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EDUCATIONAL

Point-Of-Care-Ultrasound Doppler Training for Clinicians (Part 1)

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1. Introduction

Today, clinicians use ultrasound, similar to the use of a stethoscope ten years ago. We will soon see ultrasound probes in the pockets of every medical student (1), Nowadays, ultrasound probes are used in the examination of patients, and ultrasound is no longer considered a para-clinical procedure, and during patient examinations, we also perform ultrasounds for our patients in order to limit differential diagnosis (2). As a result of these examinations and applying clinical and ultrasound findings, the desired treatment is determined.

In ultrasound, one challenge that always arises is the Doppler field and vascular flow. Recent articles have emphasized the importance of using ultrasound for clinicians (3-5).

There is a general lack of enthusiasm among clinicians when the term Doppler is mentioned.

Due to this, I considered it necessary to write an educational article in an easy-to-understand manner and at the same time practical in this field for the medical community, especially clinicians.

It is my goal to provide the information in a simple and practical manner.

2. Training in Doppler for clinicians, First part

Sonography is based on sound waves sent from the probe crystals and returned from the tissue. Everything that appears on the monitor screen results from sound waves. The device's processors combine these sound waves into a unified image for us.

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So, probes and the processor of ultrasound devices play an influential role in the images obtained for us (this leads to the price difference between the devices). As a result, our image is a real-time image and a gray scale image since it is composed of a spectrum of grays, a spectrum ranging from absolute white to absolute black.

However, if the device can provide us with the wavelength of sound it receives, does it match the original wave with the same wavelength, or has the return wavelength changed up or down, or has the return frequency changed, and if so, how much? This means that our device has Doppler capabilities(6).

There are two types of Doppler modalities:

- Pulsed wave Doppler
- Continuous wave Doppler

Using this model of Doppler, Pulse-wave Doppler Called, if the probe sends a wave and then pauses to receive the return wave, it can calculate the depth, distance, and speed between the waves and send the next wave after interpretation.

By default, the probes are in this mode, allowing us to calculate the difference between speed and frequency accurately. It is important to note that when the device is operating in continuous mode, it continuously transmits only the transmitted waves from one side of the crystals and continuously receives the return waves from the other side (7).

I would like to clarify that, in pulse mode, the device will check the waves more intelligently and will interpret the wave more accurately. As a result of being more precise, it has taken its toll, and we are unable to interpret waves at speeds greater than two meters per second from the terrace.

Continuous Doppler has no limitation in calculating speed, despite being less accurate and displaying fewer details. (Figures 1 and 2) Ultrasound probes are available in a variety of piezoelectric crystal models. There are crystals that are responsible only for creating B-mode and gray-scale images. As well as these crystals, there are other crystals that send Doppler waves, pause during the sending and receiving of return waves, and interpret and resend another pulse, known as pulse waves. Consequently, when operating in Doppler mode, our device simultaneously activates two crystal models and performs two analyzes. The first analyzes the B-mode crystals for imaging, and the second analyzes the Doppler crystals' waves. The device's processor is responsible for interpreting both analyzes simultaneously. When Doppler is active, the quality of the B-mode images will be lower if the device's processor and analysis power are weak.

You may have noticed that some ultrasound devices reduce image quality when using Doppler. This is due to the fact that the device must send a Doppler wave, pause, receive the wave, calculate the Doppler shift, and analyze the information that these calculations make our frame rate decrease, leading to a feeling of slow motion in our image. The Doppler pulse wave provides the following information:

1. Spectral Doppler
2. Color Doppler
3. Power Doppler

In spectral Doppler, the changes of Doppler shift and velocity are displayed on a time-velocity graph. It is therefore possible to measure the speed of red blood cells by measuring the volume of blood passing through the sample volume in the systole or diastole phase in the arteries, or in the inspiratory and expiratory phases in the veins. Here is a view of a spectral Doppler wave in an artery. (Figures 3)

According to this image, the speed of red blood cells increased during the systole phase and then decreased during the diastole phase.

Spectral Doppler describes the movement of red blood cells within vessels.

We can observe these changes in blood movement as color. A color Doppler device displays red color when red blood cells are moving towards the cursor of our probe and the Doppler shift is positive in the vessel. If the blood cells move away from the cursor and the Doppler shift is negative, they will turn blue, which is called Color Doppler (Figures 4 and 5).

A spectrum of one color can also be used, which changes in intensity as the speed of the color box changes, which is known as power Doppler. In the event of tissue ischemia, the Power Doppler is more sensitive to the flow of blood in tissues and will show the lowest arterial flow. (Figures 6 and 7)

Duplex and Triplex:

A duplex image comprises a B-mode or gray-scale image in one corner of the image and a spectral image in another corner at the same time.

We use the term triplex when we have B-mode, spectral, and color on the screen at the same time. (Figures 8 and 9)

When should triplex be used?

When we do not see a lesion inside the vessel in B-mode, but suspect one, we use color or power Doppler. With power Doppler, we can only see the blood flowing within the vessel, where the blood flow is established and where the blood flow is with an identified problem, and then we convert this qualitative flow into a quantitative flow by using Spectral Doppler. During ultrasound of vessels, we first observe the vessels in B-mode, then we use color Doppler to get information about the qualitative flow of the vessels, and finally, spectral Doppler is used to get information about the quantitative flow.

Imagine what a large amount of information the processor of the device receives and analyzes in triplex and provides to us in real time, which is why many ultrasound machines do not have this capability.

2.1. Here is a step-by-step guide to how to draw a correct spectral Doppler

It is necessary to determine the area where we wish to measure the speed of red blood cells in the vessels in order for the ultrasound machine to be able to determine the speed of red blood cells. Once you click on the Doppler option, two parallel lines will appear on the screen, with a gate placed in the middle of the screen.

The purpose of this gate is to determine the speed of red blood cells passing through it and to draw an aspect of those cells. We call this gate Sample Volume, so the first thing is to place the Sample Volume somewhere right inside the vessels. (Figure 10)

In the middle of the artery is the best place to place the sample volume because, next to the walls, red blood cells slow down due to friction and impact. It is recommended that the diameter of the sample volume not be less than one-third of the vessel diameter and not more than two-thirds of the artery diameter, in order to calculate the best red blood cell speed in the appropriate location of the artery. (Figure 11 and 12)

In the first view of this figure, we can see that by using a large sample volume, a lower speed has been drawn for us (100 cm/s), while in the second view, a higher speed has been displayed (140 cm/s).

The next step is to determine the correct angle within the sample volume after determining the location of the sample volume. The angle of collision between red blood cells in motion and the sound beam must be chosen correctly, i.e., we must determine the direction in which the red blood cells are moving, then place the sound beam line along the direction in which the blood cells are moving (Figure 13).

We must calculate the angle of the sound beam regarding the direction of movement of red blood cells and try to keep this angle below 60 degrees. The best angle is zero degrees, but most vessels create an angle with our sound beam, and we often cannot achieve the best angle of zero degrees. In the new probes, we can angle the sound waves to one side by putting a lens on the head of the probe, which produces a close to

zero angle for us. Looking at Doppler physics will help us understand the importance of the angle. At the beginning of the presentation, I stated the device sends a sound wave with a particular frequency, waits for the return wave, and then determines the red blood cell speed based on the difference in return frequency. Based on the calculation formula, we can see that the angle of impact of the sound wave on the red blood cell is very important for us, and the closer the cosine of the angle to zero, the closer the number to one. Thus, we will determine the true speed of red blood cells passing through the volume sample.
As a result, when drawing the spectral wave, the angle must be reduced as much as possible to zero, and the greater the angle, the greater the error in calculating the speed. Considering an angle of 60 degrees, the error reaches 50%, meaning that the speed of red blood cell movement should be 100 cm/s, while for us it is portrayed as 50 cm/s. From 0 to 60 degrees, we have a fifty percent error, and we often consider this error acceptable. Suddenly, from 60 to 90 degrees, another 50% error is introduced, which is not acceptable. (Figure 14 and 15)
According to the above picture, in the first picture, when our angle is 70 degrees, the maximum speed is 36 cm/s, while in the second picture, when our angle is 40 degrees, the maximum speed increases by 103 cm/s.
The sound wave in new ultrasound devices is angled from the beginning or it can be angled by creating an angle, which is the same as creating a steer for the wave. There is a difference in steer angle between the various ultrasound devices. Using the appropriate steering, we create an angle equal to the vessel's length, and we are close to approaching the zero-degree angle. The next step is to make the angle as close to zero as possible by pressing the Angel button on the device.
As a first step, it is important to remember that the sound beam line in the Doppler must be parallel to the vessel's wall. Second, the probe should be placed lengthwise on the vessels in order to change the Steer and Angle angles. The probe should never be placed transversely on the vessels. If it is placed transversely, your angle will be 90 degrees and the device in this case cannot create a suitable angle. By adjusting the wrist angle and bringing the probe head closer to the skin, the angle must be brought below 60 degrees if we wish to draw a cross-section of the Spectral wave. (Figure 16)

2.2. In summary, the optimal Doppler examination comprises

1- Adjust gain & filter
2- Adjust velocity scale & baseline
3- Doppler angle < 60 by steering & probe position
4- Color box as small & superficial as possible
5- Sample volume size: 2/3 of vessel width in the center
6- Avoid transducer motion

3. Declarations

3.1. Acknowledgments

It is dedicated to the emergency medicine community of Iran and to all the physicians who serve in the first line of treatment and are rarely seen.

3.2. Authors' contributions

All authors; provided the necessary data, revised the article and approved this version to be published.

3.3. Funding and supports

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3.4. Conflict of interest

The authors declare no conflicts of interest in this study.

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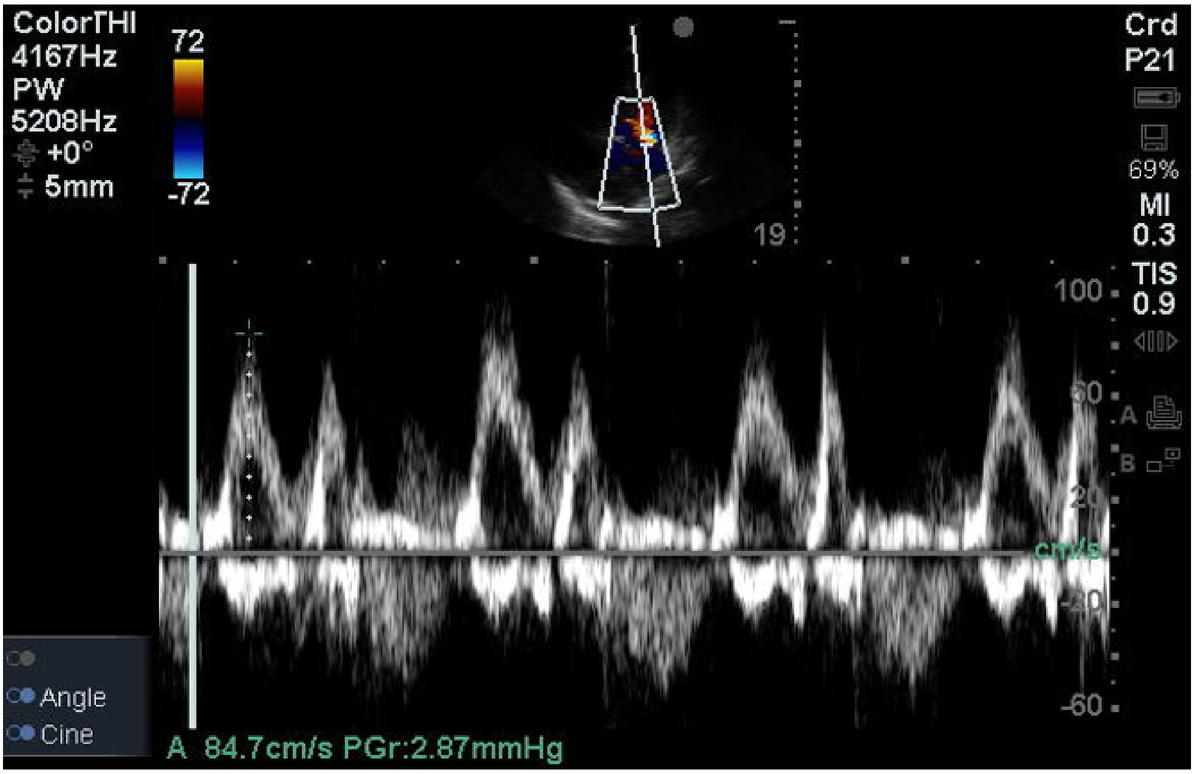

Figure 1: Pulsed wave Doppler

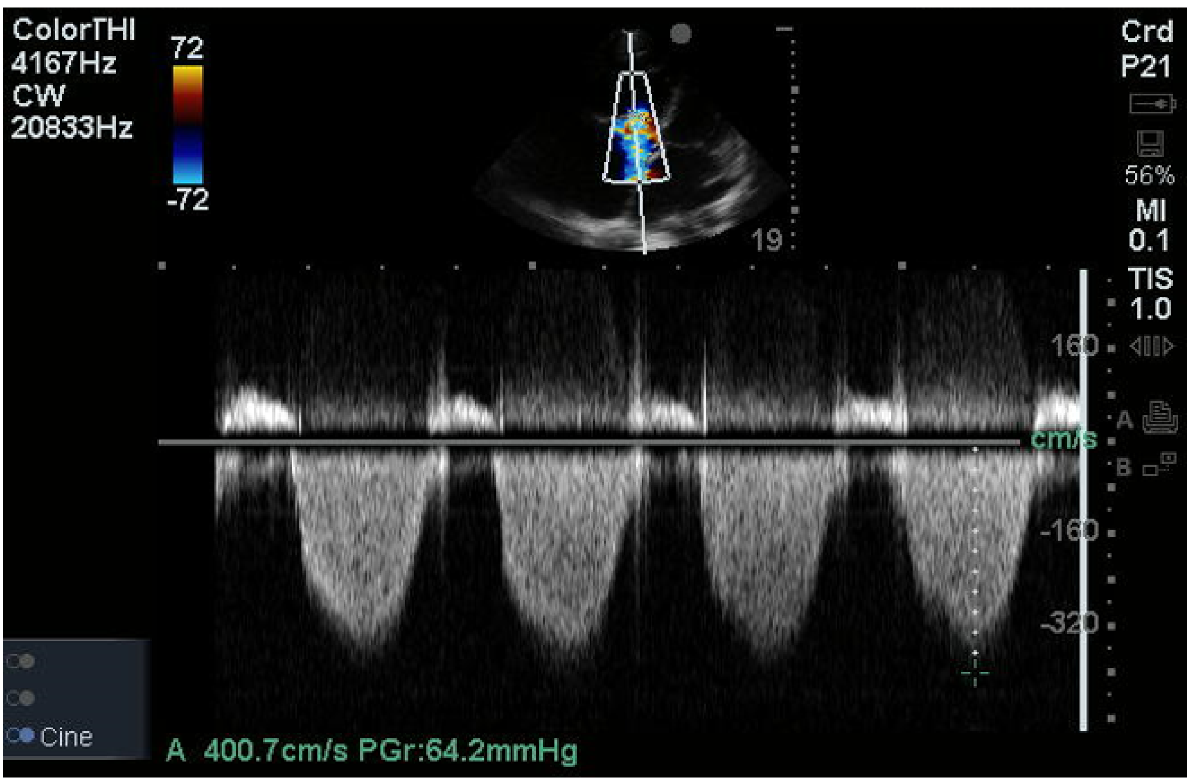

Figure 2: Continuous wave Doppler

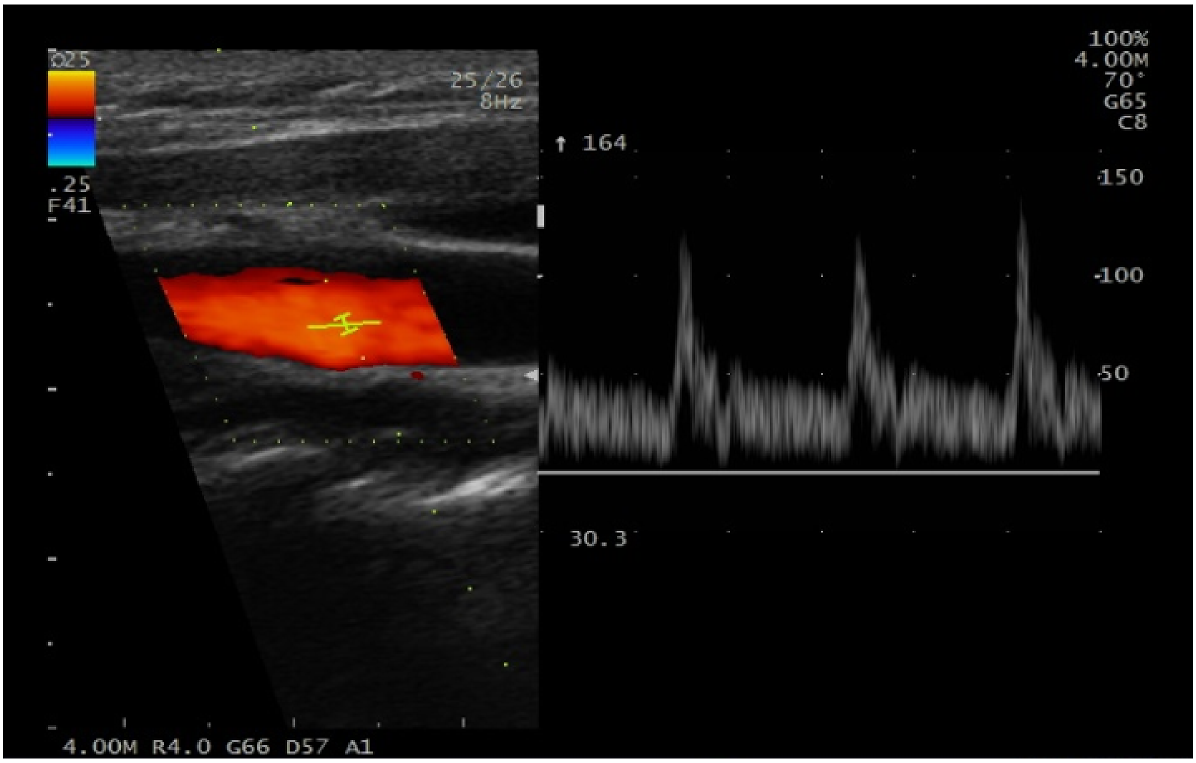

Figure 3: Spectral Doppler wave in an artery

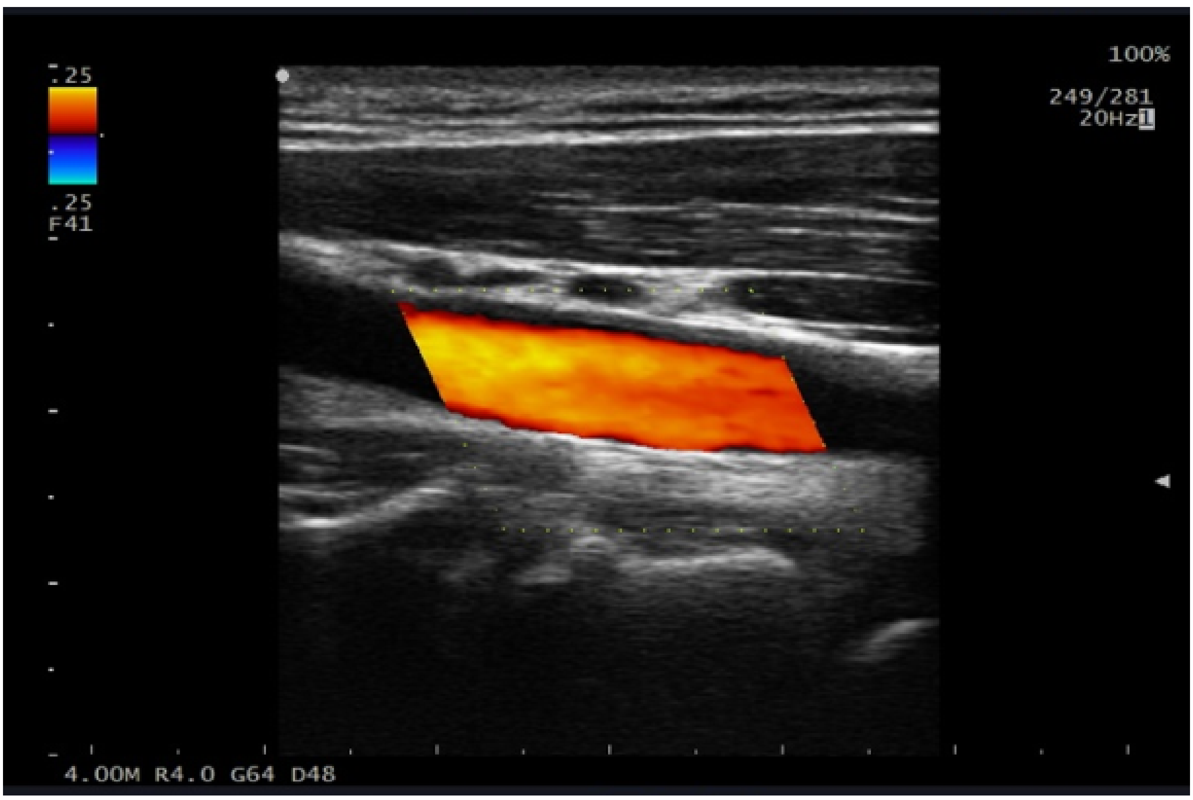

Figure 4: Color Doppler, Red blood cells move towards the cursor

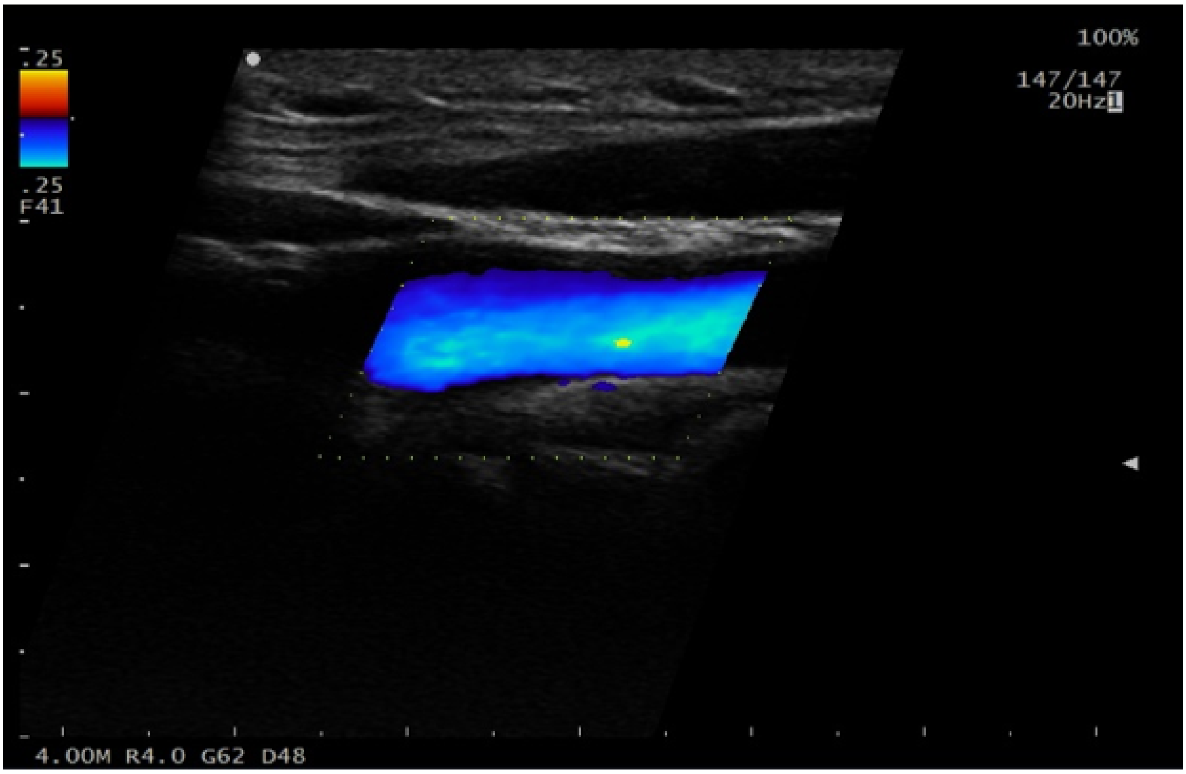

Figure 5: Color Doppler, Red blood cells move away from the cursor

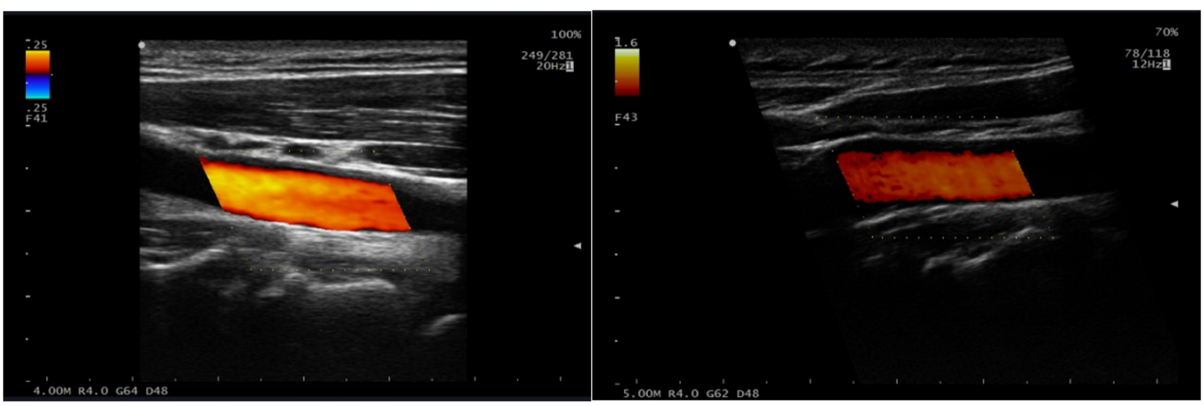

Figure 6: Color Doppler vs Power Doppler, Longitudinal view

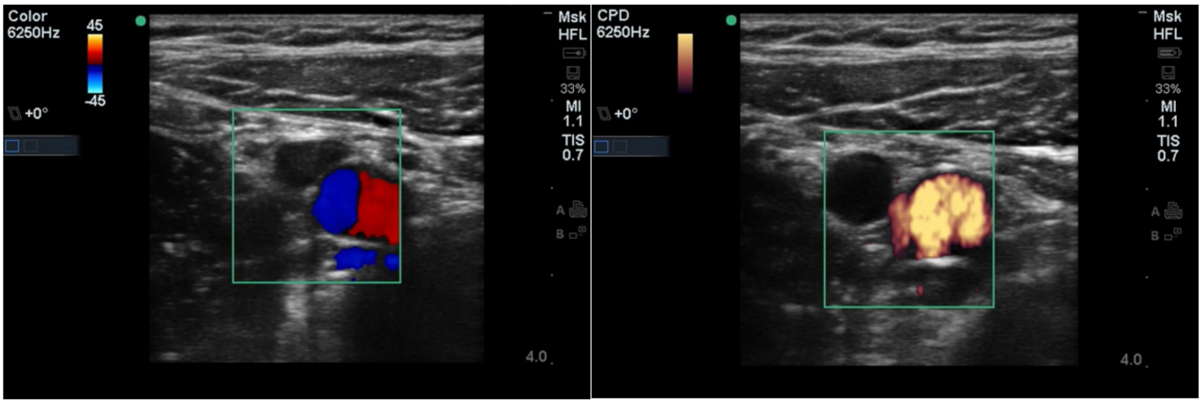

Figure 7: Color Doppler vs Power Doppler, Transverse view

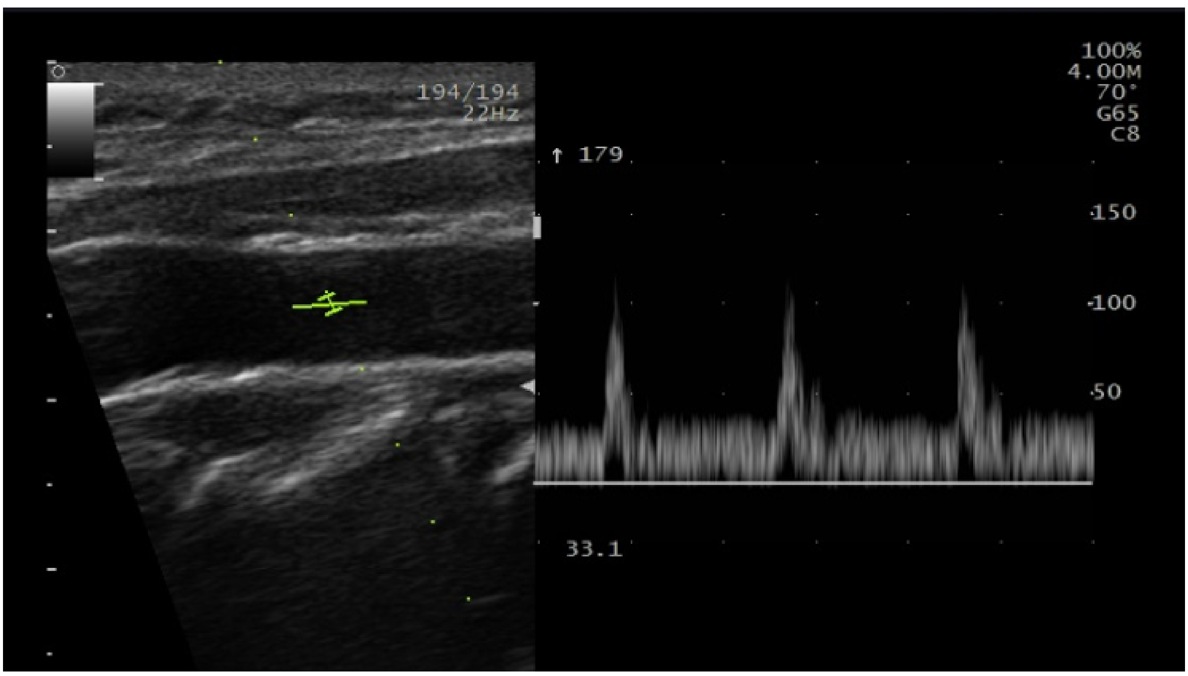

Figure 8: Arterial Duplex Ultrasound

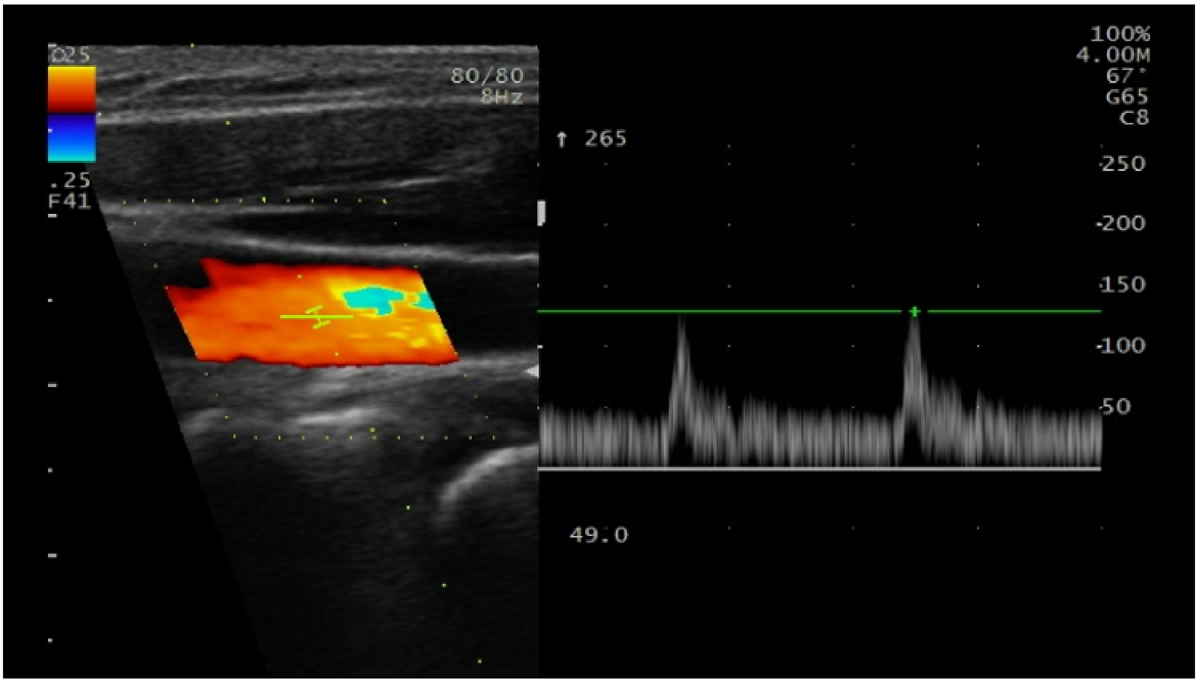

Figure 9: Arterial Triplex Ultrasound

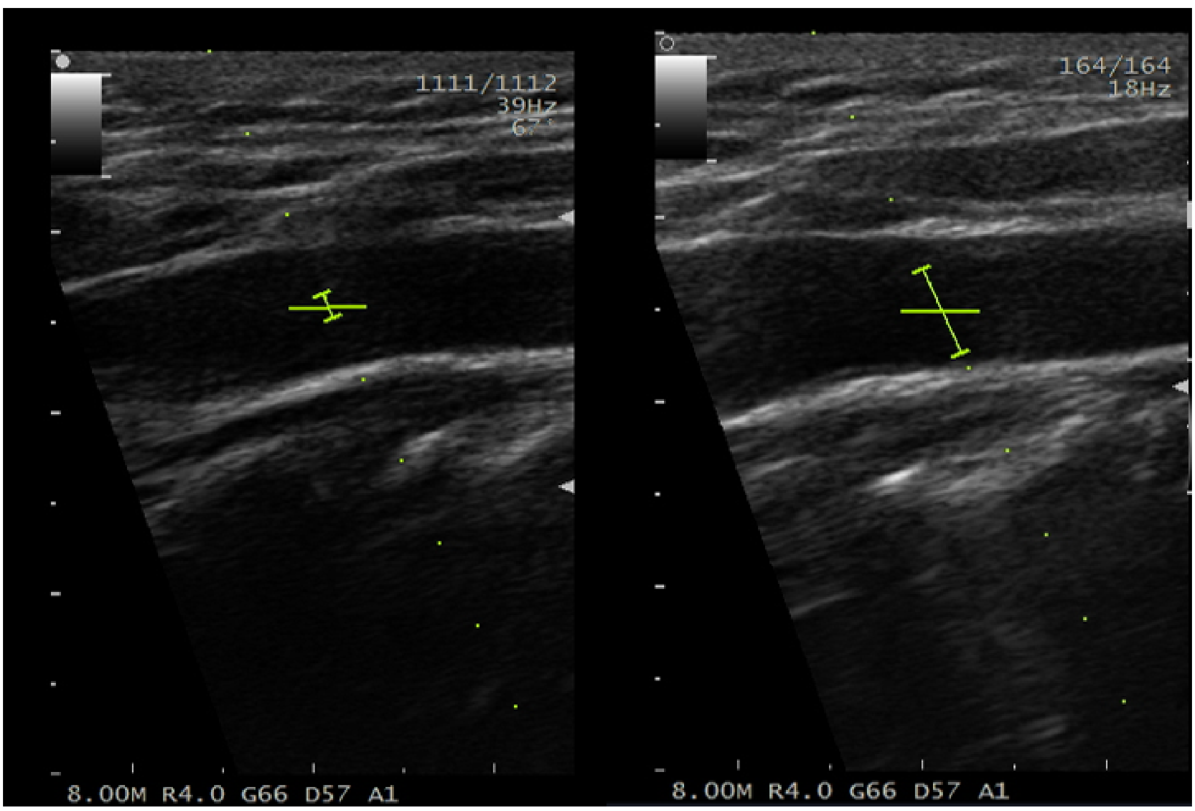

Figure 10: Spectral Doppler, Sample Volume(gate) length

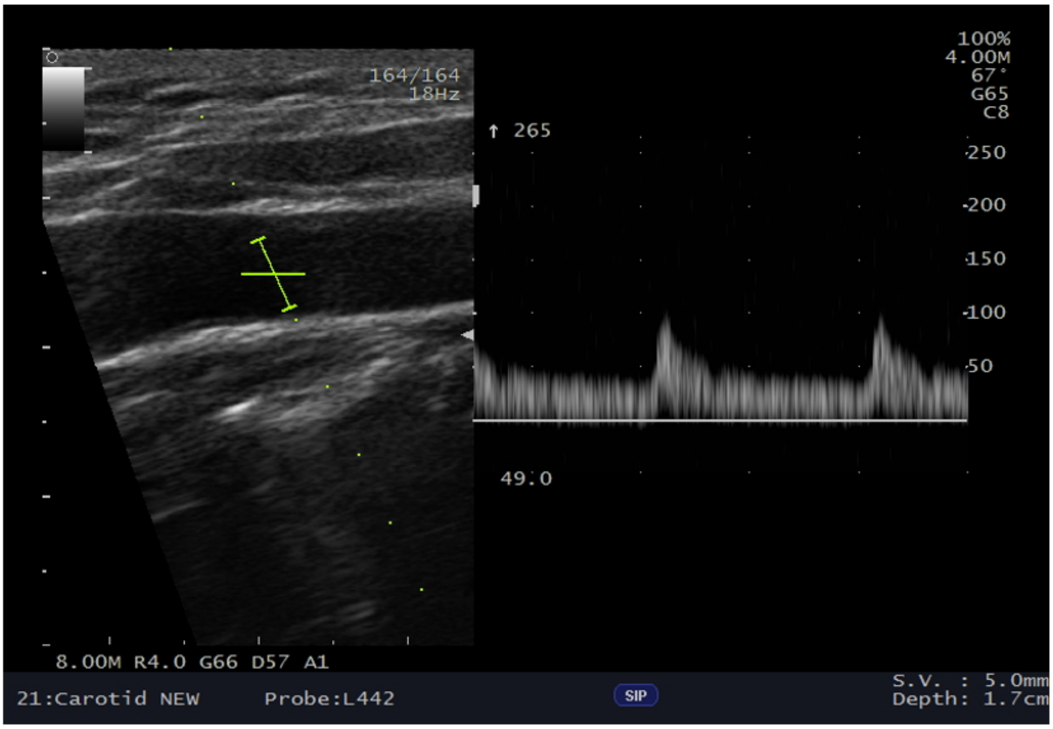

Figure 11: Spectral Doppler wave, large Sample Volume length

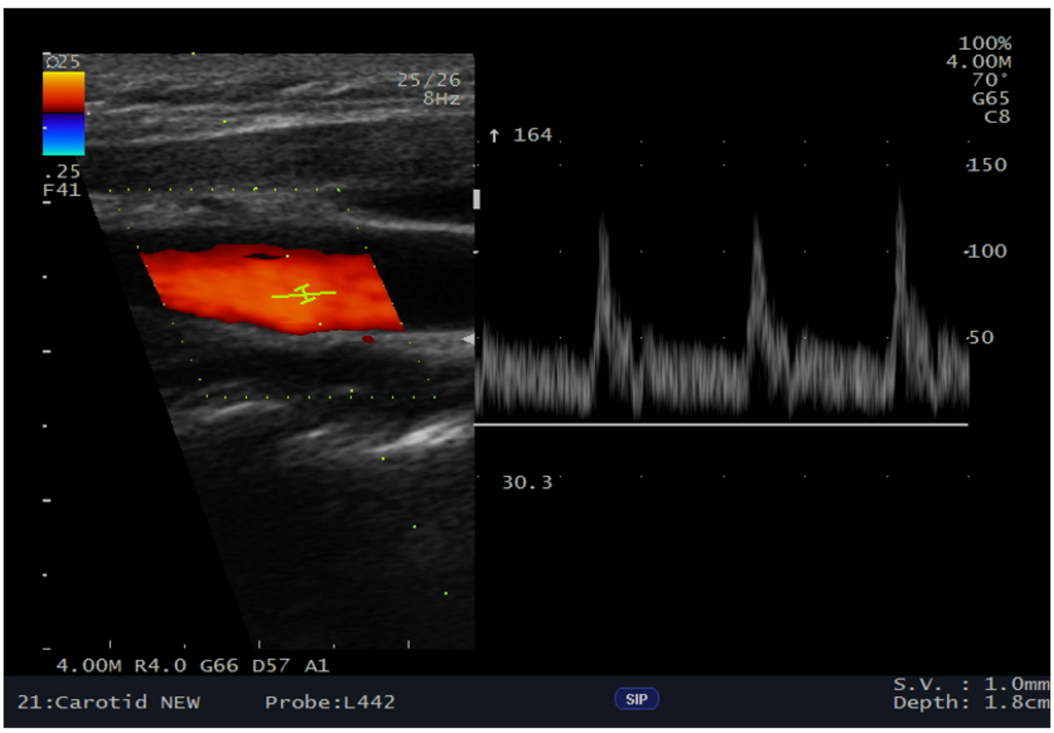

Figure 12: Spectral Doppler wave, small Sample Volume length

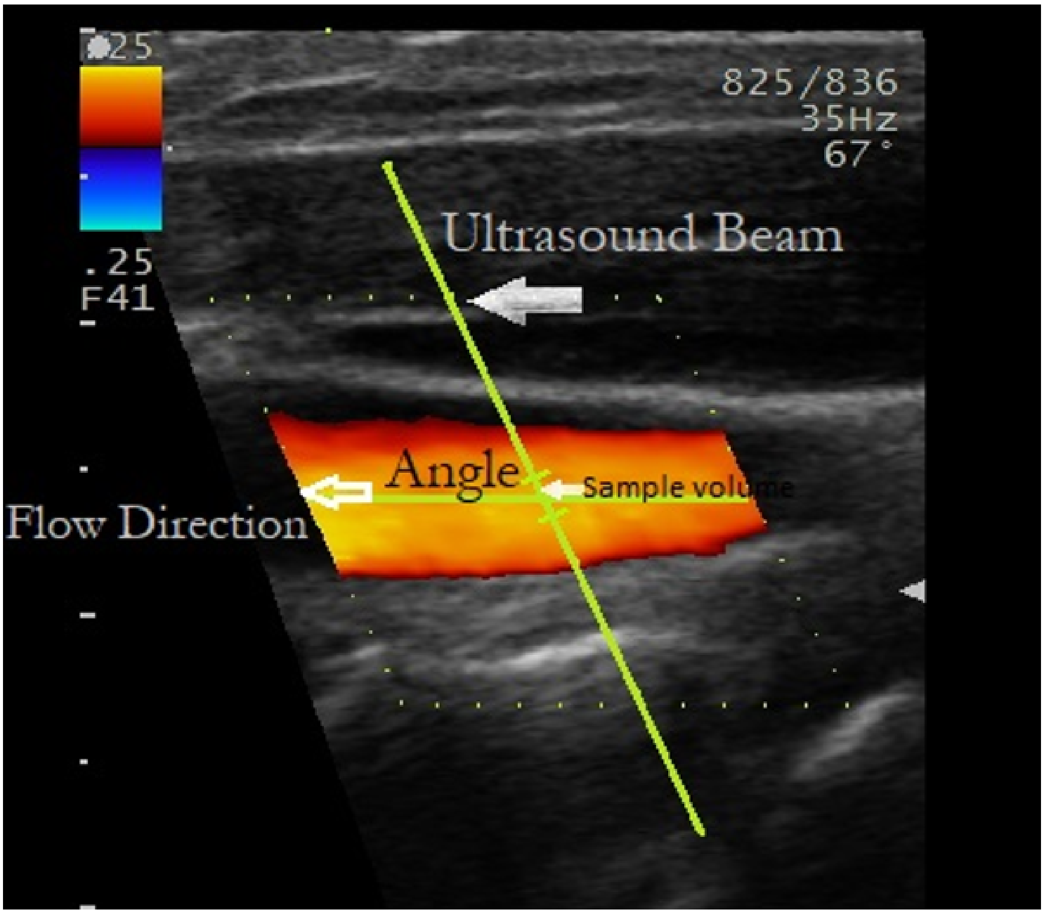

Figure 13: Spectral Doppler wave, Angle of doppler beam

Figure 14: Spectral Doppler wave, Angle 70 degree with small (0.5 mm) sample volume

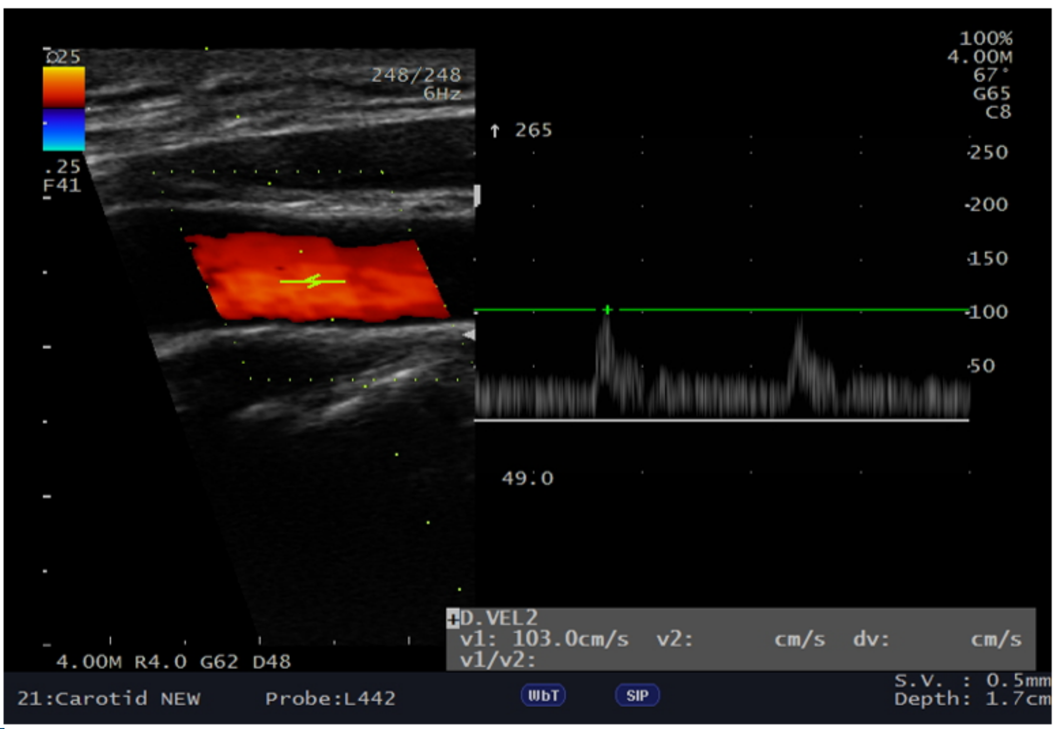

Figure 15: Spectral Doppler wave, Angle 40 degree with small (0.5 mm) sample volume

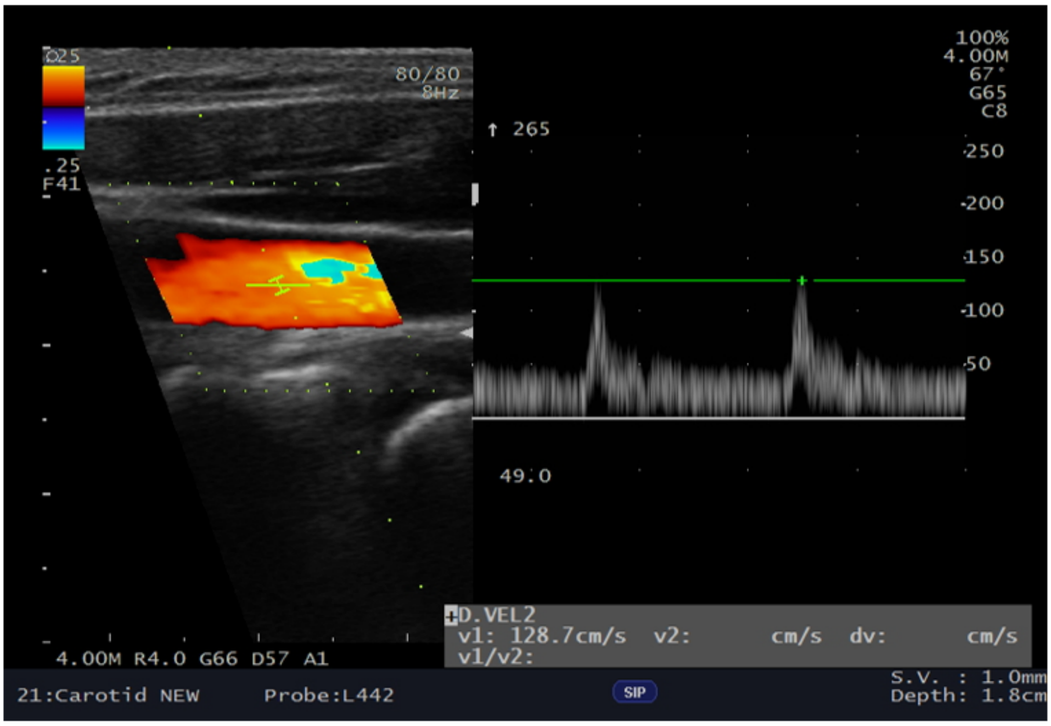

Figure 16: Spectral Doppler wave, Angle 40 degree with optimal (1 mm) sample volume