Introduction to Magnetic Resonance Imaging / RAD 433

1st Mid-term Exam 1st semester 1437-2015 (Good Luck) Dr Othman I Alomair

Student Name: ***Number:***

Q1) Essay Questions:

(A) Answer the following questions related to MR active nuclei:

i. What are MR active nuclei? 1 mark

MR active nuclei are characterized by their tendency to align their axis of rotation to an applied magnetic field. This occurs because they have angular momentum or spin and, as they contain positively charged protons, they possess electrical charge.

ii. List at least four MR active nuclei? 2 marks

Hydrogen (1H), Carbon (13C) , Fluorine (19F), Phosphorus (31P), Sodium (23Na) …..

iii. Why hydrogen ^{1}H is the most imaged MR active nuclei? 2 marks

It is used because hydrogen is very abundant in the human body, and because its solitary proton gives it a relatively large magnetic moment.

(B) Answer the following questions related to Net Magnetisation Vector (NMV):

i. Explain briefly how the Net magnetisation vector is created (you can explain using your own words or draw or sketch diagram)? 4 marks

The sum of all the tiny magnetic fields of each spin is called net magnetization or macroscopic magnetization. Normally, the direction of these vectors is randomly distributed. Thus, the sum of all the spins gives a null net magnetization, in the absence of an applied magnetic field.

Within a large external magnetic field (called B0), nuclear spins align with the external field. Some of the spins align with the field (parallel) and some align against the field (anti-parallel). Applying quantum theory to MRI, hydrogen nuclei possess energy in two discrete quantities or populations termed low and high. Low - energy nuclei align their magnetic moments parallel to the external field (shown as a white arrow and are termed spin - up nuclei (shown in blue in next figure). High-energy nuclei align their magnetic moments in the anti- parallel direction and are termed spin-down nuclei. The factors affecting which hydrogen nuclei align parallel and which align anti-parallel are determined by the strength of the external magnetic field and the thermal energy level of the nuclei.

Low thermal energy nuclei do not possess enough energy to oppose the magnetic field in the anti-parallel direction. High thermal energy nuclei, however, do possess enough energy to oppose this field, and as the strength of the magnetic field increases, fewer nuclei have enough energy to do so. The thermal energy of a nucleus is mainly determined by the temperature of the patient.

In clinical applications this cannot be significantly altered and is not important. This is called thermal equilibrium. Under these circumstances it is the strength of the external field that determines the relative quantities of spin - up to spin - down nuclei. In thermal equilibrium there are always fewer high - energy nuclei than low - energy nuclei, therefore the magnetic moments of the nuclei aligned parallel to the magnetic field cancel out the smaller number of magnetic moments aligned anti - parallel. As there is a larger number aligned parallel, there is always a small excess in this direction that produces a net magnetic moment.

ii. What is the relationship between NMV and magnetic field strength? 2 marks

When a patient is placed in the bore of the magnet, the magnetic moments of hydrogen nuclei within the patient align parallel and anti - parallel to B0. A small excess line up parallel to B0 and constitute the NMV of the patient. The energy difference between the two populations increases as B0 increases. At high field strengths fewer nuclei have enough energy to join the high - energy population and align their magnetic moments in opposition to the stronger B 0 field. This means that the magnitude of the NMV is larger at high field strengths than low field strengths, resulting in improved signal.

(C) Answer the following questions related to Image weighting and contrast

i. What is proton density (PD)? 1 mark

A proton density image is one where the difference in the numbers of mobile hydrogen protons per unit volume in the patient is the main determining factor in forming image contrast. Proton density weighting is always present to some extent.

ii. Describe briefly the process of generation of T1 weighted contrast (assume you want to create contrast between fat and water or any other components)?

4 marks

As the T1 time of fat is shorter than that of water, the fat vector realigns with B0 faster than the water vector. The longitudinal component of magnetization of fat is therefore larger than that of water.

After a certain TR that is shorter than the total relaxation times of the tissues, the next RF excitation pulse is applied. The RF excitation pulse flips the longitudinal components of magnetization of both fat and water into the transverse plane assuming a 90 ° pulse is applied)

As there is more longitudinal magnetization in Fat before the RF pulse, there is more transverse magnetization in fat after the RF pulse. Fat therefore has a high signal and appears bright on a T1 contrast image. As there is less longitudinal magnetization in water before the RF pulse, there is less transverse magnetization in water after the RF pulse. Water therefore has a low signal and appears dark on a T1 contrast image. Such images are called **T1 weighted images.**

(D) Answer the following questions related to spatial encoding

i. What are the main functions of the gradients in MR pulse sequence? 2 marks

Gradients perform many important tasks during a pulse sequence. Gradients can be used to either dephase or rephase the magnetic moments of nuclei.

Gradients also perform the following three main tasks in encoding:

Slice selection–locating a slice within the scan plane selected.

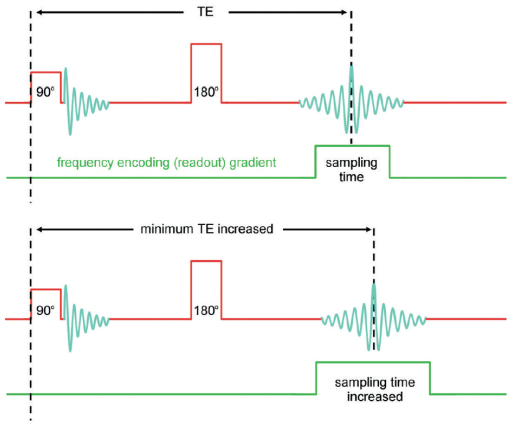
Spatially locating (encoding) signal along the long axis of the anatomy – this is called frequency encoding.

Spatially locating (encoding) signal along the short axis of the anatomy – this is called phase encoding.

ii. What are the relationships between echo time (TE) and sampling time (acquisition window)? 2 marks

If the receive bandwidth is halved to 16 KHz, the sampling frequency also halves to 16 KHz and so 16 000 data points are acquired per second. If the acquisition window is still 8 ms, only 128 data points can be collected instead of the required 256. To collect the necessary data points at that bandwidth, the acquisition window must be doubled to 16 ms and results in a 4 ms increase in the minimum permissible TE, i.e. the peak of the echo moves to occur in the middle of the longer acquisition window. For example, if the minimum TE was 10 ms using a bandwidth of 32 KHz and a frequency matrix of 256, by halving the receive bandwidth to 16 KHz the minimum TE increases to 14 ms).

In addition, increasing the frequency matrix has the same effect. Using the example above, if the frequency matrix is increased to 512, then 512 data points are required and frequencies must be sampled 512 times during the acquisition window. If the receive bandwidth is maintained at 32 KHz then the acquisition window and therefore the minimum TE must be increased to attain the required number of data points.



Q2) True or False Questions, Which of the following statements are True or False? 8 marks

(A) The TE determines how much decay of transverse magnetization is allowed to occur (T)

(B) For resonance of hydrogen to occur, an RF pulse of energy at exactly the Larmor frequency of hydrogen must be applied therefore only the hydrogen nuclei will resonant and other MR active nuclei will not (T)

(C) A free induction decay is a process of returning NMV to realign with B_0 (F)

(D) The phase encoding gradients are applied frequently during the application of the excitation and refocusing radiofrequency pulses (F)

(E) Proton density contrast is always present and depends on the patient and the area being examined (T)

(F) The TR determines the amount of longitudinal relaxation that is allowed to occur between the end of one RF pulse and the application of the next (T)

(G) According to the Larmor equation, the precessional frequency is inversely proportional to the magnetic field strength (F)

(H) The duration of the readout gradient is called the sampling time or acquisition window (T)

Q3) Fill the blank Questions; write down the appropriate words within the dashed lines

(A) In a standard spin echo pulse sequence, the slice select gradient is switched on during the …..90 ° and 180° RF pulses. The phase encoding gradient is switched on after ……the excitation pulse The frequency-encoding gradient is switched on during……the collection of the signal (the echo) 3 marks

(B) The slope of the slice select gradient determines ….. the slice thickness and ……slice gap (along with the transmit bandwidth) 2 marks

(C) The sampling rate or sampling frequency is the rate at which frequencies are……which frequencies are sampled or digitized during the acquisition window *per second* 1 mark

Q4) Multiple Choice Question (MCQ), choose the most appropriate answer in the following:

6 marks

(A) T1 recovery or relaxation is described as:

i. Intrinsic tissue property
ii. Extrinsic tissue property
iii. It is caused by the nuclei giving up their energy to the surrounding environment or lattice
iv. Both i and iii

(B) Which of the following you can change or adjust during MRI experiment?

i. TR and TE
ii. T1 and T2
iii. Flip angle
iv. Both i and iii

(C) Which of the following statements are correct about result of resonance?

i. One of the results of resonance is that the NMV moves out of alignment away from B0.
ii. When flip angles less than 90 ° are used; only a portion of the NMV is transferred to the transverse plane.
iii. The other result of resonance is that the magnetic moments of hydrogen nuclei move into phase with each other.
iv. All of the above.

(D) To acquire T1 weighted images, the following parameters should be adjusted accordingly:

i. Short T1 and short T2 relaxation times
ii. Short TR and short TE
iii. Long TR and Long TE
iv. Both i and ii

(E) Which of the following statements are correct in describing gradients?

i. They are static magnetic field.
ii. They are altered or changing magnetic field, which result in changing the precessional frequency therefore allows allocating of the spins.
iii. They are usually expressed in small measuring unit such as Gaussian.

iv. Gradients can be used to either dephase or rephase the magnetic moments of nuclei.

v. ii, iii and iv are correct

(F) Which of the following statements are correct in describing slice selection?

i. The scan plane selected determines which of the three gradients performs slice selection during the excitation pulse.

ii. The *Z gradient alters the field strength and precessional frequency along the Z–axis of the* magnet and therefore selects sagittal slice.

iii. The *X gradient alters the field strength and the precessional frequency along the X-axis of the* magnet and therefore selects axial slices.

iv. None of the above