Lecture 1: Introduction & Basics of MRI

Provide a basic overview of MRI imaging

- Protons possess a spin
- When you have a moving electrical charge, you have an electric current
- Electric current induces a magnetic field
- Protons align themselves in the external magnetic field; for protons inside an external magnetic field, there are 2 possible alignments
- The protons may align in the direction of the external magnetic field, or they may align in the opposite direction, anti-parallel to the external magnetic field: these 2 alignments have different energy levels
- Hydrogen has a high natural abundance (99.985)
- Hydrogen has a high biological abundance (0.63)
- when the proton becomes magnetised, the magnet provides a magnetic field to align the protons; this magnetic fields is called the external magnetic field (B_0)
- the protons are aligned in the magnetic field and then moved out of alignment by RF pulses
- the frequency of the RF pulses is selected to resonate with the protons in the body (only protons with the correct resonate frequency are moved out of alignment)
- as the out of alignment protons move back into alignment, they produce an RF signal, which is used to construct the MR image

Discuss the advantages and disadvantages of MRI

ADVANTAGES	DISADVANTAGES
- high contrast sensitivity to soft tissue differences - inherent safety to the patient resulting from the use of non-ionising radiation - multi-planar	- high equipment and sitting costs - scan acquisition complexity - relatively long imaging artifacts - significant image artifacts - patient claustrophobia problems

Hydrogen Nucleus

- nucleus contains a single proton: mass number = 1
- relatively large magnetic moment: high sensitivity; relative sensitivity = 1
- the hydrogen nucleus is the MR active nucleus predominantly used in clinical MR

Discuss the effect of an external magnetic field on the proton nuclei

- The strength of magnetisation depends on the presence of magnetic nuclei
- A material is considered to be MR active as long as its mass number is odd: needs to have a net charge
- Nuclei that have a net charge and are spinning (moving) acquire a magnetic moment
- Nuclei with a net magnetic moment align their axis of rotation to an applied magnetic field (B_0)

Ultrasound Module 4: Beam

Pulse Diameter and Beam Width

- Important characteristic of an US pulse is its diameter
  - It is the width of the US beam
  - The diameter of a pulse changes as it moves along the beam path
- The diameter of the pulse is determined by the characteristics of the transducer
  - At the transducer surface, the diameter of the pulse is the same as the diameter of the crystal
  - As the pulse moves through the body, the diameter generally changes; determined by the focusing characteristics of the transducer

Transducer Focusing

- Transducers can be designed to produce either a focused or non-focused beam
- A focused beam is desirable for imaging:
  - Produces pulses with a small diameter
  - Gives better visibility of detail in the image
  - Best detail will be obtained for structures within the focal zone
  - Distance between the transducer and the focal zone is the focal depth

Unfocused Transducers

- An unfocused transducer produces a beam with two distinct regions:
  - Near field or Fresnel zone
  - Far field or Fraunhofer zone

- Near field
  - US pulse maintains a relatively constant diameter
  - Beam has a constant diameter that is the diameter of the transducer
  - Length of the near field is related to the diameter, D, of the transducer and the wavelength
- Far field
  - The major characteristics is that the beam diverges and pulses will be larger in diameter and have less intensity along the central axis
  - Divergence is decreased by increasing frequency: higher US frequencies produce beams that are less divergent and generally produce less blur and better detail
  - The approximate angle of divergence is related to the diameter of the transducer, D, and the wavelength by

Grating Lobes

- For multi-element arrays, side lobe emission occurs in a forward direction along the main beam
- By keeping the individual transducer element widths small (less than ½ wavelength) the side lobe emissions are reduced
- Grating lobes result when US energy is emitted far off-axis and are a consequence of the non-continuous transducer surface of the discrete elements
- This misdirected energy of relatively low amplitude can result in the appearance of highly reflective objects in the main beam

Frame Rate

- A 2D image (a single frame) is created from a number (N) of lines acquired across the FOV
  - N is typically 100 or more
  - A larger number of lines will produce a higher quality image; however, the finite time for pulse-echo propagation places an upper limit on N that also impacts the desired temporal resolution
  - The acquisition time for each line T_{line} is given by:

Ultrasound Module 5: Focussing & Resolution

Describe axial resolution

- R_A: determines how close together two objects can be along the axis of the beam and still be detected as 2 distinct objects
- Related to the spatial pulse length
  - Boundaries separated by distances greater than SPL/2 are resolved
  - Boundaries separated by distances less than SPL/2 are not resolved
- The smaller resolution the better
  - It should be of the order of 1mm or better
- Higher frequencies result in better resolution