David Young
3/21/2013

PLAB 3: Ultrasound

Problem 1.1:

Obtaining accurate images from the frog was extremely difficult.

Below is the best obtained image of possible atria. The atria are indicated by the red arrows.

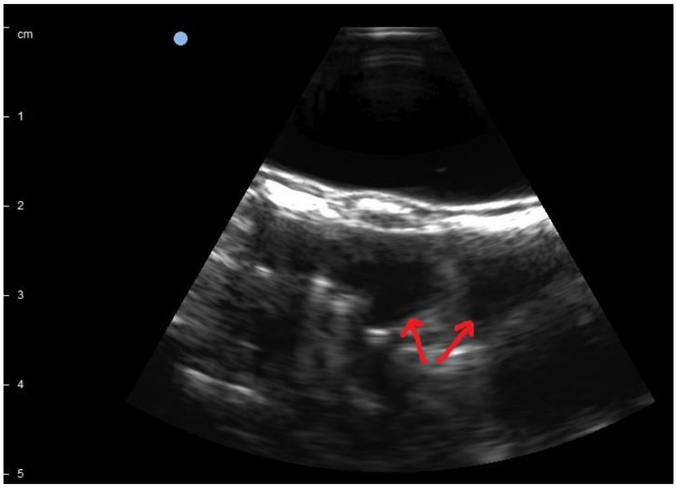


Figure 1: Frog Heart Atria

Below is the best image of valves.

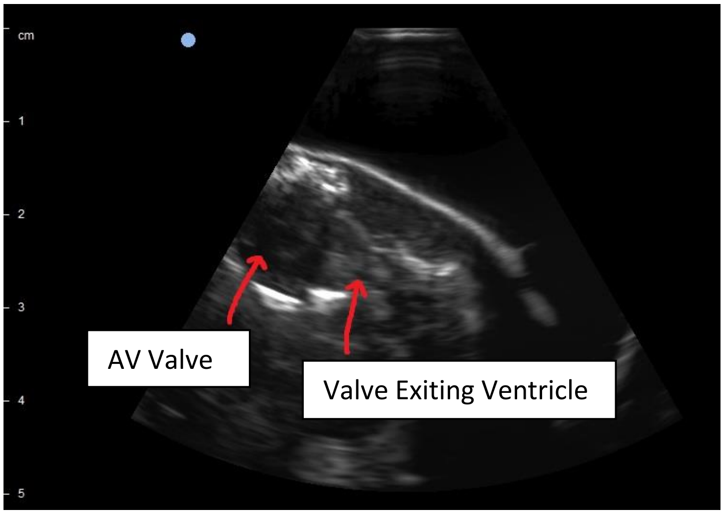


Figure 2: Frog Heart Valves

Calculation of stroke volume

Shown below is a snapshot from a video of the beating frog heart. Although a snapshot can only show a single representation of heart size, the smallest and largest diameters of the crudely spherical heart are shown. The end systolic volume would be roughly calculated by the volume of a sphere with the smaller of the two diameters being used. And the end diastolic volume would be calculated similarly but with the larger of the two diameters. The difference between the two is the stroke volume.

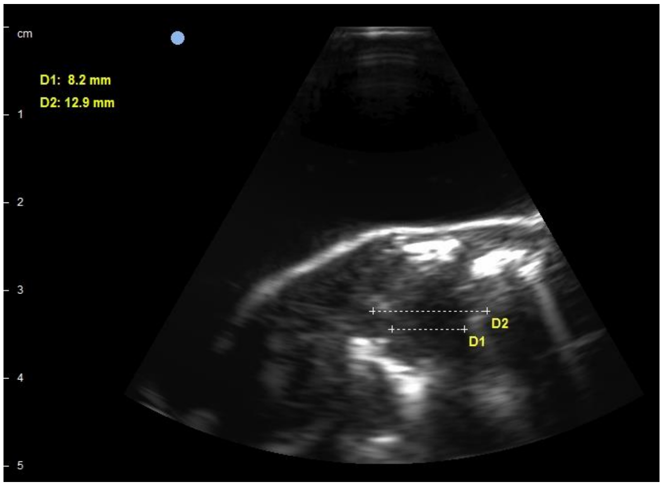


Figure 3: Frog Heart Change in Volume

$$Vol_{Stoke} = Vol_{end\ diastolic} - Vol_{end\ systolic} = \frac{4}{3}\pi({r_{bigger}}^{3} - {r_{smaller}}^{3})$$

$$\frac{4}{3}\pi({r_{bigger}}^{3} - {r_{smaller}}^{3}) = \frac{4}{3}\pi({6.45_{mm}}^{3} - {4.1_{mm}}^{3}) = 835.3mm^{3} = 0.8353\ ml$$

To verify this was an accurate range, the answer for stoke volume was compared to a peer's data that clearly showed the ventricle morphing in size. The pictures are shown below, and the stroke volume was 0.864ml. The two stroke volumes were very similar. These photos also show the ventricular chamber well, as it is the portion that is changing size most dramatically, outlined in these pictures.

Figure 4: ventricle expanded

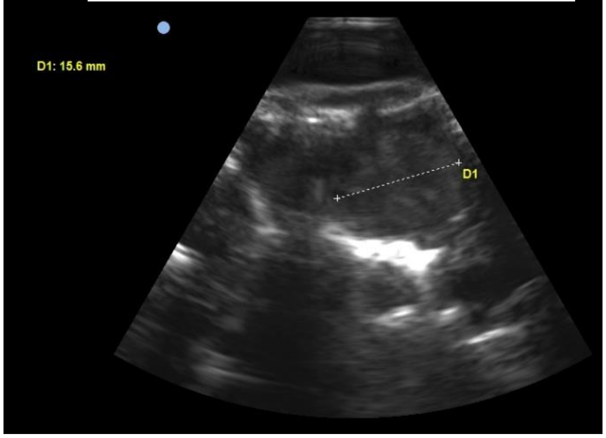
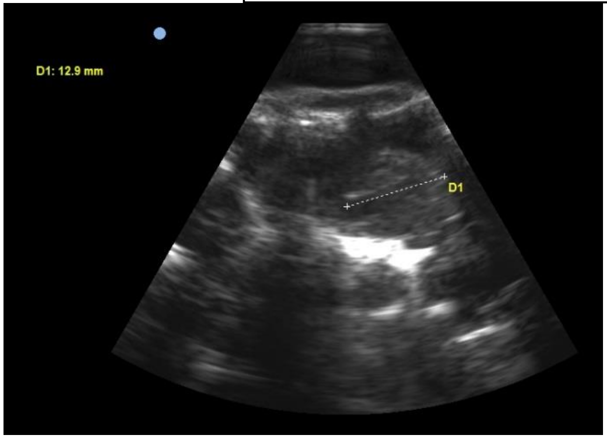


Figure 5: ventricle contracted



Problem 1.2 (a):

The longitudinal image of the carotid artery is shown below. It is very difficult to discern which depth it resides based off a still shot where one cannot see any representation of flow. But, the arrow indicates the artery.

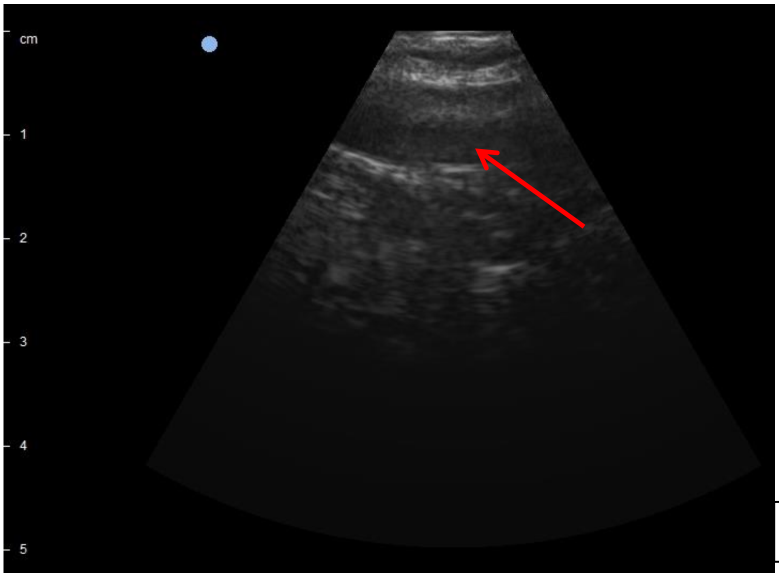


Figure 6: Carotid Artery Longitudinal

The cross sectional image is shown below to make more clear the diameter of the artery. Although this was very difficult to pick out, a TA helped identify the cross section. Below is the clean image on the left and a copy of the image on the right with the cross section outlined. The diameter was different depending on where it was measured, but ran from almost as small as .6cm to almost as big as 1cm.

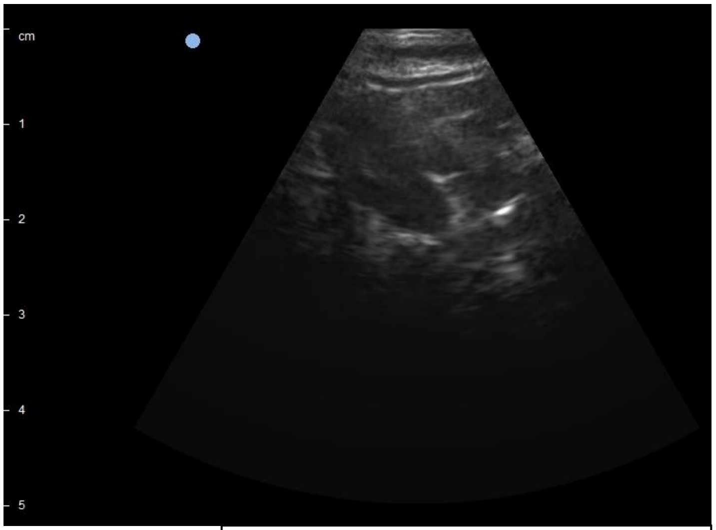


Figure 7: carotid artery cross section

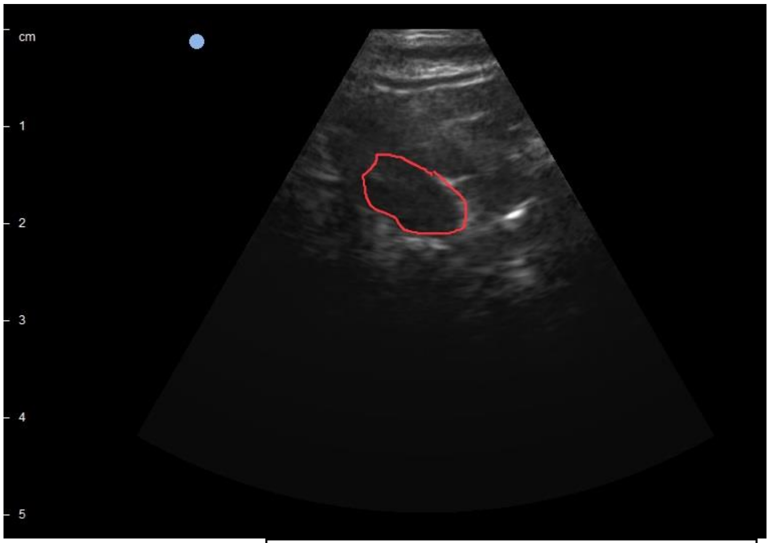


Figure 8: carotid artery cross section

Problem 1.2 b)

The radial artery is shown below under normal conditions, with a diameter of 3.4 mm.

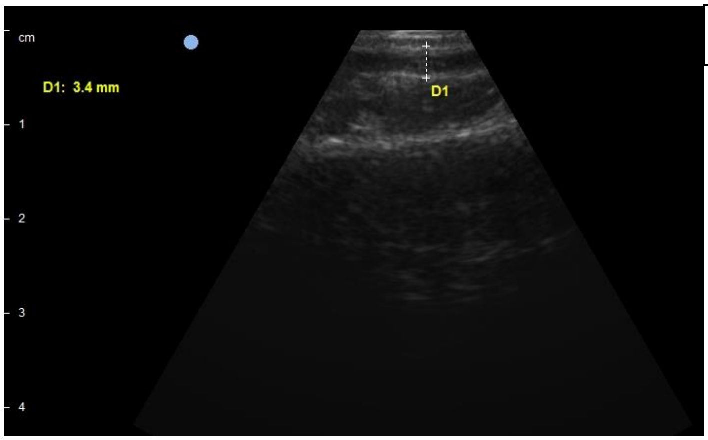


Figure 9: radial artery longitudinal

The images after occlusion from the blood pressure cuff were too distorted and cloudy to see a clear artery or measure a diameter. However, expectation was that the artery would decrease in diameter during the occlusion with little blood flowing through, and then increase in diameter (to even larger than normal) from the rush of blood through the artery after release of the cuff.

After vasoconstriction, the diameter was significantly decreased (to 1.5mm) as expected. This is shown below.

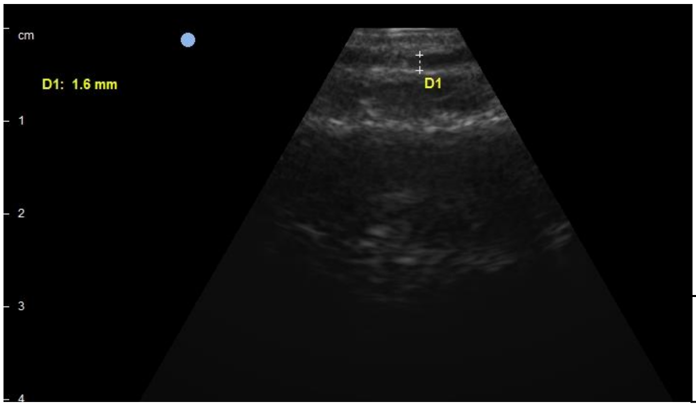


Figure 10: radial artery longitudinal showing vasoconstriction

Problem 1.3:

Both tubes are shown in the following photo of a cross section. A longitudinal view of both simulataenously was not possible, as they were at the same depth.

The cross sectional comparison between these two makes sense (jugular on the left in blue and carotid artery on the right in red), because the jugular vein is less circular, indicating it is less pressurized, which is true of veins when compared to arteries.

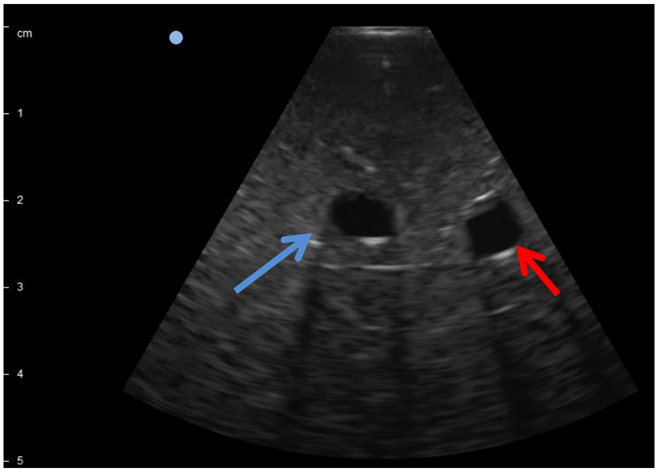


Figure 11: jugular and carotid

The longitudinal view of the artery can be seen below.

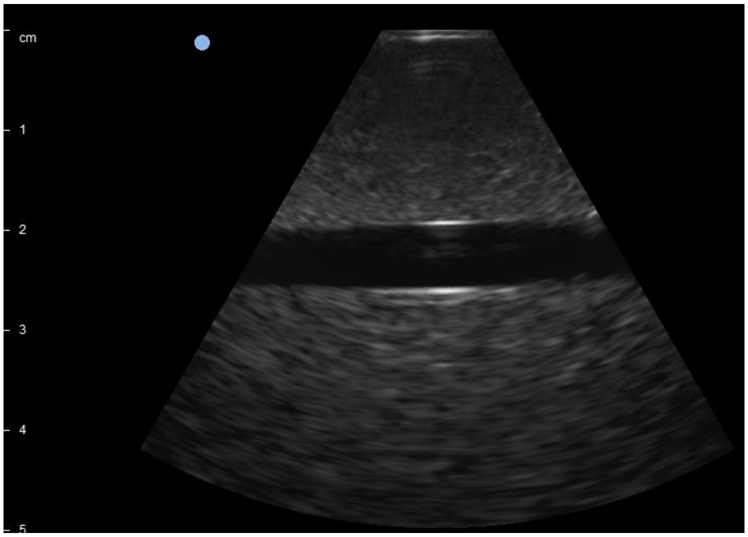
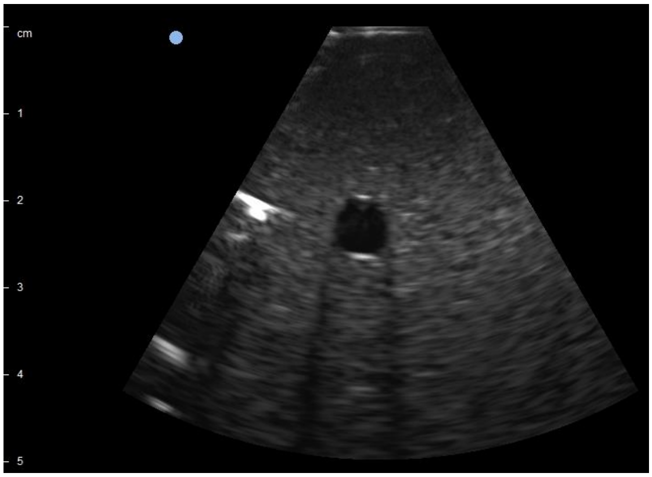


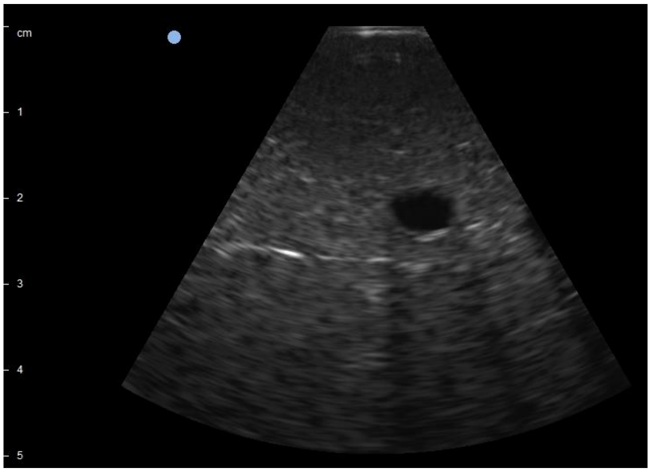
Figure 12: carotid artery

And the individual cross sections can be seen as follows:



Artery: (Diameter = 6.8mm , Area = 34.2mm^2)

Figure 13: carotid artery cross section



Jugular Vein: (Diameter = 8.1mm at its longest stretched diemnsion, but area was less at 29.3mm^2… the decreased area is an indication of reduced pressure)

Figure 14: jugular vein cross section

The puncture of the artery is shown below, with the needle entering diagonal from the left.

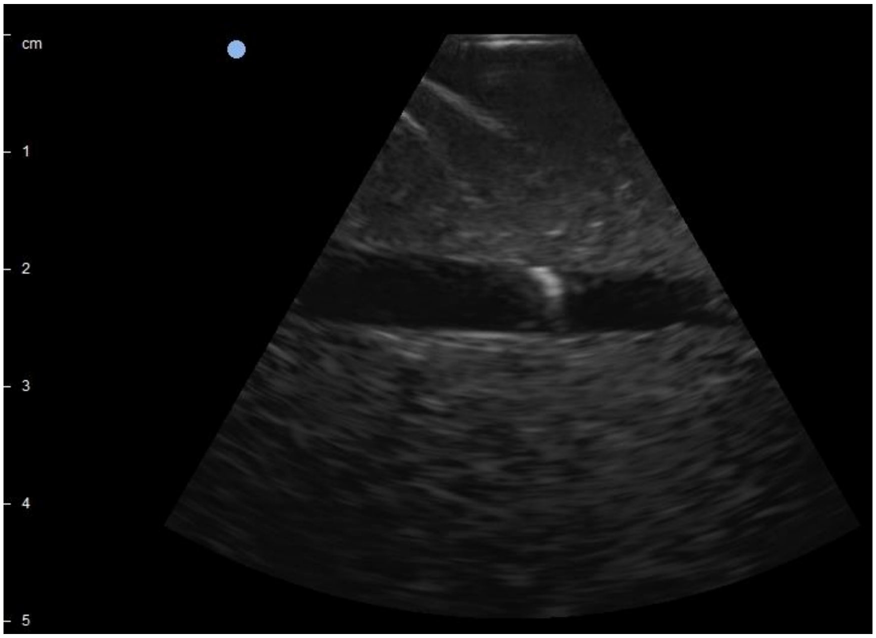


Figure 15: carotid artery puncture

Problem 1.4: Normal Ventilating Lung, Pneumothorax and Pulmonary Oedema Phantom

Normal Lung: (it is hard to state with accuracy, but there appears to be an artifact known as the "comet tail" on the lower side of the interface between meat and sponge, and represents the reverberation of ultrasound within tiny pockets of interstial fluid. A different artifact is shown towards the bottom as the horizontal white line.)

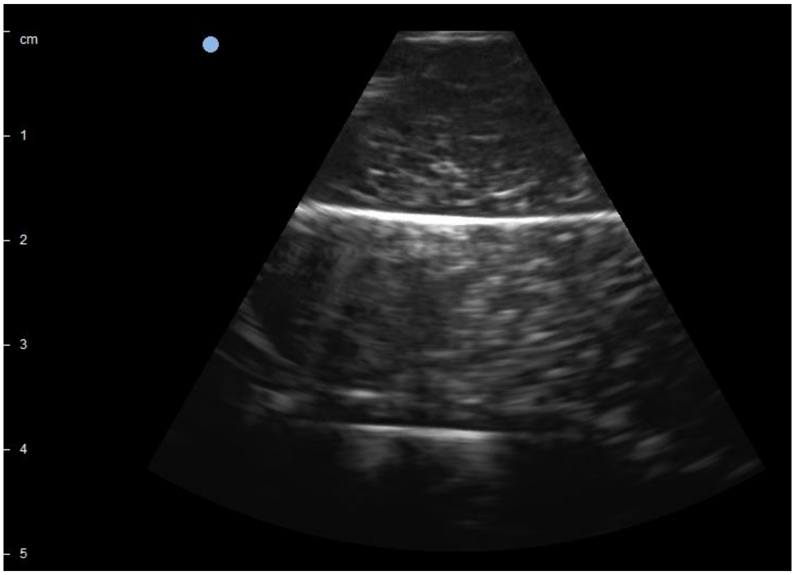


Figure 16: Normal Lung

Pneumothorax: (difficult to tell, but has lost the sliding sign and associated comet tail artifact, and the horizontal white bottom line from the normal lung is almost completely gone.)

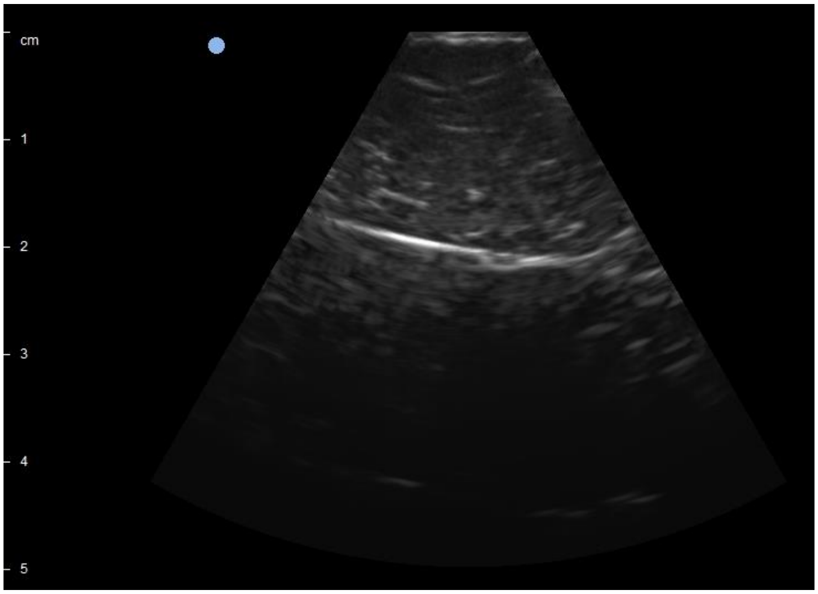


Figure 17: Pneumothorax

Pulmonary Oedema Phantom ("wet lung"): You can clearly see the "lung rockets," (the white streaks downward) characteristic of edema where very clear resovled artifacts extend deep into the ultrasound image. This is because the fluid present fights the loss of ultrasound energy by allowing the energy to reverberate more.

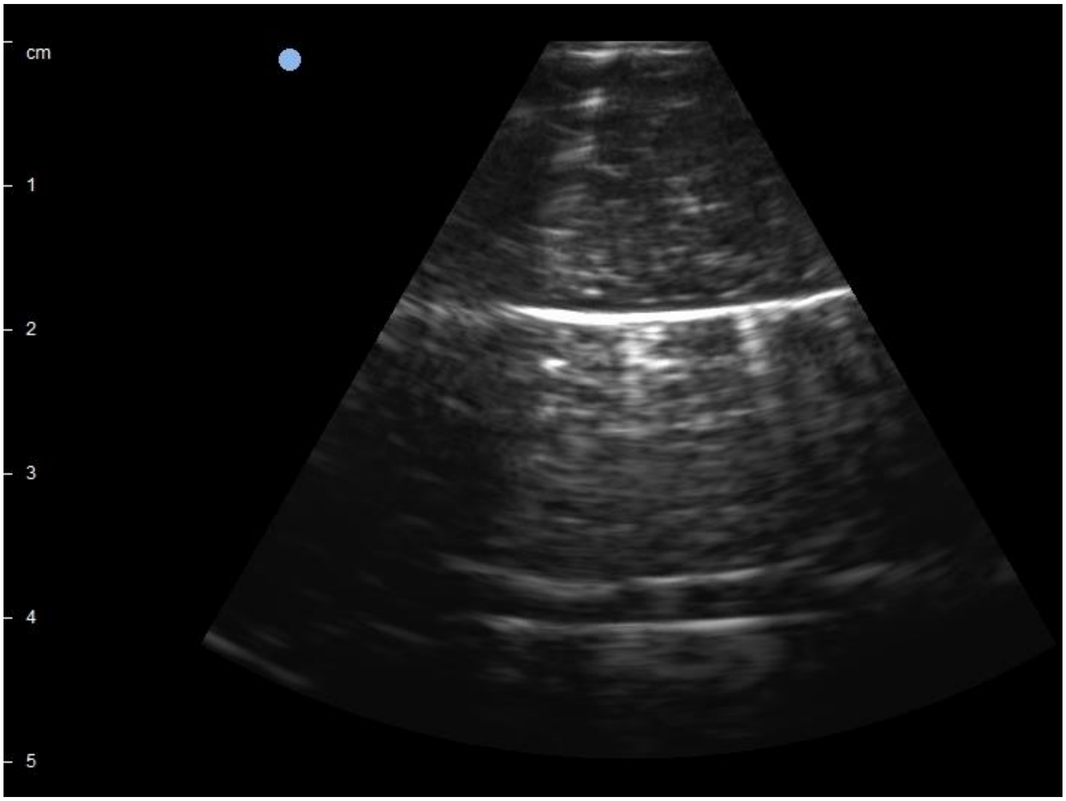


Figure 18: Pulmonary Oedema

Problem 1.6:

There are many benefits of ultrasound imaging. First is relative affordability. A cheaper X-ray machine can still be in 5 figures, and a cheap ultrasound can be had for under 100 dollars. This gives access to a wider range of users, provides cheaper and easier training and lowers cost to patients. Second benefit is portability. The device used in this lab was a usb chord with a handheld probe. It could be put in a backpack or briefcase of a traveling doctor in foreign countries or on house calls. The ultraound also benefits from ease of use. No extreme procedures or methods are required to obtain useable images. This lab is proof of that benefit as useable images were obtained by new users. Additionally ultrasound is safe without radiation or invasive components. This allows it to be used for things such as fetal imaging, and on patients with existing degraded conditions. There is no exclusivity toward certain patient contions, it is universally applicable. Lastly ultrasound is a real time imaging. Videos can be taken which can make clear the movement or changes in objects when compared to a still photograph.

There are however limitations to ultrasound imaging. It is hard to image deep structures. Even in this lab it was clear that structures closer to the surface produced superior resolutions. The ultrasound propogates poorly through gas, and scatters from microstructures, and it cannot see behind bones. Lastly, images cannot be exactly reproduced as there is an individual user component to the imaging.

In this lab, ultrasound of the normal lung phantom gave the worst images. A modality better suited to the normal lung image would be X-Ray imaging (chest Xray). This is because X-Ray is not diluted by tissue or gaseous medium to the extent that ultrasound is. It probably woulnd't work well for edema because Xrays don't differentiate soft tissue or fluids very well, but for normal lung it is quite applicable.

Problem 1.7:

Ultrasound is a device that works off echos. It transmits high frequency sound pulses. The sound waves travel through materials and when they encounter a boundary (of material with different acoustic impedences) some of the sound waves are reflected back toward the probe while others trasmit through. The machine notes the reflected waves and calculates distances from the ultrasound probe to the boundaries that reflected waves. This calcualtion is made possible by knowing the speed of sound in a tissue and a very accurate log of the time a sound wave reflects back to meet the probe. Transforming distances and intensities into two dimensional images produces the image we see on a screen.

It is important to note the reflection coefficient which is the fraction of wave intensity that is reflected, as well as the acoustic impedence. Acoustic impedence is a material property defined by the material density times the speed of sound. The difference between acoustic impedences of two materials at an interface is beneficial in differentiating the materials and defining their boundary. A larger difference between acoustic impedences at a given bounary between two materials will produce a larger reflection coefficient and will lead to a larger intensity of the signal reflected back toward the probe.

(Sources: http://www.physics.utoronto.ca/~jharlow/teaching/phy138_0708/lec04/ultrasoundx.htm)

Problem 1.8:

The follow table is taken from Anastasio's lecture 3 slide 30 on Ultrasound imaging. It shows the reflectivity at different interfaces. The higher the reflection coefficient, the more the signal is reflected, and less it is transmitted. This means a stronger image of the interface on the visual side of things.

Materials at Interface	**Reflectivity**
Brain-Skull Bone	0.66
Fat-Muscle	0.10
Fat-Kidney	0.08
Muscle-Blood	0.03
Soft Tissue – Water	0.05
Soft Tissue - Air	0.9995

Some of the interfaces shown were not imaged in this lab, but they are useful values to demonstrate how larger differences in density between materials at an interface produces more reflected signal back to the probe and allows easier differentiation of the boundary/interface. For example, muscle-blood has the lowest reflectivity on the table. It was also the most difficult interface to discern in the ultrasounds. Many of the images were of chambers or vessels filled with liquid, and yet the actual blood or liquid was far too difficult to discern from the musclar vessel or chamber that held it. This was evident in the frog heart images as well as artery or vein images. On the other hand, the interface of fat and muscle has a reflectivity (10) over 3 times greater than muscle-blood (3). This made the interface between muscle (such as that of the myocardium or the vessel walls) easier to discern from the outside. The heart and vessels were often clearly outlined, but their insides were difficult to see. This is because the reflectivity of the outside boundary between muscle and fat/soft tissue was higher than the reflectivity of the inside boundary with fluid.

Discussants:

Paras Vora, Lauren Bedell, Mathew Everett

Sources:

1. Anastasio Lecture 3
2. Borrowed data/ images from Paras Vora and lab group
3. http://www.physics.utoronto.ca/~jharlow/teaching/phy138_0708/lec04/ultrasoundx.htm