Week 7 lecture 13

Magnetic resonance imaging (MRI), Ultrasound imaging and therapy

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I will not get too hung up on MRI, as usually you hardly ever see this topic represented in exams. The reason is that Prof. Panyi head of the dept. said he realizes it's a very complicated issue, which he himself does not understand thoroughly. Maybe that explains why the only question I ever saw on MRI addressed whether it was using ionizing radiation or not (it does not).

Magnetic Resonance Imaging – this medical imaging technique provides us with an anatomical image of the body, using principles of NMR (if you are not familiar with NMR, please do so if you wish to understand MRI). The one most important difference between MRI and NMR is that while NMR employs a homogenous magnetic field, MRI in addition to that field employs gradient magnetic fields. Those are basically magnetic field whose strength changes over a distance, they are not uniform and homogenous like the big magnetic field applied.

NMR Spectroscopy give us the composition of elements in our tissue, and we get a spectrum analysis of such information. The MRI employs those Gradient magnetic field to check that same information in a unit volume. Now we know what is the composition at a give point and can form an image that shows us the composition of material across space (bones, soft tissues, etc.) Basically MRI shows us the density of Hydrogen nuclei in a unit of volume (minimal #84)

It's important to know that MRI is an anatomical imaging device and NOT a functional one. It does not show us the function of one or other organ in the biological system, but a clear image of the anatomy of said system.

It's also important to know MRI employs magnets and Radio Wave EM radiation – which is very low frequency and is non-ionizing.

Ultrasound – Principles of US were discussed in the document “week 4 lecture 7” and will not be gone through again in this document. All I will do is remind you of key principles to connect the dots. The main principle you should always bear in mind is that the information we get from US is intensity and frequency of beams reflected from the boundary of two materials having different acoustic impedances.

Generation of US, therapeutic applications, interactions with tissues were all discussed in the “week 4 lecture 7” document. And will not be reviewed here.
I know I can generate an ultrasound with an inverse piezoelectric effect, electrostriction and magnetostriction, but how do I read it?

The piezoelectric effect is a reversible effect, meaning I can apply voltage in succession and cause rapid changes in shape that generate a mechanical sound wave, and I can also using the same crystal absorb mechanical sound waves and generate voltage (piezoelectric effect). Basically I can use the inverse piezoelectric effect to generate US and the piezoelectric effect to read it. US transducers have a minimum of two such piezoelectric crystals – one for transmitting US and one for reading the US (also referred to as the “echo”)

Focusing the US beam – the US beam has a focus point, which is the narrowest point of the US beam. To get ideal spacial resolution (the word “spacial” means “through space”) we would focus our US on the object at the narrowest point, called the focal zone.

Let's consider lecture slide #18 describing lateral resolution: we have (on the right is the same picture from the lecture slide) an US beam projected into tissues to resolve the points 1, 2 and 3. Basically I want to get as clear image as I can regarding these points.

You can see that the US beam is not focused on these points at its narrowest width, and due to that the borderline of the US beam hits point #1 and point #2 at the same time, causing both of them to be read as one single point. This is a picture that helps us understand that better focusing of the US beam on the object can get us better resolution

We can also consider axial resolution which is the power to resolve points as different along the line of the US beam (as if one behind the other). It is shown on lecture slide #19:

These above pictures are taken from that lecture slide depicting two different situations in which two points, one behind the other may or may not be resolved as two different points. The reason for that will be the wavelength of the US. In order for two points to be resolved as two different points the wavelength of US between them has to be at least 1.5 the size of one period.

As shown on the upper left image you can see that there will be around 2 cycles before the beam will interact with the 2nd point, where in the upper right you can see that due to the wavelength being longer, it is less than one period before the US beam will interact with the second point, thus in that instance those two points will be read as one point.
Diagnostic Sonography or “ways to present US information” (Slides #14-16) These slides refer to three basic types of US, or different modes, A, B and M modes. In this I will use the term echo which simply means the reflected US beam so let's get to it:

A mode (amplitude) – this mode of US takes the echoes reflected from the tissues and analyzes the time it took them to return to the transducer, and their intensity and time changes (minimal # 273) and builds a nice graph, by which the different amplitudes correlate to different intensity over time changes in the echoes read. As shown on the right (the green graph; taken from lecture slide #14). For instance based on this graph, I can see that there is an acoustic impedance barrier close to my transducer (the big peak) and after it there is also another barrier (by “after” I mean a unit of distance is between barrier A and B, the two peaks, because it took longer for the second echo to be read, represented by the second peak on the graph)

B mode (brightness) – this is the same method as the A mode only the data is represented in a different way, by spots of different brightness, like the different amplitude peaks on the A mode graph. On the right side you can see a simplification of A and B mode, where A mode is the top part and B is the bottom part, only you can imagine the B points should have different brightness.

Both A and B mode are one dimensional.

M mode (motion) – this method employs B modes spread over a distance can give us a three-dimensional image, being that we're getting readings over an area rather than one beam in one place. (as shown in slide #16)

Doppler Ultrasounds – employs the Doppler effect (reviewed in lecture notes about physical properties of sound). The Doppler US uses a continuous wave of US aimed at blood vessels to detect bloodflow velocities in said blood vessels. As expected the frequency shift of the echo reflected from the blood flowing depends on the direction and speed of the flow. This is the essence of Doppler US.

Minimal requirement questions

minimals #84; 273 were reviewed in this document.