarditis. In particular, in HCM there is now accumulating evidence that extent of LGE may be used to consider whether patients should receive a prophylactic ICD for primary prevention. Some groups have suggested that >15% LGE mass can be used as 1 of the risk factors to consider for ICD implantation as it confers a higher arrhythmic risk of SCD from VT (Kramer et al, JACC 2018;72(8):871-3)

On T1 weighted inversion recovery sequences that are used to visualize LGE, fat also appears bright (as does scar), thus the differentiation of fatty metaplasia from scar may require native T1 mapping or fat-water separation techniques (Dixon multi-echo mapping) to make the distinction. (Kellman et al, Curr Cardiovasc Imaging Rep. 2010 Apr; 3(2): 83–91)

22. B

Myxoma is overall the most common benign cardiac tumor but is rarely seen on cardiac valves. It is most commonly present in left atrium.

Fibroelastoma is a benign cardiac tumor which is commonly present on the cardiac valves. It most commonly involves aortic valves followed by mitral valve, tricuspid valve and pulmonic valve.

Cardiac Fibroma is a benign tumor commonly seen in children and usually involves interventricular septal myocardium of the left ventricle.

Angiosarcoma are malignant tumor which commonly involves right atrium.

23. C

Asymetric LVH is not part of physiological adaptation to sport activity

24. C

Both ventricles should be proportionally dilated

25. B

To minimise the off-resonance artefacts.

26. A

Allow to correctly sample images throughout the spectrum of T2* relaxation times.

27. D

1. In the case of a PDA, Qp is the ascending aorta flow and Qs is the pulmonary flow.
2. Shunt flow should be calculated as L/min rather than ml/beat to account for variability in heart rate.

28. D

A sinus venosus defect arises from a deficiency in the back wall of the SVC which allows for anomalous drainage of one or more right pulmonary veins as well as an atrial level shunt. This defect is best imaged in the axial stack beginning at the 3 vessel view (superior vena cava, aorta and pulmonary arteries) where the right pulmonary vein(s) are seen communicating with the SVC-RA superiorly and an atrial level defect is seen inferiorly.

29. D

CMR imaging through the valve tips can accurately assess the valve orifice area using planimetry around the valve tips
The other aspects cannot be assessed well with CMR

30. C

The pulmonary valve can usually be assessed well with CMR
Multiple valve lesions and pulmonary stenosis can be assessed well, and most prosthetic valves are safe at both 1.5 and 3T

31. A

SSFP cine images allow for visualization of the dissection flap, with high blood pool signal in both the true and the false lumen. The presence of slow flow in the false lumen may be associated with lower intensity in the false lumen relative to the through lumen.

32. B

The characteristic image appearance of an acute aortic intramural hematoma is an eccentric thickening of the aortic wall with high signal intensity on T1-weighted black blood images.

33. B

Assessment of coronary stenosis by MR is challenging, because the need of high-resolution data sets of the whole coronary tree requires long scan times, with the potential for imaging artefacts from cardiac and respiratory motion. So, in clinical practice, MR is not used for the assessment of coronary stenosis, in particular as coronary CT has emerged as a much faster, higher resolution, and technically less challenging alternative to MR.

34. C

Coronary motion is typically minimal during diastasis that occurs in mid diastole after rapid ventricular filling and before atrial filling. End systole is another phase of relatively little cardiac motion. In patients with high heart rates, the mid-diastolic rest period is shortened, and the end-systolic rest period can be used as the imaging window.

35. B

Claudication with plans for revascularization is an indication for angiography. Left leg weakness may be indicative of a neurologic process. Giant cell arteritis may be an indication for cerebral angiography. Gadolinium is contraindicated in ESRD

36. D

QISS (quiescent inflow in steady state) is a non-contrast MRA technique. TWIST and Bolus-chase MRA techniques use gadolinium. CEST is a metabolic, not angiographic, technique.

37. B

Rare condition of uncertain etiology, either congenital or secondary to post infectious obliterative bronchiolitis

38. B

Reversed halo sign is characterized by the presence of a central infarcted area with preserved air spaces, and the peripheral rim due to dense inflammation, granulation tissue, or hemorrhage within the alveolar air spaces

39. C

40. B

41. C

42. C