

**Sononerds**  
in the classroom



ARDMS Topic:  
Doppler Imaging Concepts

# Unit 20: Doppler Application

Sononerds Ultrasound Physics  
Workbook & Lectures

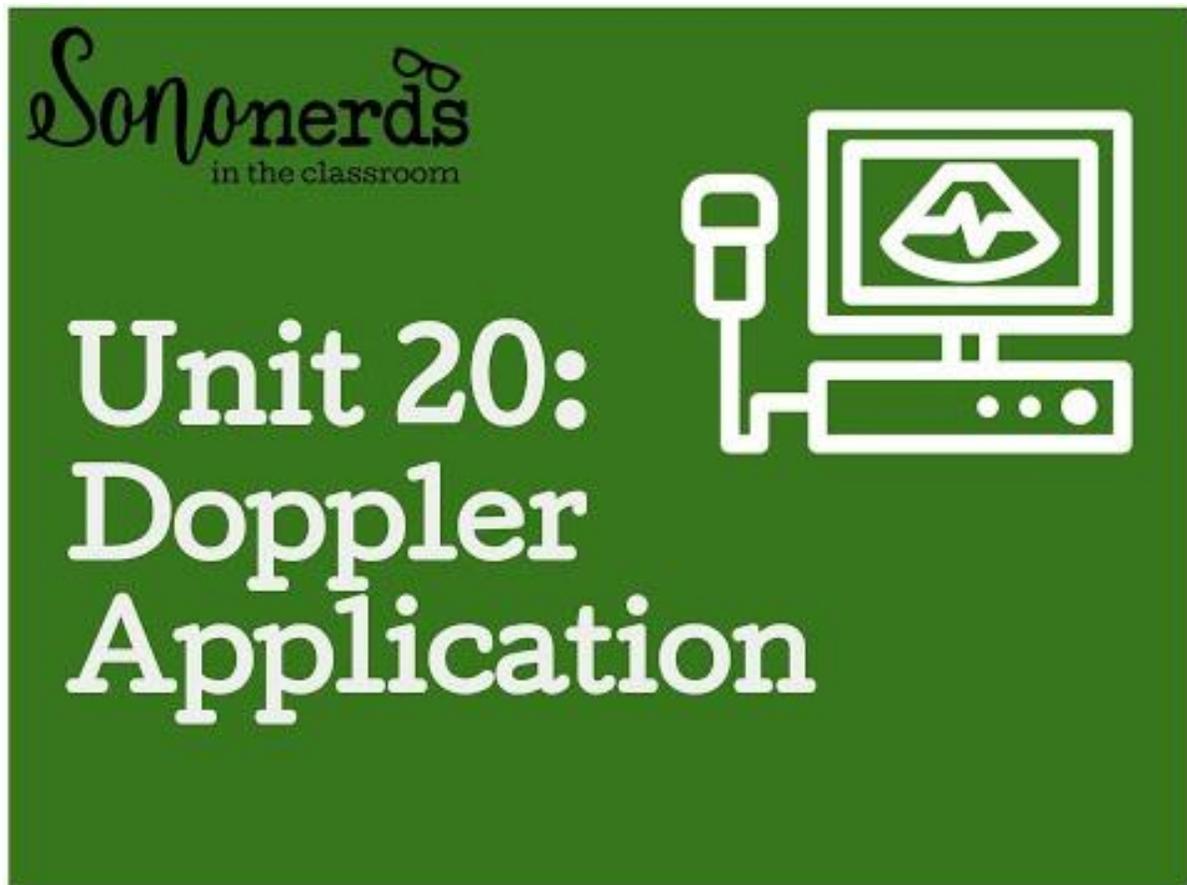
# Unit 20: Doppler Application

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# Unit 20: Doppler Application

Entire Unit 20 Lecture:



Did you know you can time jump to each section by using the “chapters” in the YouTube video playbar OR timestamps in the video description?

# Unit 20: Doppler Application

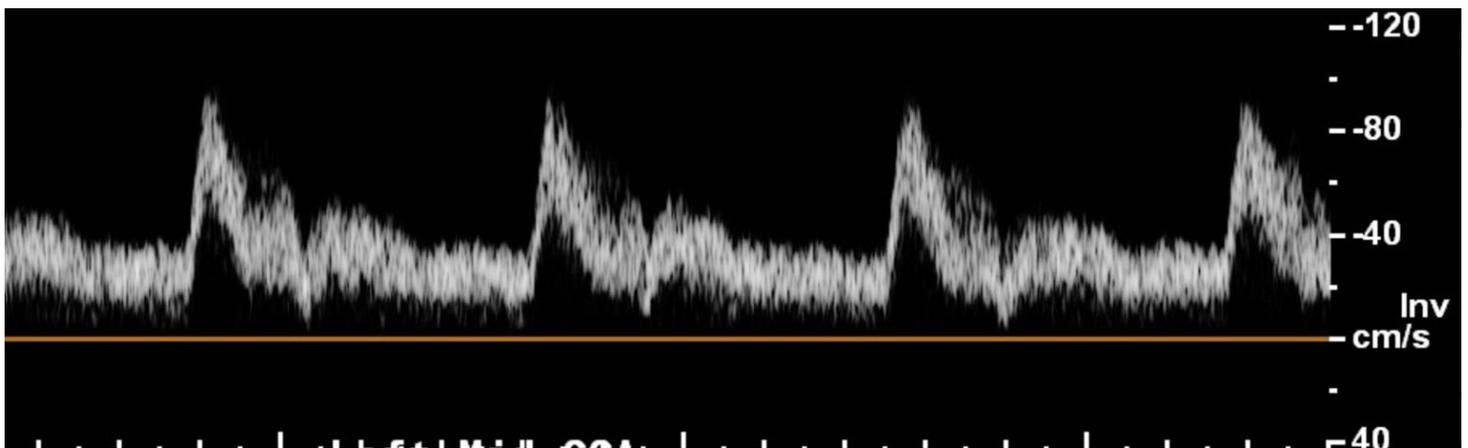
Now that we have a basic understanding of the physics and instrumentation behind Doppler ultrasound, this unit is going to focus on more of the clinical application of Doppler.

We will briefly look at what we can see in a waveform, how to identify color flow and direction in a vessel, and most importantly how to identify artifacts created by Doppler settings and how to fix them.

# Section 20.1 Spectral Tracing

The spectral tracing is the graph that appears on the bottom (or side) during duplex (triplex) imaging. The resulting graph will show echoes that are returning from the sample volume or gate. The echoes are reflections from red blood cells that have traveled through the gate and returned a frequency that is either more or less than what was emitted.

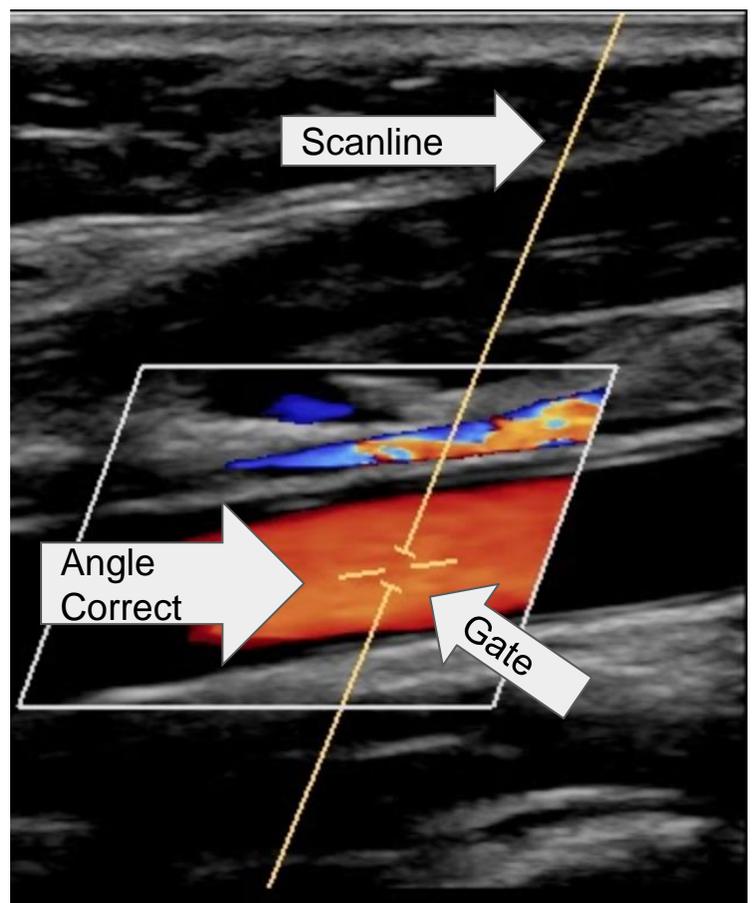
Through the fast fourier transform and calculating velocity, the machine can now display diagnostic information for the sonographer and clinician to analyze.



## 20.1.1 Placing the Gate

Recall that when the PW Doppler is activated, a scanline, gate and angle correct will appear on the screen.

The scanline and therefore the gate are mobile. This means that you can place the gate anywhere you would like. This is a HUGE advantage to PW Doppler.



When placing the gate, the gate should be placed where flow is the fastest. Knowing that vessel flow is parabolic, we typically place the gate in the center of the vessel.

You may want to observe the color that is visible and place the gate in other fast flowing areas. This will be especially true for cardiac application and stenotic vessels.

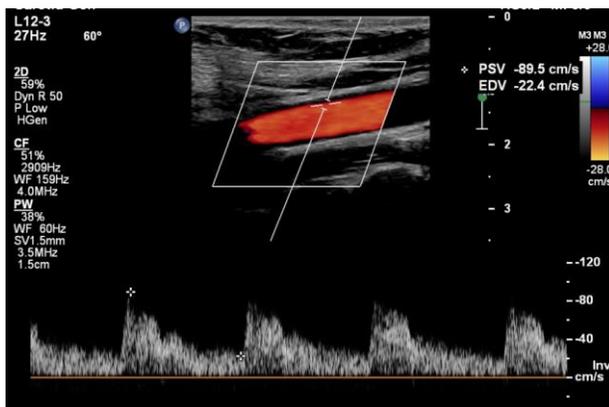
Once the gate is placed, determine the size of gate needed.

- **Small gates record fewer blood cell reflections, thus creating a thinner spectral tracing**
- **Large gates record many blood cell reflections and can make the spectral tracing fill in more due to more varying velocities.**

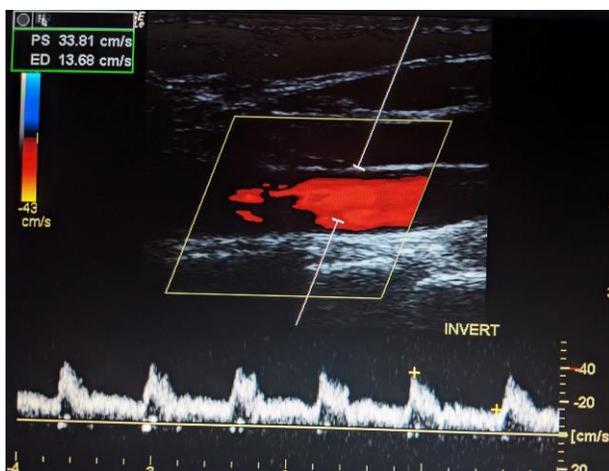
This gate is well placed. It is in the center of the flow. The gate is also small. The resulting spectral tracing shows similar velocities of blood flowing through the gate, creating a clean waveform.



Notice that the angle correct is placed **parallel** with the flow, telling the machine how blood is flowing in relation to the scanline.

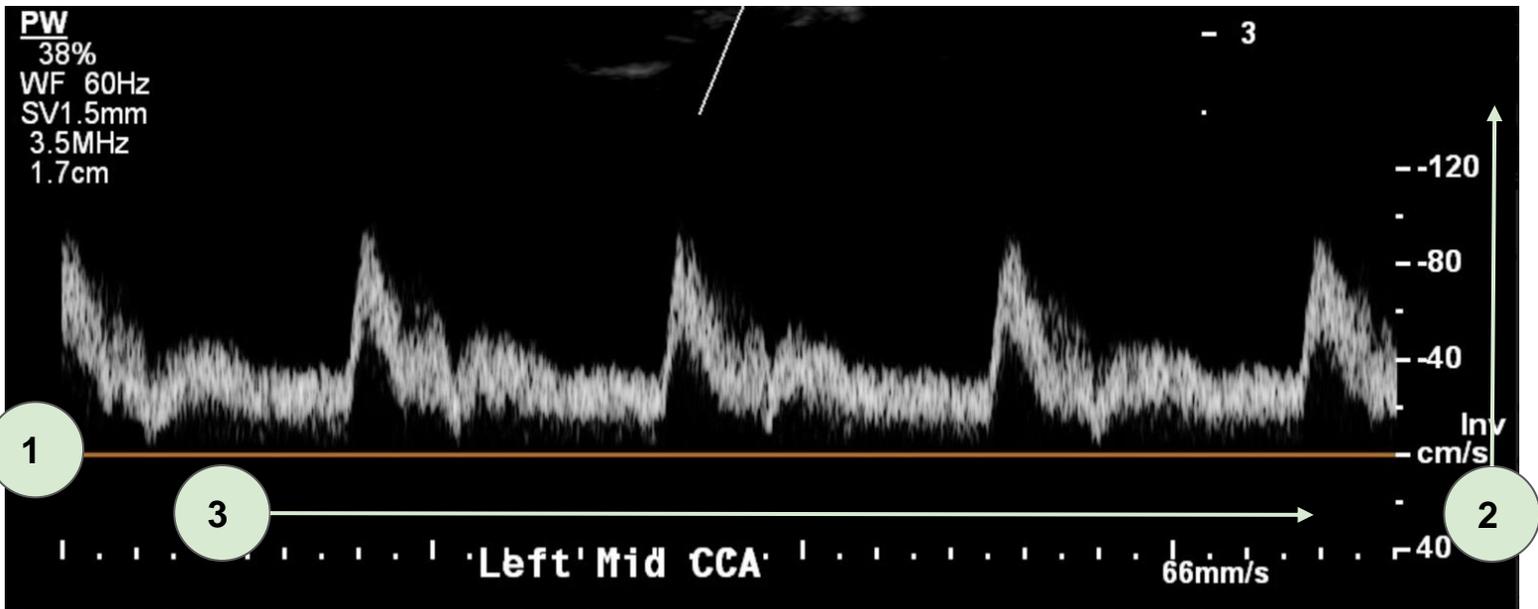


This gate has been placed near the edge of the vessel. The spectral tracing is now showing more variance in the velocities of red blood cells, thus there are more specks in the tracing near the baseline. This may mimic turbulent flow, but what it is really showing are the red blood cells that are flowing slower at the edge compared to the ones that are towards the center. A wide gate will show a similar waveform.



## 20.1.2 Spectral Waveform

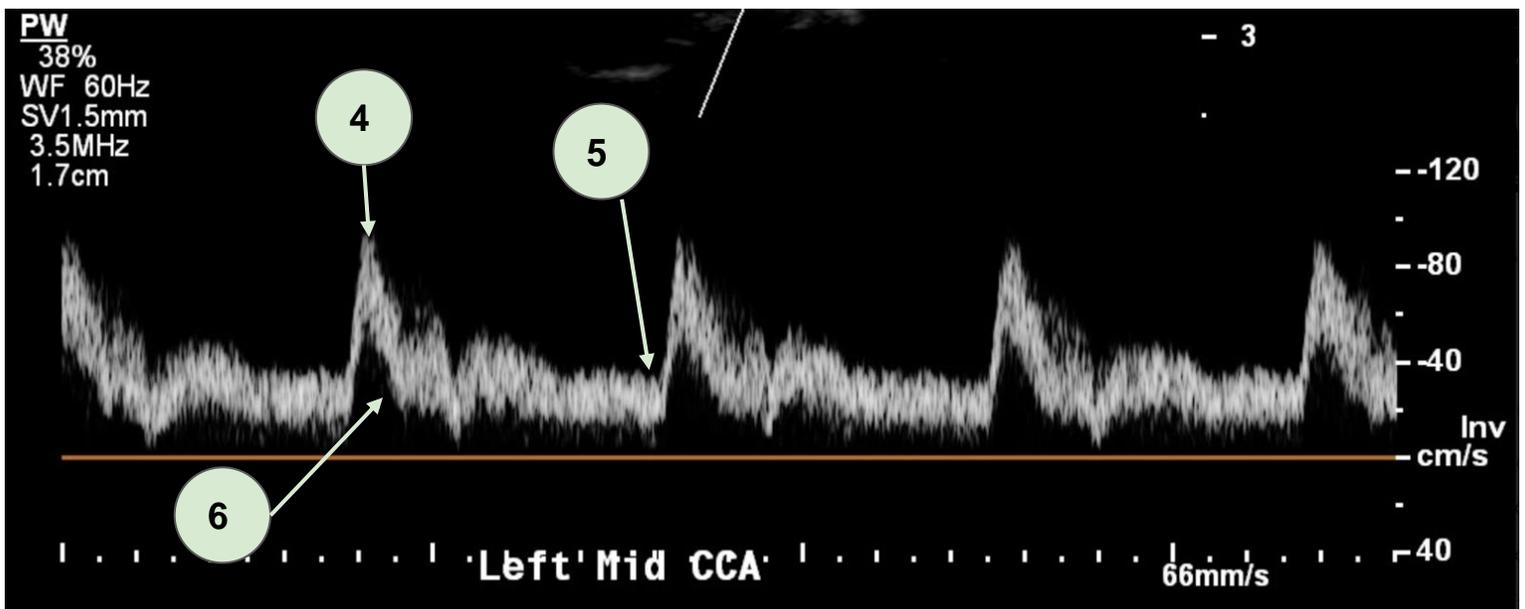
The spectral waveform has A LOT of information that it can tell us. We can get even more information when we use machine tools to measure different aspects of the spectral tracing. Deep analysis of the spectral waveform is more specific to cardiac and vascular technologies and not necessary for physics, but let's look at some of the basics, as we will need to know these terms when discussing artifacts later.



**#1 - Baseline** - The baseline is the 0 point on the scale. It demarcates the switch between positive and negative velocities. The baseline can be moved up and down with a knob.

**#2 - Y-Axis** - The Y-axis is the vertical portion of the graph. **This is where the velocity information is displayed.** This example uses cm/s, but some machines used m/s. Notice how this example has negative velocities displayed above the baseline and positive below. This can be inverted with a button to follow industry standards for displaying velocity information. **The scale of velocity is adjustable by changing the PRF of the Doppler scanline.**

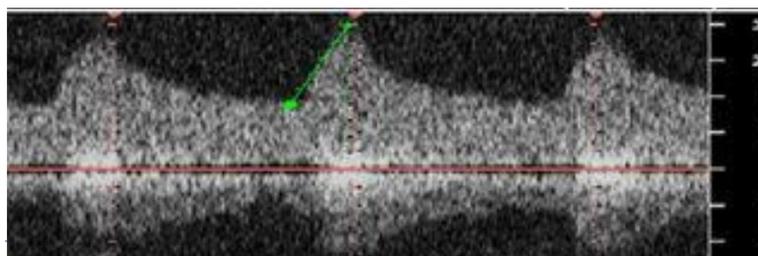
**#3 - X-Axis** - The X-axis is the horizontal portion of the graph. **Time is displayed on the X-axis.** As Doppler information is being recorded, the waveform will "scroll" or refresh, this is the blood flow over time through the gate. How fast the time goes by can also be adjusted through a knob called sweep speed.



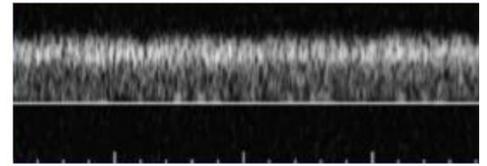
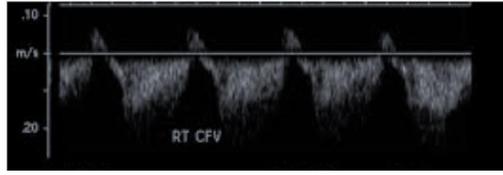
**#4 - Peak Systolic Velocity** - The peak systolic velocity (PSV) is the fastest velocity recorded on pulsatile waveform. The PSV corresponds with the ventricular contraction of the heart. When determining the scale for velocities, it is good practice that the PSV be just below the maximum velocity a scale can show. This will make it easier to measure.

**#5 - End Diastolic Velocity** - The end diastolic velocity (EDV) is the speed at which the blood cells are flowing during ventricular relaxation. It is typically measured right before the ventricle contracts again. Comparing PSV and EDV tells us about the organ that is receiving blood. If it has low resistance or high resistance.

**#6 - Spectral Window** - The spectral window is the area under the PSV. In **Laminar** flow, the spectral window is "open," there are no reflectors. The thin line in the spectral tracing represents blood cells that are flowing at similar velocities. In **turbulent** flow, the spectral window fills in because the red blood cells are flowing in multiple directions and speeds. The spectral window can falsely be filled in if we use incorrect Doppler settings.



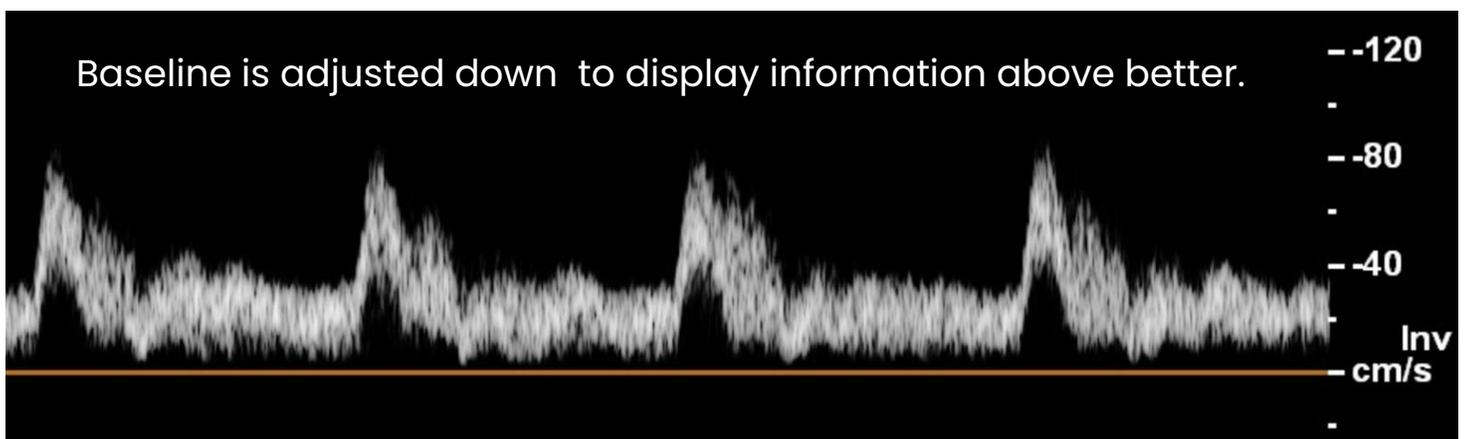
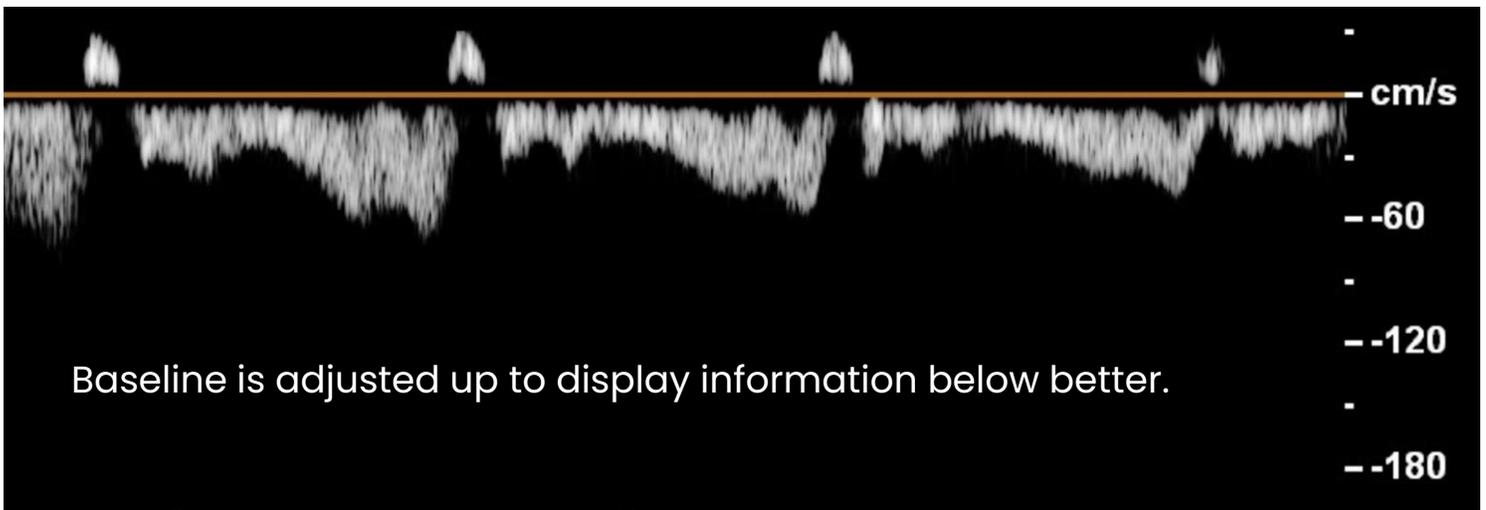
The waveform displayed can also tell us some more information about the type of flow being exhibited such as pulsatile, phasic or steady.



## 20.1.3 Doppler Controls

The PW Doppler application also has some controls that are specific to the spectral tracing. Knowing how these affect the spectral tracing will also help your clinical knowledge.

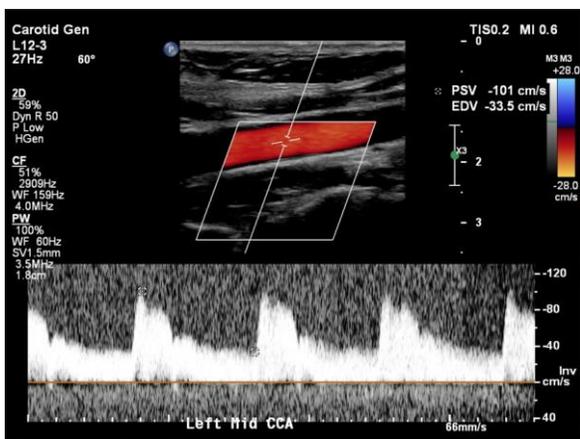
**Baseline** - The baseline is adjustable in the up or down position. This just changes how much of the scale can be displayed. Move the baseline so that side in which velocities are can be displayed appropriately.



**Gain** - The spectral tracing has its own gain. Echoes from closer blood cells tend to come back stronger, so they are displayed as brighter whites in the spectral tracing. Weaker echoes are displayed as less bright. If the waveform is too bright or too dark, the gain can be adjusted. **Gain will change all of the echoes returning.**

Changing the gain can also change the PSV or EDV values we measure. Too much gain can cause us to over measure velocities. Too little gain can cause us to under measure velocities.

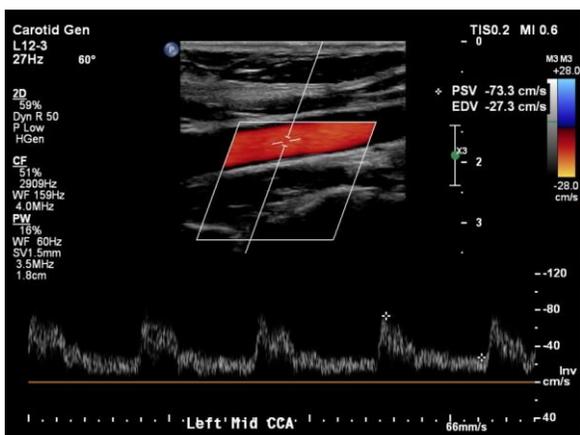
Best practice is to have the gain one "click" below the point where specks start to show in the background of the spectral tracing. It should be anechoic or near anechoic.



This gain is too high. The spectral window is filled in and the PSV measurement is over measured at 101 cm/s.



This gain is appropriate. The spectral window is open and the background is anechoic. The PSV is accurately measured at 94 cm/s.



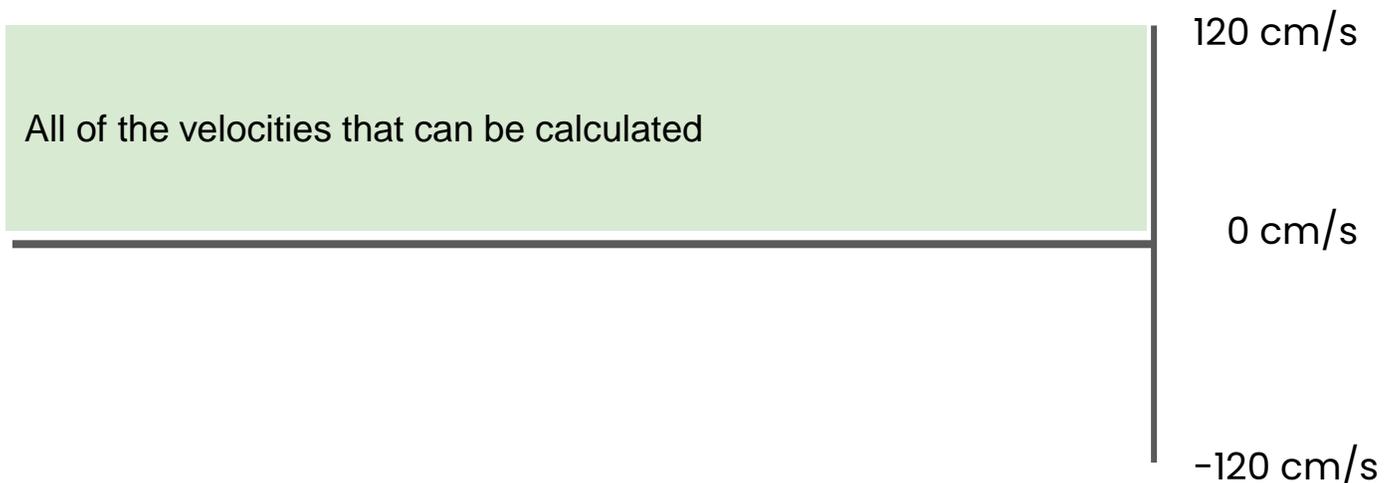
This gain is too low. The spectral window is open, but the tracing is difficult to see and the PSV is under measured at 73 cm/s.

**PRF / Scale** - The Y-axis shows us the velocity scale. **Remember that the frequency shift is measured and velocity is calculated.**

When a gate is placed at a certain depth, this will cause the machine to have a maximum PRP and PRF. This is self limited by having to place the gate in an area of flow and the fact that sound can only travel at 1540 m/s.

For example, middle of the vessel is 10 cm into the body. This tells us that in soft tissue the PRP is 130 microseconds ( $10 \times 13\mu\text{s}$ ). This means the PRF is 7700 Hz. ( $77,000 / 10 \text{ cm}$ ) The maximum Doppler shift that can be recorded is  $\frac{1}{2}$  the PRF, so the max Doppler shift in scenario that can be measured is 3,850 Hz or 3.85 kHz. (Don't worry about the math, just watch what happens)

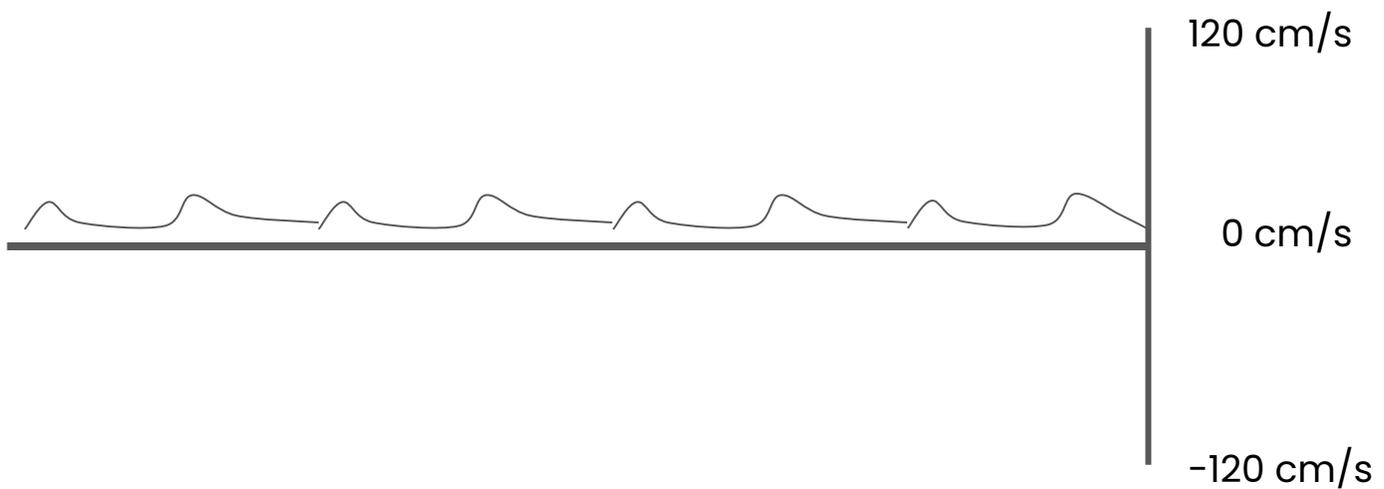
If we are using a 5 MHz transducer to get the Doppler information as described above at a 60 degree Doppler angle, the highest velocity that can be calculated is about 120 cm/s.



By maxing the PRF, we increase our scale to display the maximum velocities possible.

- **When you increase the PRF, you increase the scale.**
- **The PRF is limited by the depth and can only go so high.**

What happen though if your Doppler tracing is only reporting velocities around 30 cm/s?



You get a small spectral tracing. That is because the velocities reported are really only a small percentage of what the machine could display.

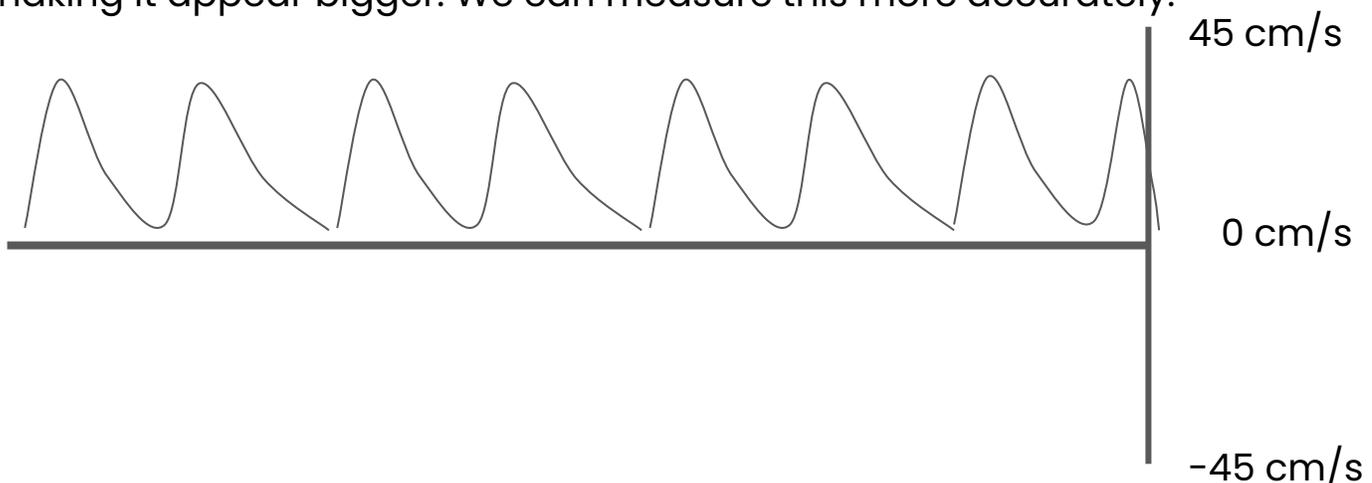
→ **If your waveform is too small, DECREASE the PRF**

When you decrease the PRF, the machine adds in time to the PRP so the machine won't send another pulse as quickly, this added time decreases the PRF.

Using all the same set up as the previous example our gate is still at 10 cm, and the PRP is 130 microseconds, PRF is 7,700 Hz. This is the FASTEST it will ever be.

BUT, we can decrease the PRF by adding in "dead time" to the PRP. The machine is still getting information from 10 cm depth, but now might add in an additional 65  $\mu$ s of dead time, making the PRP 195  $\mu$ s. This lowers the PRF to 5,133 Hz. Making the max Doppler shift measurable to 2567 Hz and max velocity recordable to about 45 cm/s.

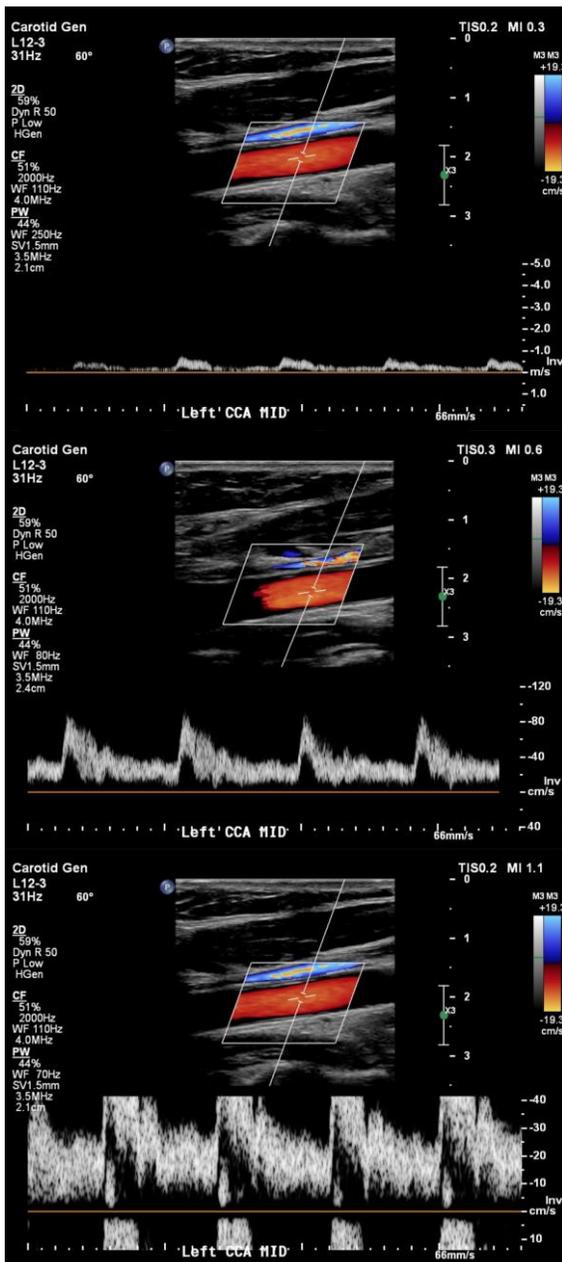
Now, our 30 cm/s waveform takes up a greater percentage of the area, making it appear bigger. We can measure this more accurately.



So that was a lot of math to come back to these principles around PRF/ Scale

- **PRF and Scale are synonyms**
- **Increasing PRF, increases the velocity scale**
- **Increasing PRF will make your waveform look smaller in relation to the scale**
- **Decreasing PRF, decreases the velocity scale**
- **Decreasing PRF will make your waveform look bigger in relation to the scale**
- **PRF & scale are finite – they have a maximum they can be increased to**

There will be a knob/button/slider to increase and decrease the scale. Adjust the scale so the spectral tracing fits nicely into the window.



PRF is set too high. The max velocity this depth and transducer can record is 500 cm/s

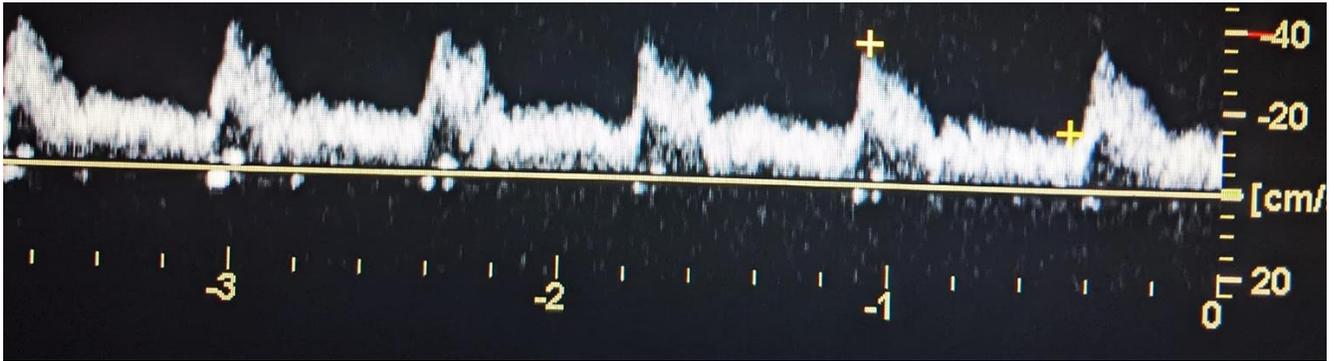
The PRF has been lowered with a max velocity at 120 cm/s. The same waveform as above now looks bigger because the velocity scale is smaller. This fills the window nicely and will be easy to accurately measure.

The PRF has been lowered even more The same waveform as above now looks even bigger, really even too big to be displayed accurately now that the max velocity is 40 cm/s.

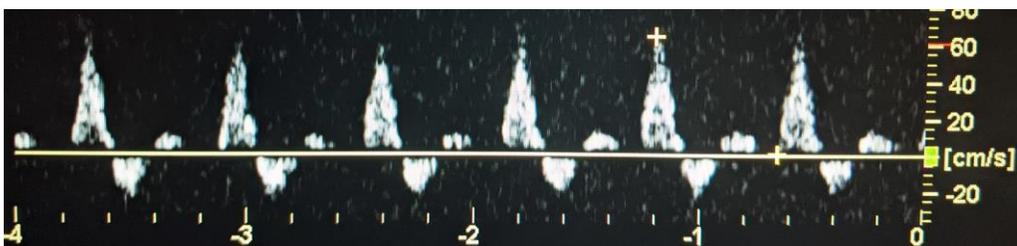
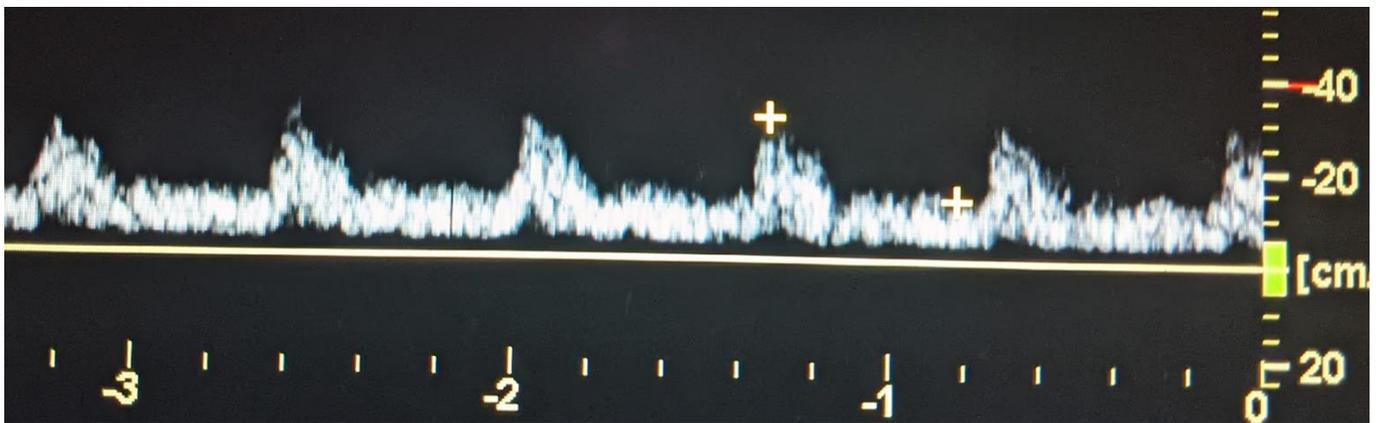
**Wall Filter** - The wall filter is another knob on the machine that can be adjusted to get rid of slower velocities. The velocities still exist, but they are not being displayed in the spectral tracing.

→ **The wall filter is also known as the hi-pass filter.**

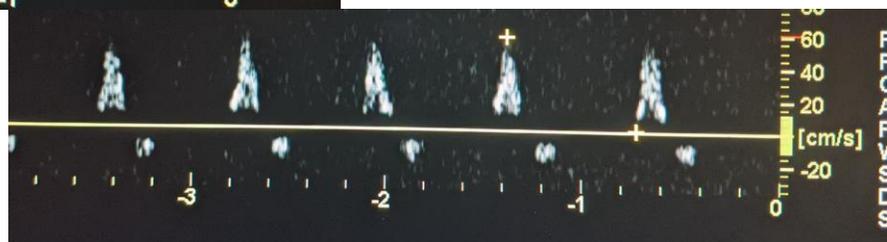
When the wall filter is turned down or off, more slow velocities are displayed in the spectral tracing.



When the wall filter is increased, less slow velocities are displayed in the spectral tracing. This makes the waveform look like it is floating. Be careful to not adjust the wall filter so high that it gets rid of important information like the EDV or small velocity changes.



Increased wall filter too much!



# Section 20.2 Optimizing Spectral Tracing

When discussing the controls that can be used for spectral tracing, I showed you some examples of too high gain vs. too low gain, high PRF vs. low PRF, no wall filter vs. high wall filter.

With PW Doppler spectral tracings, we're always looking for those "just right" settings to create a diagnostic image. One of the biggest challenges we face is how to correct for certain artifacts, especially aliasing.

## 20.2.1 Aliasing

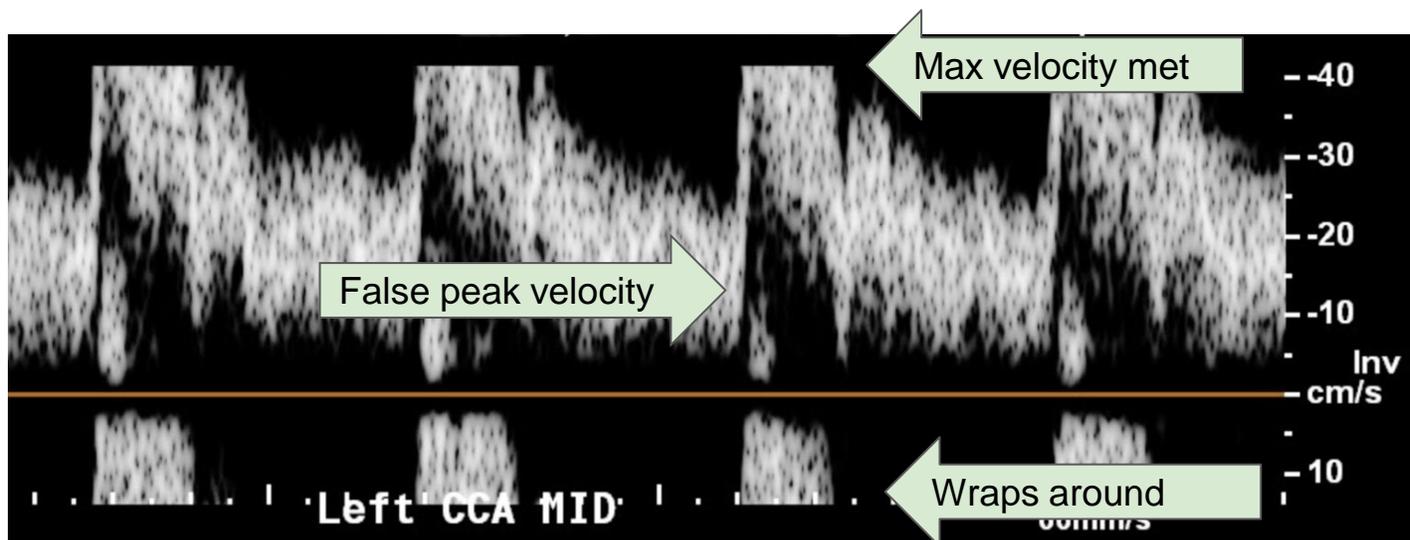
Artifacts occur when ultrasound displays don't match what is truly occurring the body, be it anatomy or velocity displays.

→ **Aliasing is an artifact that causes high velocities to be displayed incorrectly when using Doppler.**

One of the main disadvantages of PW Doppler is that it is not able to accurately detect and display high velocities.

This is due to the PRP and PRF that are inherent to pulsed wave ultrasound.

Recall that when we were talking about PRF & Scale that there is a maximum Doppler shift that could be detected based on the depth of the gate. If there is a maximum Doppler shift, this also means there is a maximum velocity that the machine can calculate accurately. If the velocity (or Doppler shift) exceeds the maximum as determined by the settings, the waveform will wrap around.



Aliasing officially occurs when the Doppler shift exceeds the Nyquist limit. The Nyquist Limit will then also limit the velocities that can be displayed.

The Nyquist limit determines the velocity that is at the top (or bottom) of our graph and is calculated:

$$\text{Nyquist Limit (kHz)} = \frac{\text{PRF (kHz)}}{2}$$

Anything that affects the PRF will then affect the Nyquist limit. Recall when we were discussing increasing or decreasing the PRF. These actions change the Nyquist limit, which changes how the waveform is displayed.

PRF is limited by the depth of the gate (PRP) and propagation speed.

This was the example I used from earlier:

For example, middle of the vessel is 10 cm into the body. This tells us that in soft tissue the PRP is 130 microseconds ( $10 \times 13\mu\text{s}$ ). This means the PRF is 7700 Hz. ( $77,000 / 10 \text{ cm}$ ) The maximum Doppler shift that can be recorded is  $\frac{1}{2}$  the PRF, so the max Doppler shift in scenario that can be measured is 3,850 Hz or 3.85 kHz.

This highlighted portion is the Nyquist limit! We calculated the PRF based on the gate depth and then divided that by 2 to get the Nyquist limit, which is the maximum Doppler shift based on the depth of the gate.

Here are two more examples:

**Depth of Gate = 2 cm**

$$\text{PRP} = 26 \mu\text{s} \quad (2 \text{ cm} \times 13\mu\text{s})$$

$$\text{PRF} = 38.5 \text{ kHz} \quad (77,000 \frac{\text{cm}}{\text{s}} \div 2 \text{ cm} = 38,500 \text{ Hz})$$

$$\text{NL} = 19.25 \text{ kHz} \quad \left(\frac{38.5 \text{ kHz}}{2}\right)$$

**Depth of Gate = 4 cm**

$$\text{PRP} = 52 \mu\text{s} \quad (4 \text{ cm} \times 13\mu\text{s})$$

$$\text{PRF} = 19.25 \text{ kHz} \quad (77,000 \frac{\text{cm}}{\text{s}} \div 4 \text{ cm} = 19,250 \text{ Hz})$$

$$\text{NL} = 9.625 \text{ kHz} \quad \left(\frac{19.25 \text{ kHz}}{2}\right)$$

To know what the max velocity is, we would need to know the Nyquist limit and more information such as transducer frequency and Doppler angle.

Let's use the last examples with a 3 MHz transducer & 60° Doppler angle (this gives us a cosine of theta value of 0.5).

**Depth of Gate = 4 cm**

**PRP = 52  $\mu$ s** (4 cm  $\times$  13 $\mu$ s)

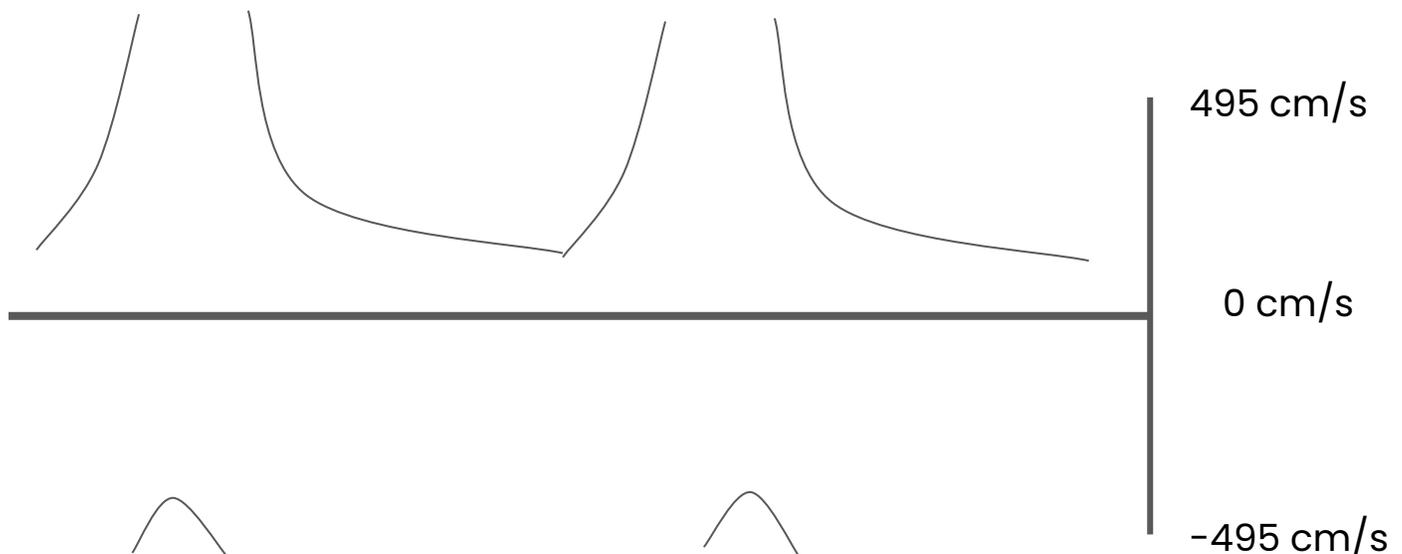
**PRF = 19.25 kHz** ( $77,000 \frac{cm}{s} \div 4 \text{ cm} = 19,250 \text{ Hz}$ )

**NL = 9.625 kHz** ( $\frac{19.25 \text{ kHz}}{2}$ )

**Max Velocity = 495 cm/s** ( $\frac{154000 \frac{cm}{s} \times 9.625 \text{ kHz}}{2 \times 3000 \text{ kHz} \times 0.5}$ )

By using the max Doppler shift and the velocity formula, we can calculate that the highest velocity this setup can display is 485 cm/s. If the velocity exceeds 495 cm/s or the Doppler shift excess 9.625 kHz, then aliasing will occur.

If the velocity of blood is 550 cm/s, it might look something like this:



If the Nyquist limit determines the max velocities and Doppler shifts, then we need to know what can affect the Nyquist limit so we can keep our waveforms from aliasing. .

Looking back at a few of our formulas from this semester we can draw some conclusions about relationships : Note that the max Doppler shift is the Nyquist limit.

$$PRP \times PRF = 1$$

If gate depth increases, then PRP increases and PRF decreases. This causes the NL to decrease.

→ **Increasing gate depth increases the likelihood of aliasing.**

$$PRP(\mu s) = 13 \mu s \times depth (cm)$$

$$PRF(hz) = \frac{77,000 \text{ cm/s}}{depth (cm)}$$

If PRF decreases, the NL decreases, and the max Doppler shift decreases, this causes the max velocity to decrease.

→ **Decreasing PRF increases the likelihood of aliasing.**

$$f_D(kHz) = \frac{2 \times f_0(kHz) \times v \left(\frac{cm}{s}\right) \times \cos\theta}{c \left(\frac{cm}{s}\right)}$$

If we increase the transducer frequency, that will increase the Doppler shift.

→ **Increasing the transducer frequency increases the likelihood of aliasing.**

$$Max v \left(\frac{cm}{s}\right) = \frac{c \left(\frac{cm}{s}\right) \times Max f_D(kHz)}{2 \times f_0(kHz) \times \cos\theta}$$

If we know what is more likely to cause aliasing, we can do the opposite to correct it.

$$Nyquist \text{ Limit } (kHz) = \frac{PRF (kHz)}{2}$$

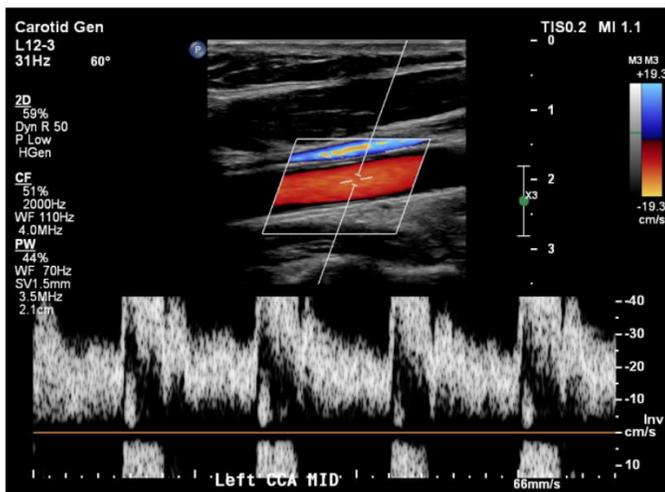
## 20.2.2 Correcting for Aliasing

There are 5 ways in which we can eliminate aliasing if we see it in our spectral tracing:

1. Increase the scale
2. Decrease the depth of the sample
3. Use a lower frequency
4. Move the baseline
5. Switch to continuous wave Doppler

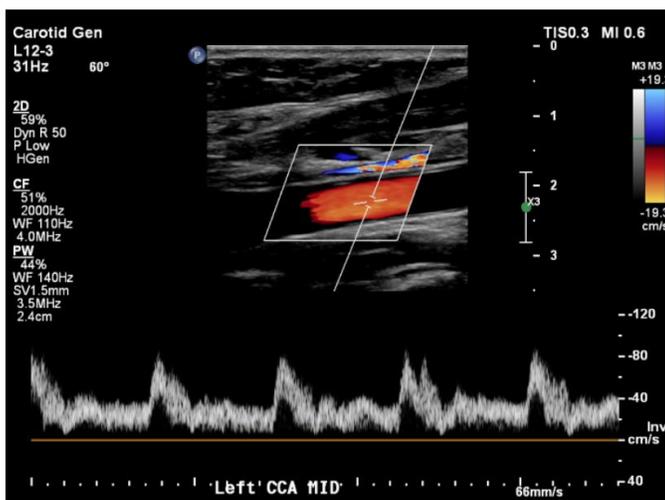
### 1. Increase the scale

When PW Doppler is activated, the Doppler shift that returns may be higher than the Nyquist limit and current PRF allow. If you can, increase the PRF by increasing the scale. When you increase the scale, you increase the PRF, which increases the Nyquist limit.



In this example, the scale was originally set at 40 cm/s.

The scale was increased to 120 cm/s to resolve the aliasing.



**If you increase the PRF or scale to its maximum, and aliasing is still occurring, then another technique is needed.**

## 2. Decrease the sample depth

When the sample gate is used in a particular window, it may be placed very deep within the body. This decreases the PRF, which will decrease the Nyquist limit. If the sonographer is experiencing aliasing in this window, they can try a new window that will allow them to move the sample gate to a shallower position. By moving the gate shallower, the PRF will increase, which increases the Nyquist limit.

## 3. Use a Lower Frequency Transducer

Frequency is directly related to Doppler shift. High frequency transducers have larger Doppler shifts. The larger the Doppler shift, the more likely it will alias. The sonographer should try switching to a lower frequency transducer to decrease the Doppler shift, thus staying below the Nyquist limit. Remember the Nyquist limit is based on the depth of the gate and the PRF. The velocities will respond more to a lower frequency. There is very little trade off, but some resolution is lost with a low frequency transducer.

A little math to show this concept:

**Gate Depth = 3 cm**

**Nyquist Limit = 12.8 kHz**

### Transducer #1

12 MHz, blood is flowing at 150 cm/s with a 0° Doppler angle.

Doppler Shift for Transducer #1 = 23.4 kHz ← This will alias, it is more than NL

### Transducer #2

4 MHz, blood is flowing at 150 cm/s with a 0° Doppler angle.

Doppler Shift for Transducer #2 = 7.8 kHz ← This will NOT alias, it is less than NL

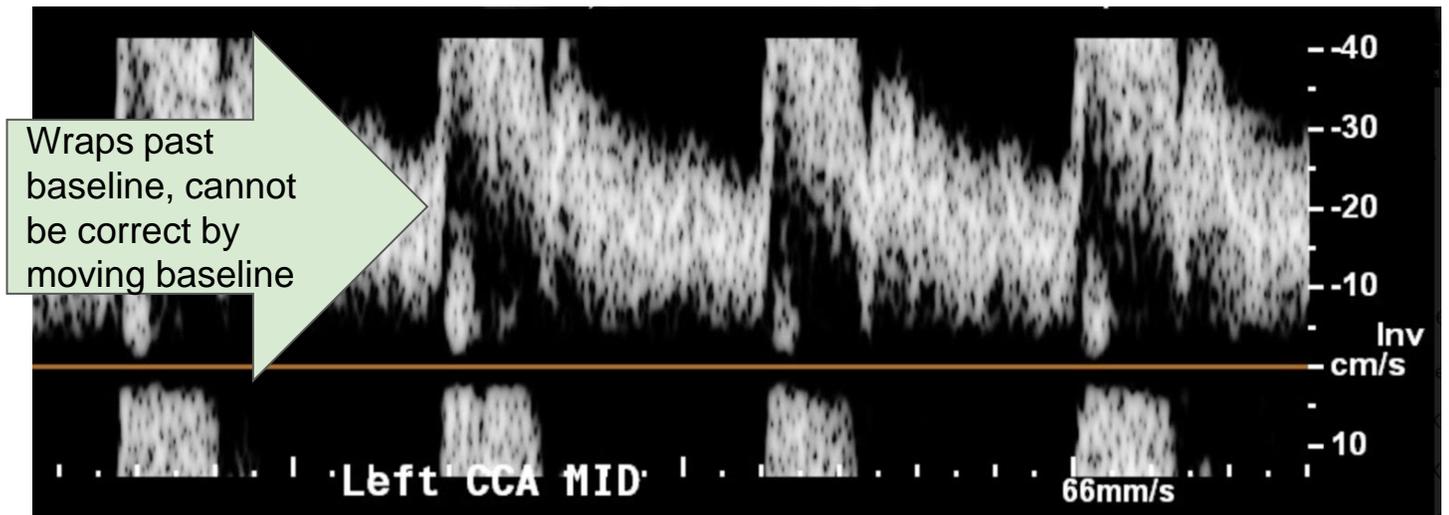
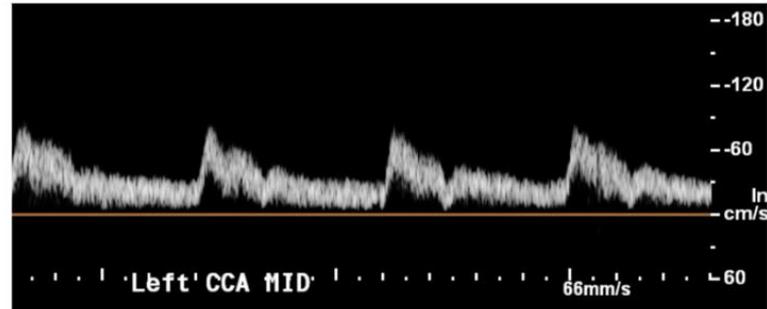
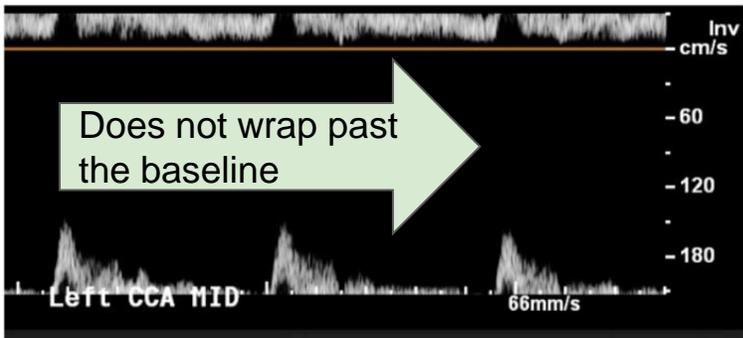
Doppler shift values were calculated using the Doppler Equation:

$$f_D(\text{kHz}) = \frac{2 \times f_0(\text{kHz}) \times v \left(\frac{\text{cm}}{\text{s}}\right) \times \cos\theta}{c \left(\frac{\text{cm}}{\text{s}}\right)}$$

## 4. Move the Baseline

The baseline is the zero point for away and toward flow. The baseline is adjustable to allow a large window on either side of it.

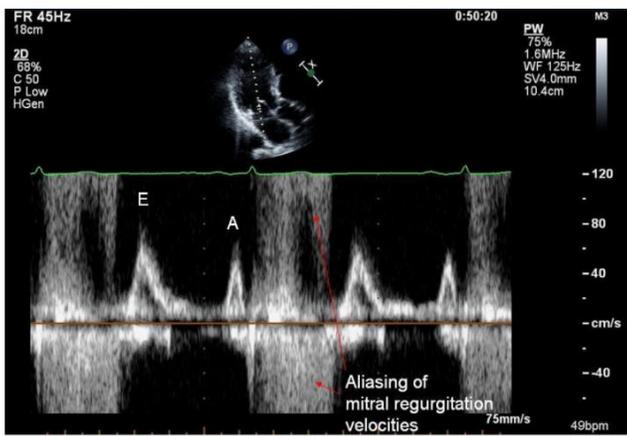
This will not help if the waveform wraps all the way around itself and crosses the baseline.



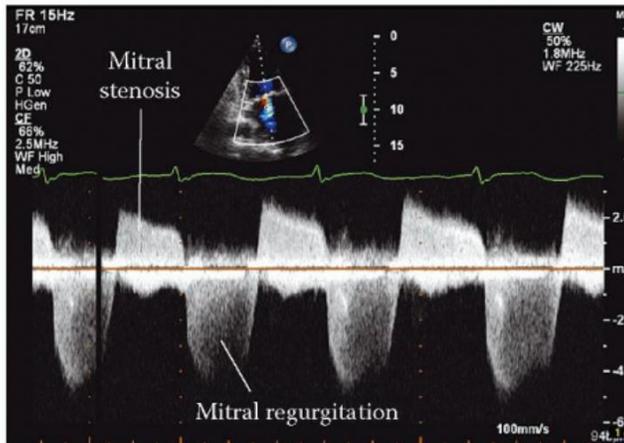
## 5. Switch to Continuous Wave Doppler

**Aliasing can only occur with PW Doppler.** When all else fails and aliasing is still occurring CW Doppler is an option. If the sonographer has the option to switch to continuous wave, they should. The disadvantage is that they can no longer choose where the sample is coming from exactly, but should be able to get better diagnostic information regardless.

Many general and vascular application don't allow the transition to CW Doppler, but cardiac imaging does and used quite often. This should not be confused with high PRF or HPRF. HPRF uses a combination of PW & CW to be able to achieve higher velocities.



Aliasing occurring at the mitral valve with PW Doppler.



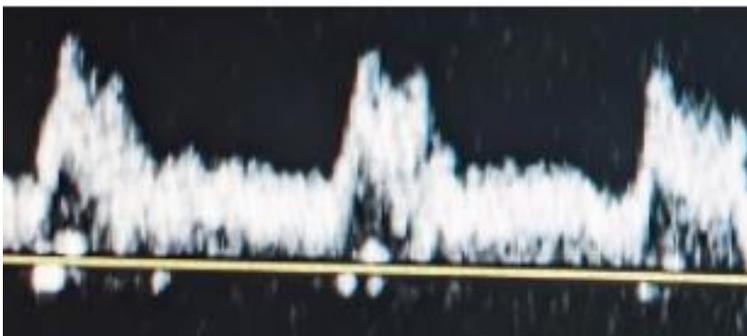
Switched to CW Doppler and now the peak velocities are easily measured.

## 20.2.3 Other Spectral Doppler Artifacts

There are other spectral Doppler artifacts that can be corrected with machine settings.

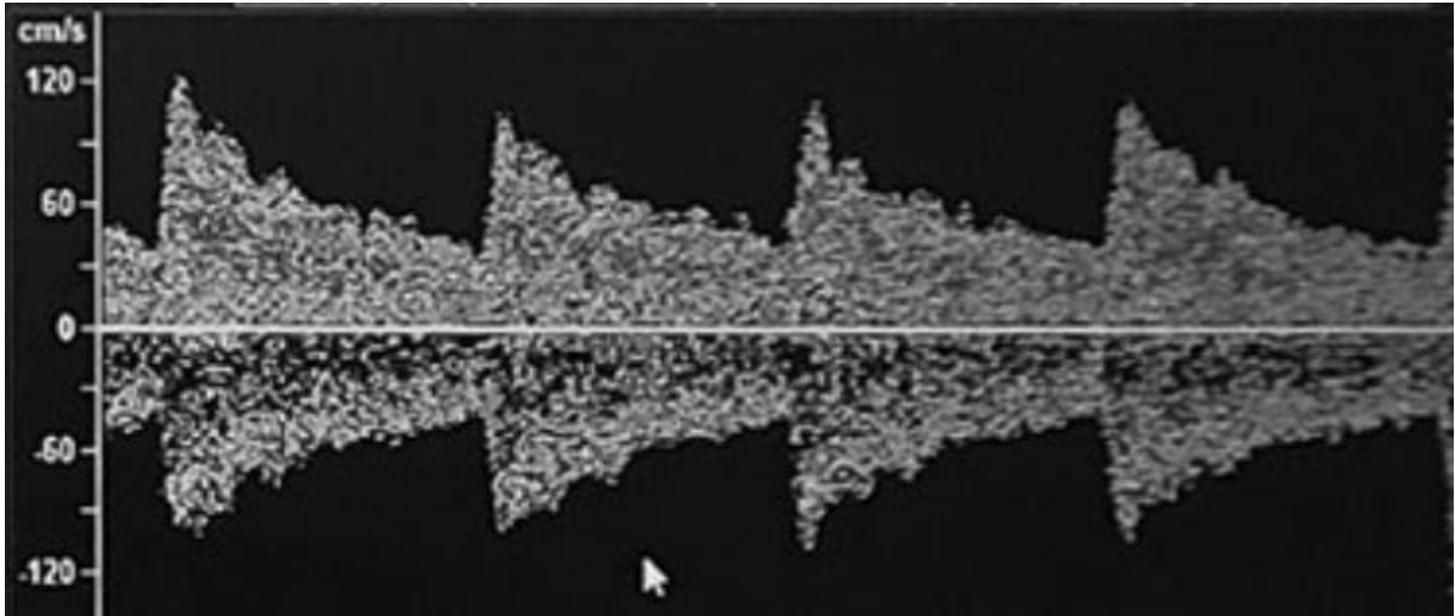
### Clutter

Clutter artifact and thump artifact comes from small movements in the body (like the heart muscle or pulsating vessel) that are displayed as low level Doppler shifts. The wall filter is adjustable by the sonographer. It is important to not adjust the wall filter to the point that it affects the real, diagnostic information. This image shows the sonographer increasing the wall filter. You can see the signal close to the baseline disappears.



## Crosstalk

Crosstalk is a special type of mirror image artifact. It artificially shows the spectral tracing on both sides of the baseline. This is typically due to the PW gain set too high or the vessel is sitting within the focus of the beam and the beam is about 90° to the vessel.



Remember to use the rest of the spectral tools to optimize the images. At the end of this unit will be some quick reference guides to help make optimization decisions regarding PW, CW & Color Doppler.

# Section 20.3 Color Doppler Display

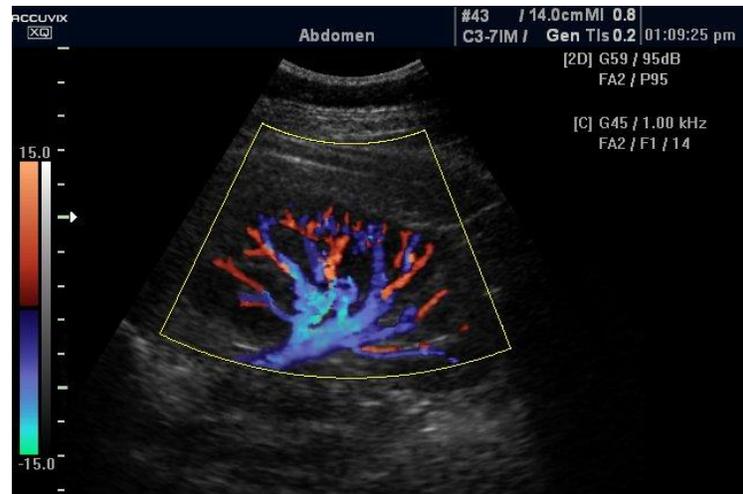
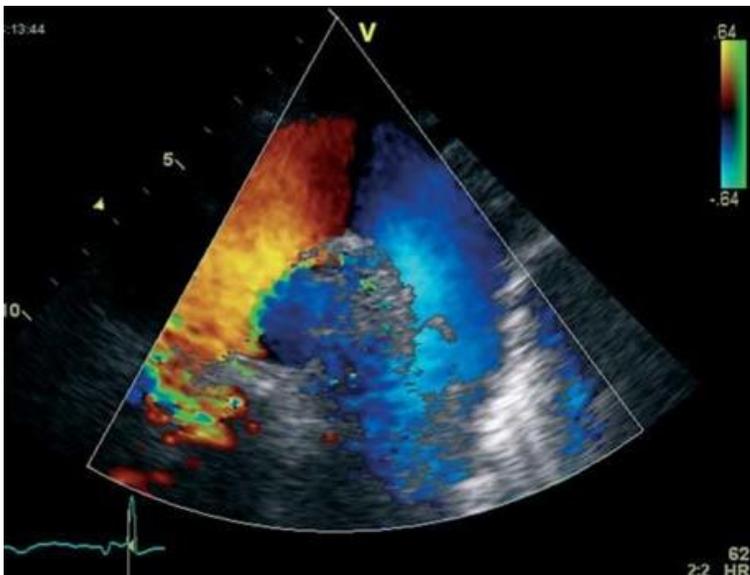
Color Doppler is a type of pulsed wave Doppler, so we will see a lot of overlap in the terminology and issues that can arise. Let's look first at what color Doppler can tell us and then how to improve it.

Remember that you DO NOT need to know anatomy for your physics boards. You will be tested on your ability to recognize how the display reflects what is happening in the body. Is blood flowing towards or away from the screen? From left to right? Right to left? Knowing what the vessel is or what normal flow is won't be helpful for the SPI.

## 20.3.1 Placing the Color Box

After activating color Doppler, a color box will appear on the screen.

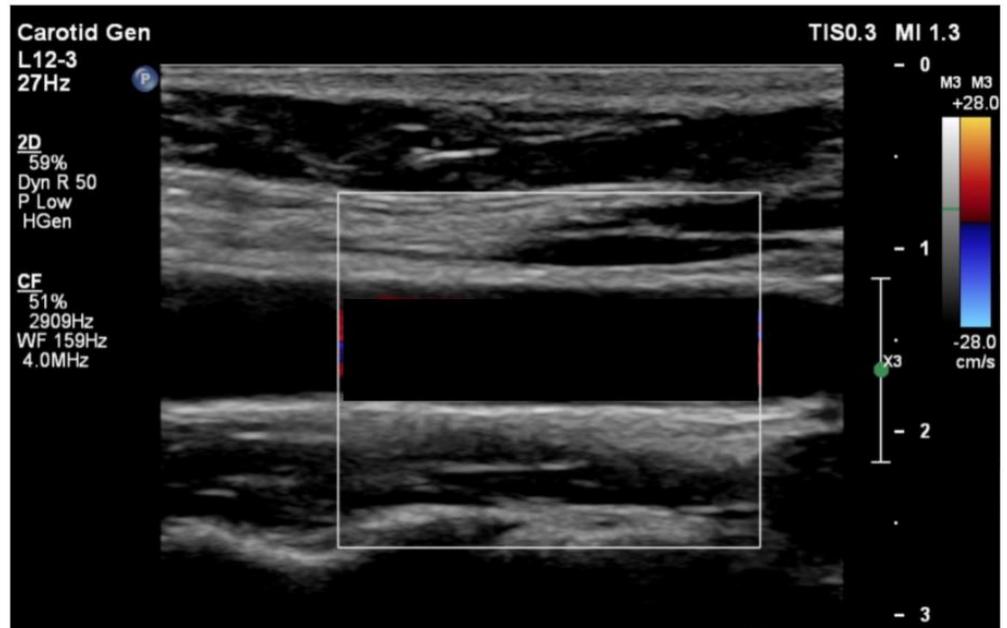
For sector transducers, the color box resembles the shape of the sector.



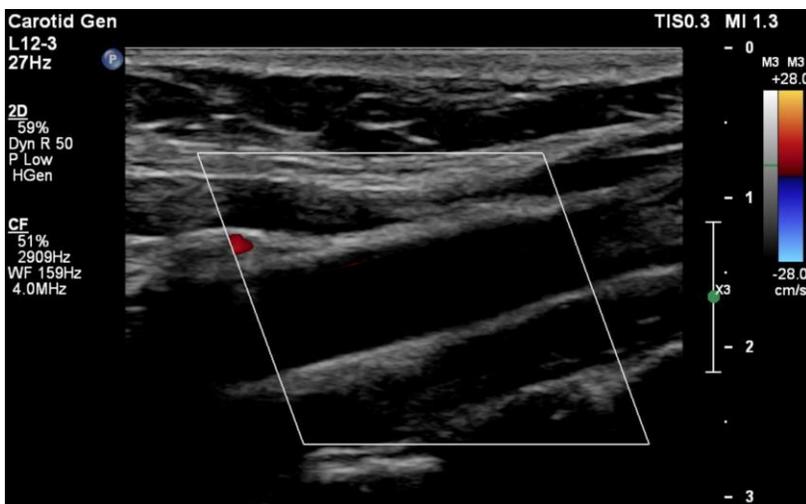
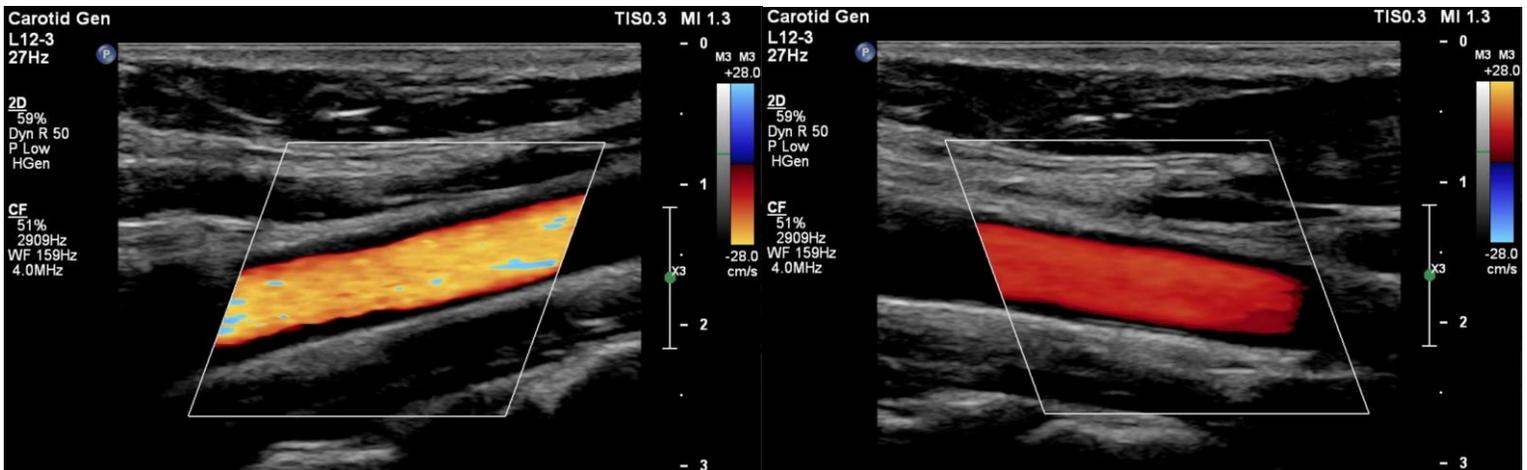
The sonographer can adjust the size and location of the color box.

- **Wider color boxes use more scan lines, which decreases the frame rate.**
- **Deep color boxes increases the PRP, which decreases the PRF and can be cause for aliasing.**

For linear transducers, the sonographer must take care to angle the box or the vessel to ensure there is NOT a 90° Doppler angle.



The box and vessel should have at least some angle so better color Doppler information can be obtained. Even with angling, if the lines are perpendicular, a Doppler shift cannot be detected.



There is knob that will steer the box in different directions. Steering the box with the vessel will bring the Doppler angle closer to 0 degrees and provide the best color fill for the area.

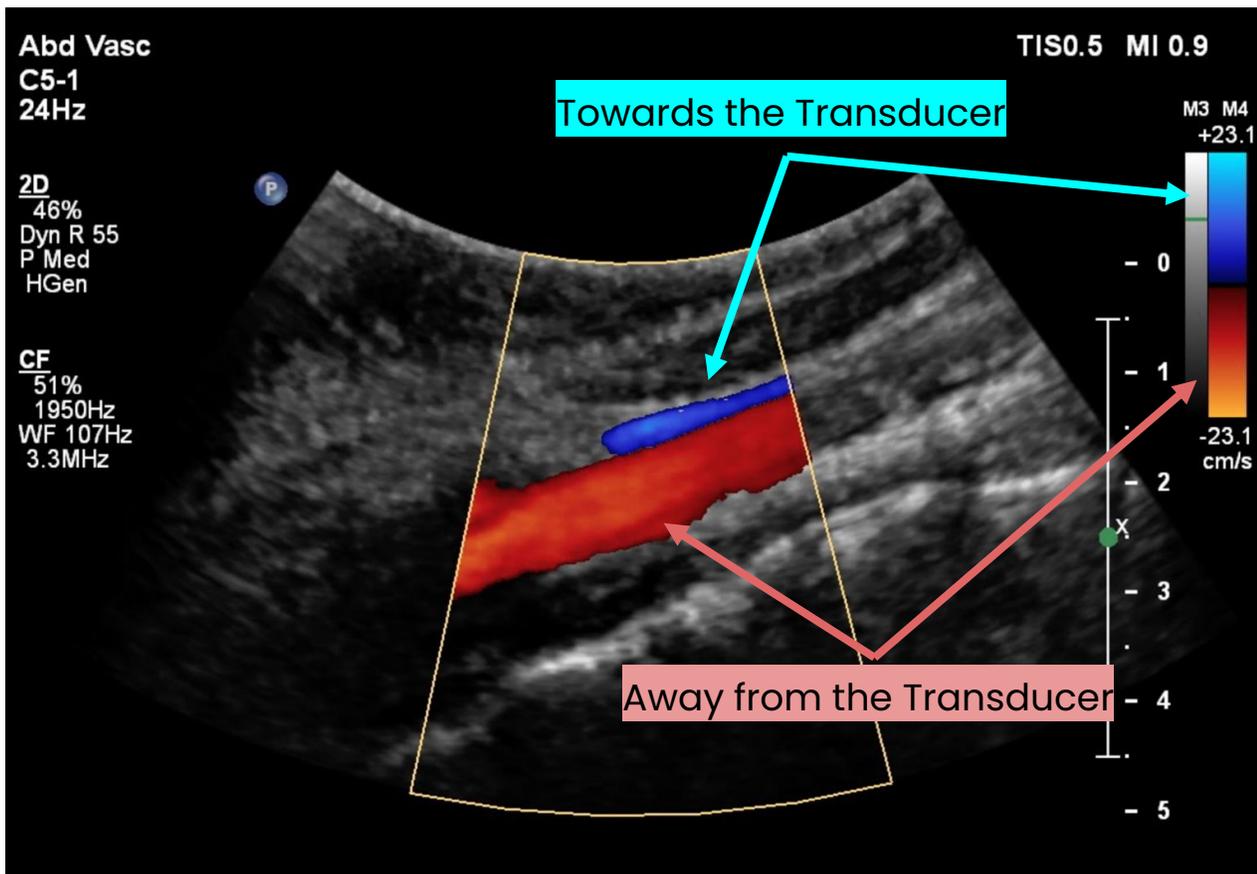
Remember that 90 degrees is also called normal incidence when referring to how the scanlines for the color box interact with the blood vessel.

Normal incidence is good for 2D imaging - not diagnostic for Doppler imaging.

## 20.3.2 Color Display and Transducer Orientation

When you look at an image, you should be able to recognize the color map and then apply the knowledge that:

- **Top color indicates flow towards the transducer.**
- **Bottom color indicates flow away from the transducer.**



Spend a moment with these images, making sure that this concept comes easily. Note that it does not matter what color is where. The color map can be flipped with a press of a button.

→ If no map is present, then you cannot tell direction of flow.

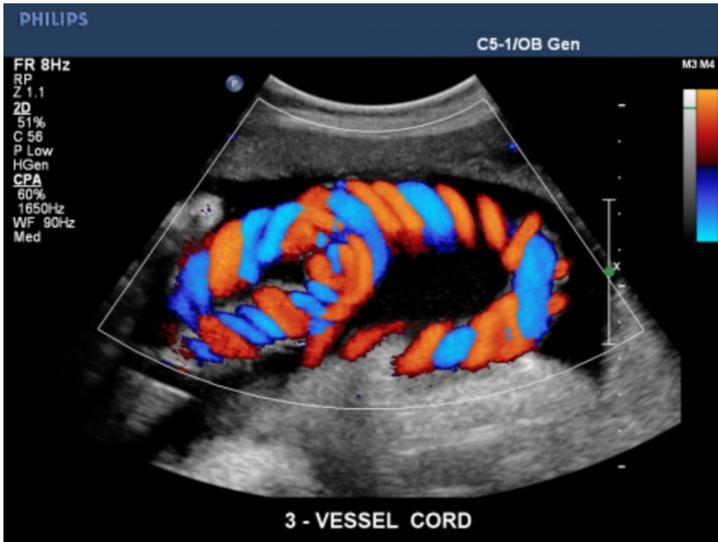
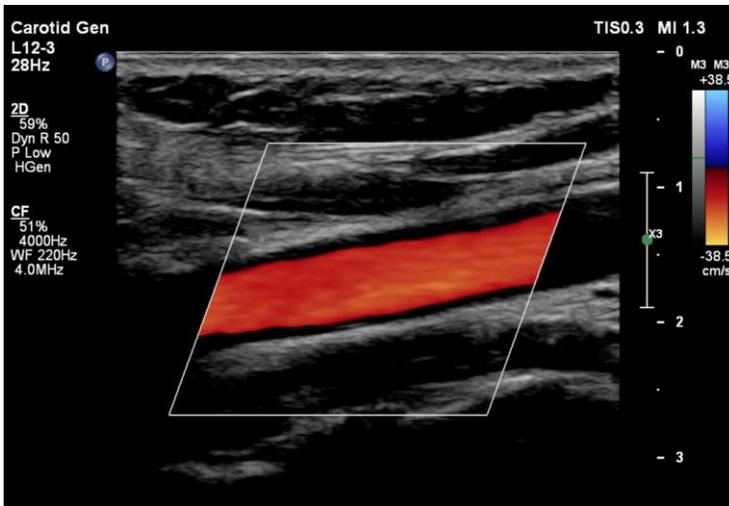
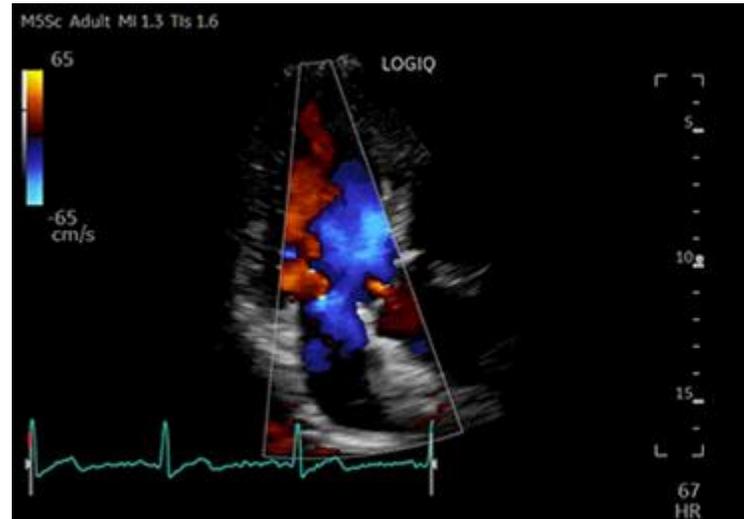
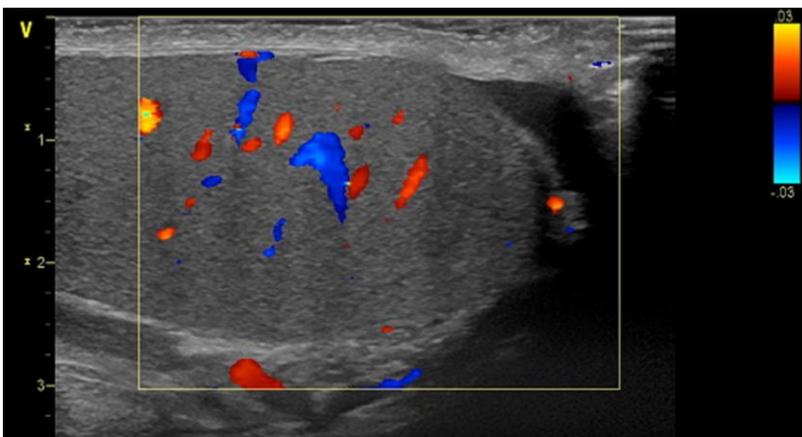


Image from GE Healthcare Image Library

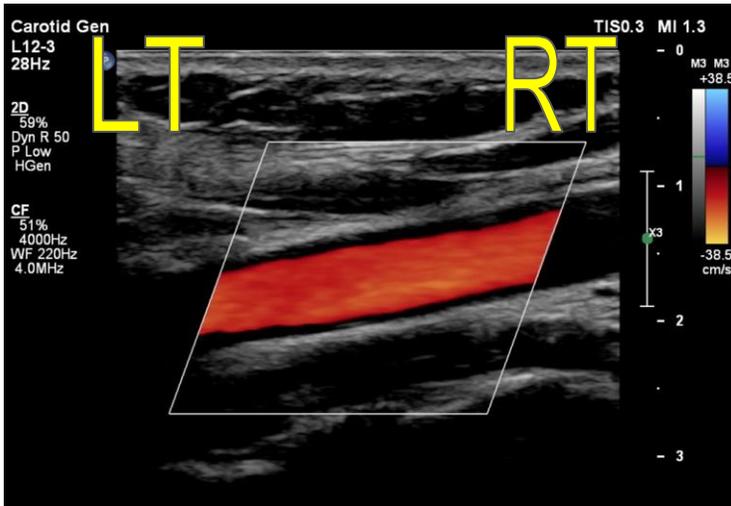


Look at this image. Can you tell if the blood is flowing from right to left or left to right?



## 20.3.3 Direction of Flow

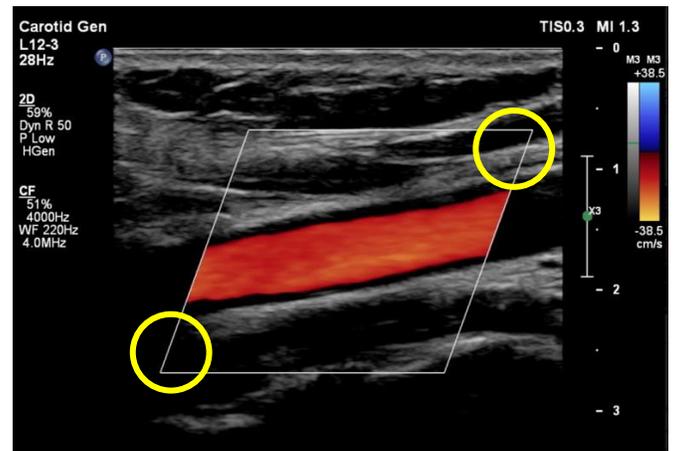
Another skill a sonographer preparing to take the SPI should have is recognizing the direction of flow. Since you do not need to know anatomy, do not assume anything based on what anatomy you think is presented. Only use the color map to make your decision.



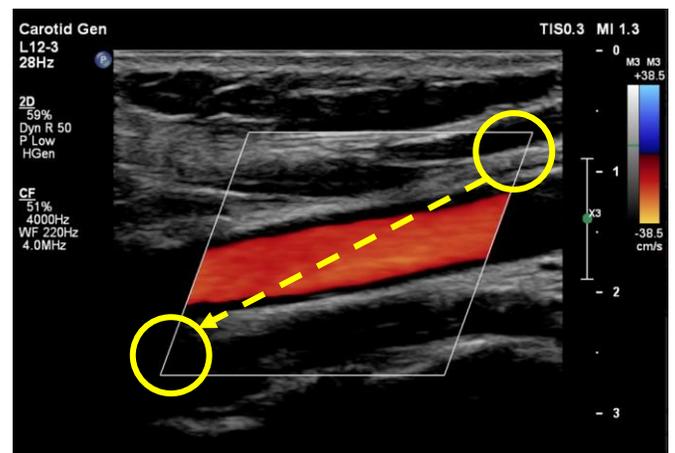
This image was from the last page.

The blood flow in this image is Right to Left

When determining blood flow form linear images, follow these steps:



**Red = Down**



**Right to Left**

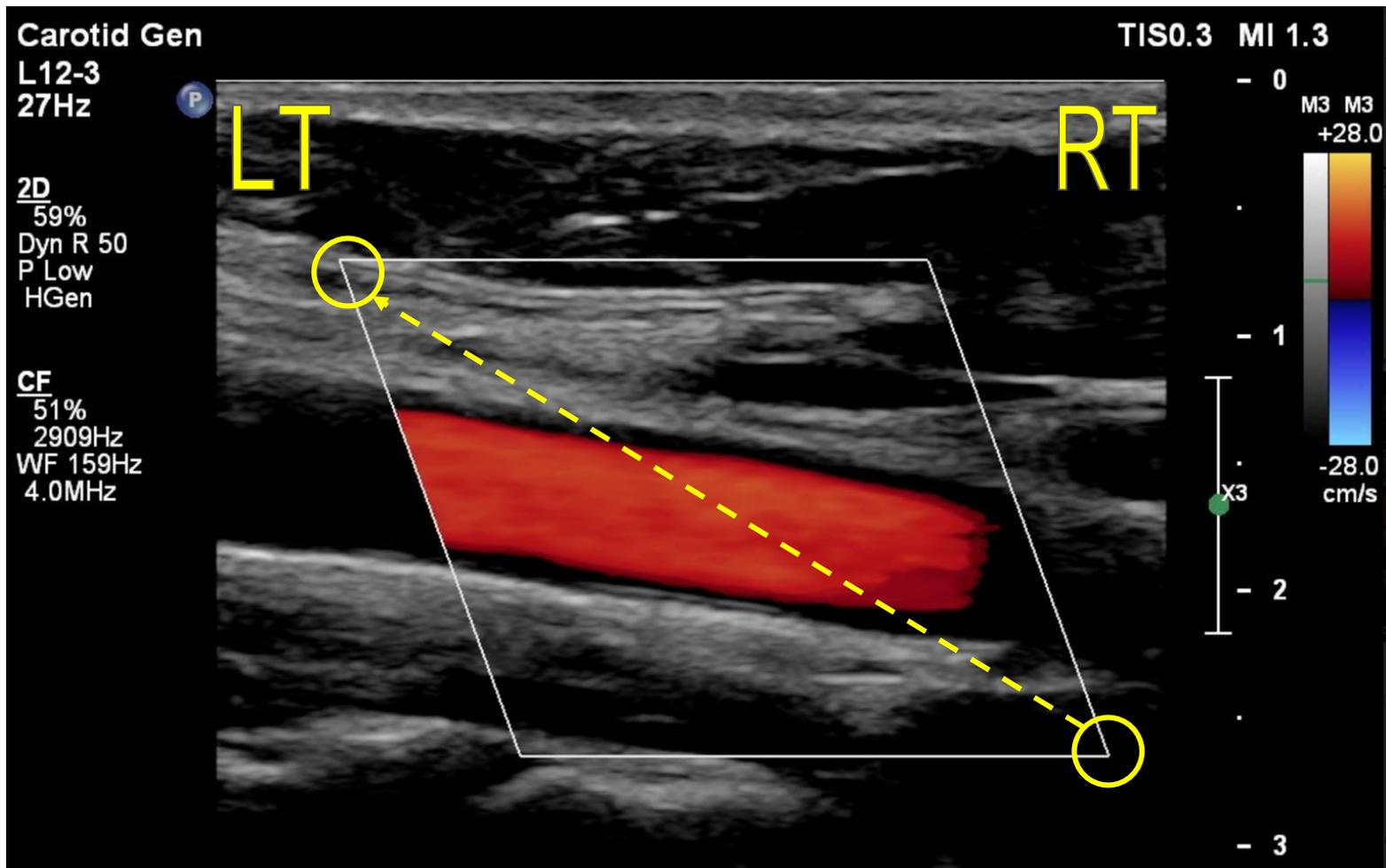
1. Find the acute angles on the color box.

2. Determine color matches top "up" color or the bottom "down" color.

3. Place a finger in a circle (acute angle) that allows you to move DOWN to the other angle.

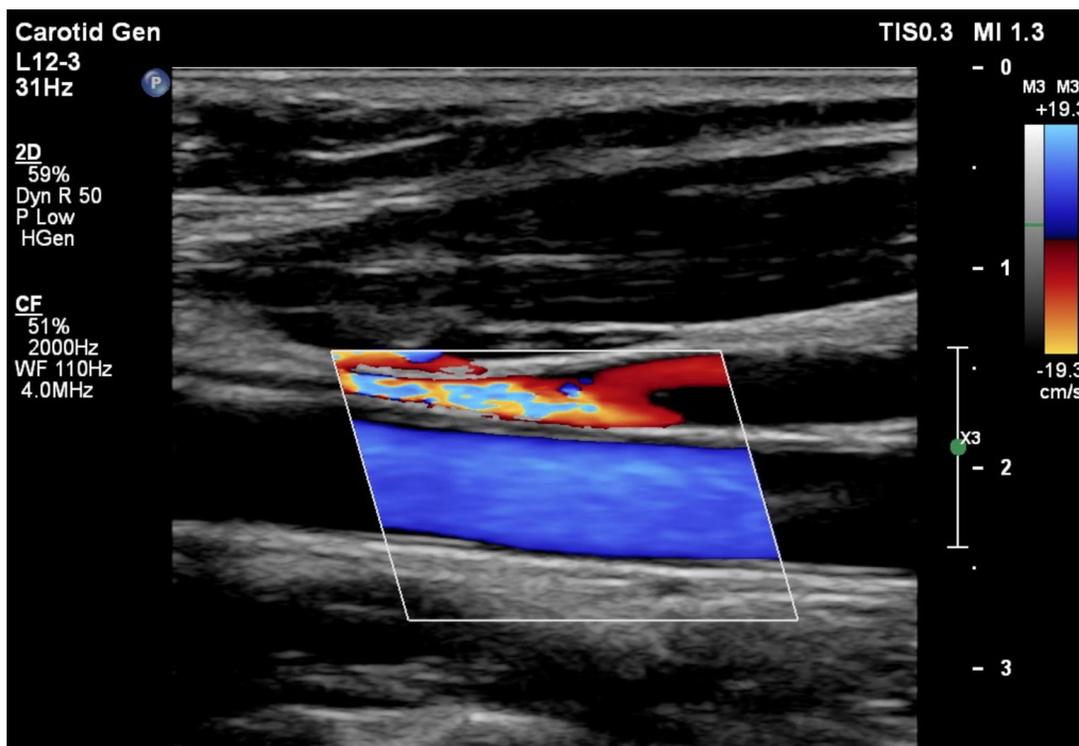
4. Did you move that finger from the right to the left or left to right?

Let's try another one. Which direction is the blood in this vessel flowing?



Red = Up

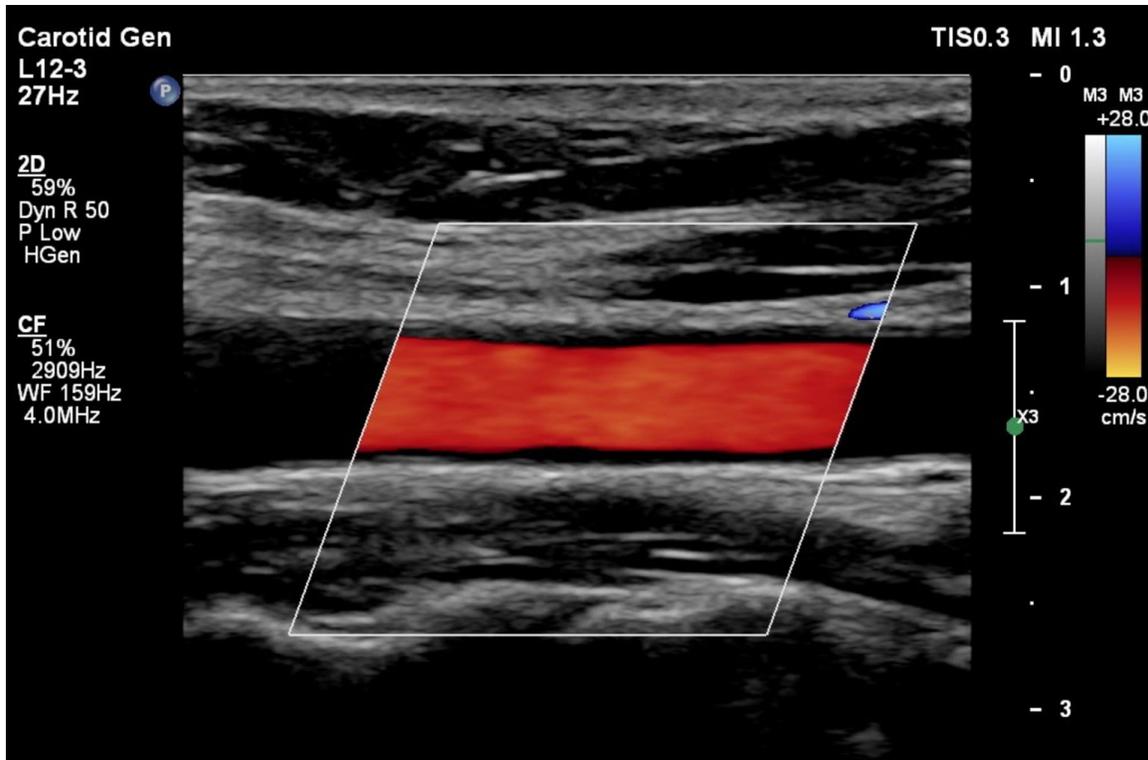
Right to Left



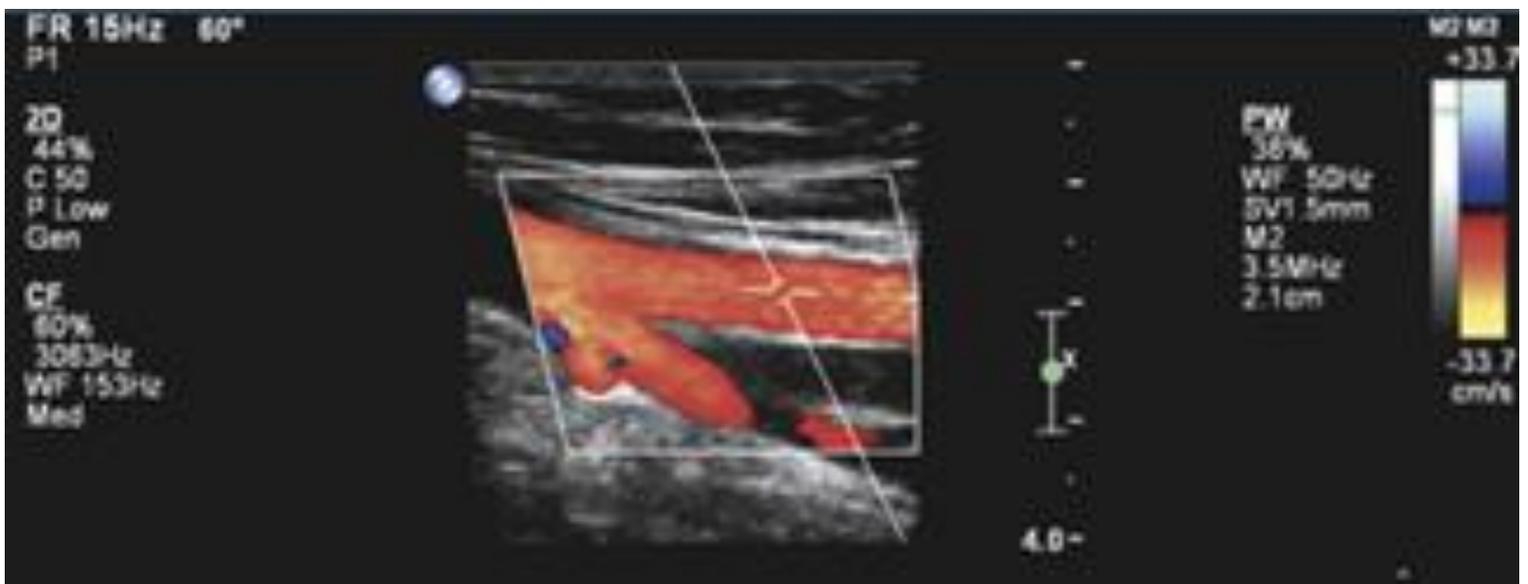
Try this one on your own.

The blue vessel was flowing Right to Left.

You may have noticed that all of those images had an angled vessel and angled color box and they may have made it easy to figure out. Try this one where the vessel is horizontal. Same steps apply.

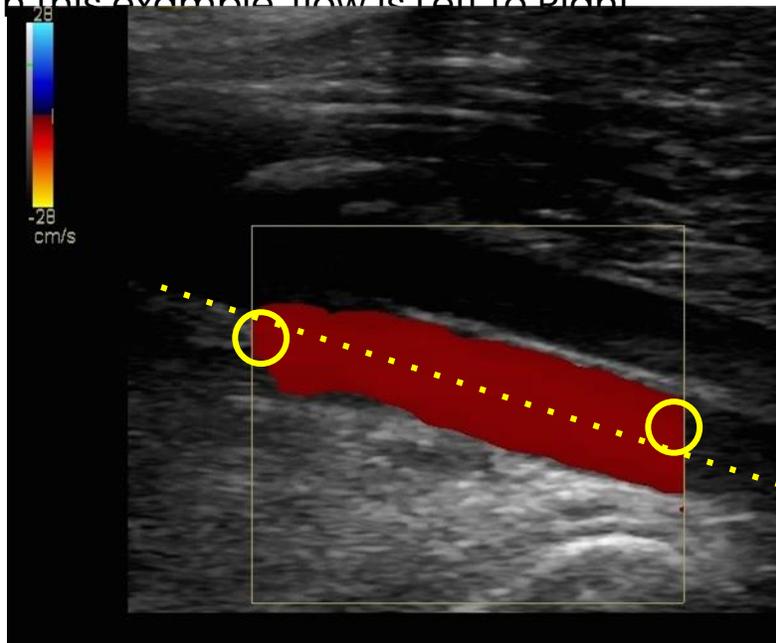


And then one more....



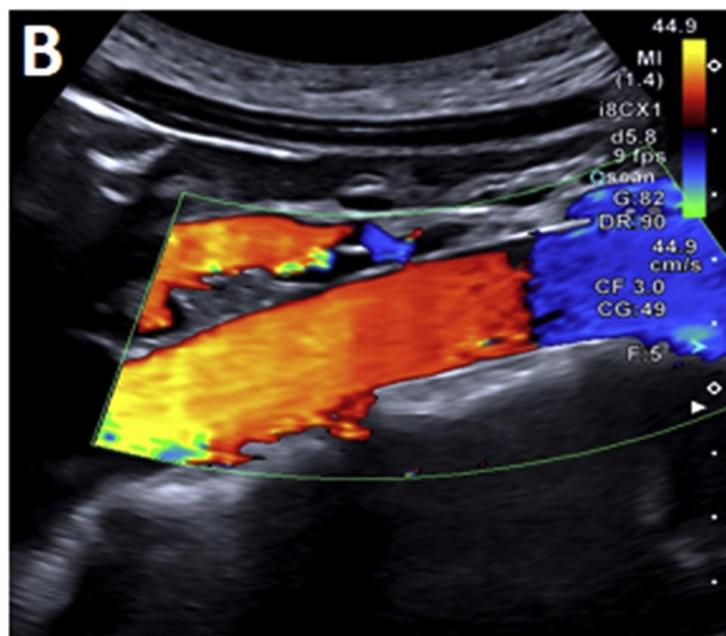
The top image flow was right to left and the bottom image flow was left to right.

Note that sometimes the box is not steered, but the vessel is angled. You should still be able to determine flow direction with a little more imagination about where the acute angles are. Use a line through the vessel and box to see the acute angles. In this example, flow is Left to Right.



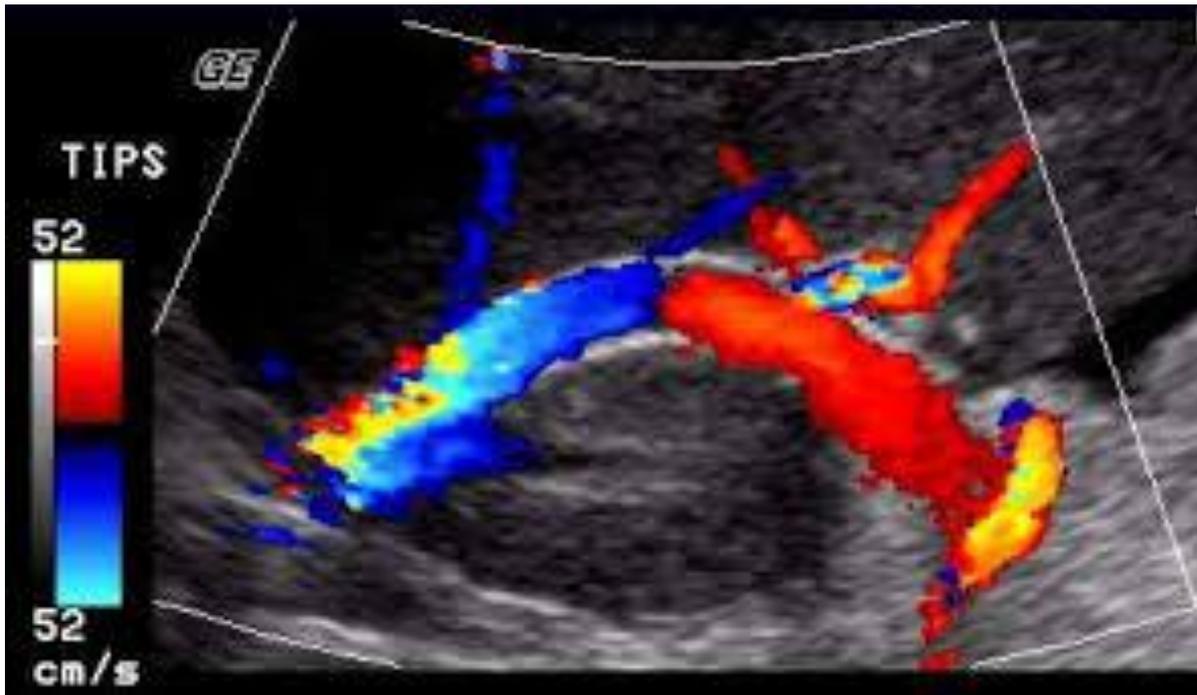
If you are using a sector probe (phased array or curvilinear) and vessels are traveling horizontally across the screen you may notice that two colors are displayed. That is because the blood is flowing towards the transducer for part of its course and then away for the other part.

→ **Flow direction is from TOP color towards BOTTOM color**



The last example is flowing from left to right.

Here is another one to try. Can you tell what direction this is flowing?



This one is flowing Right to Left.

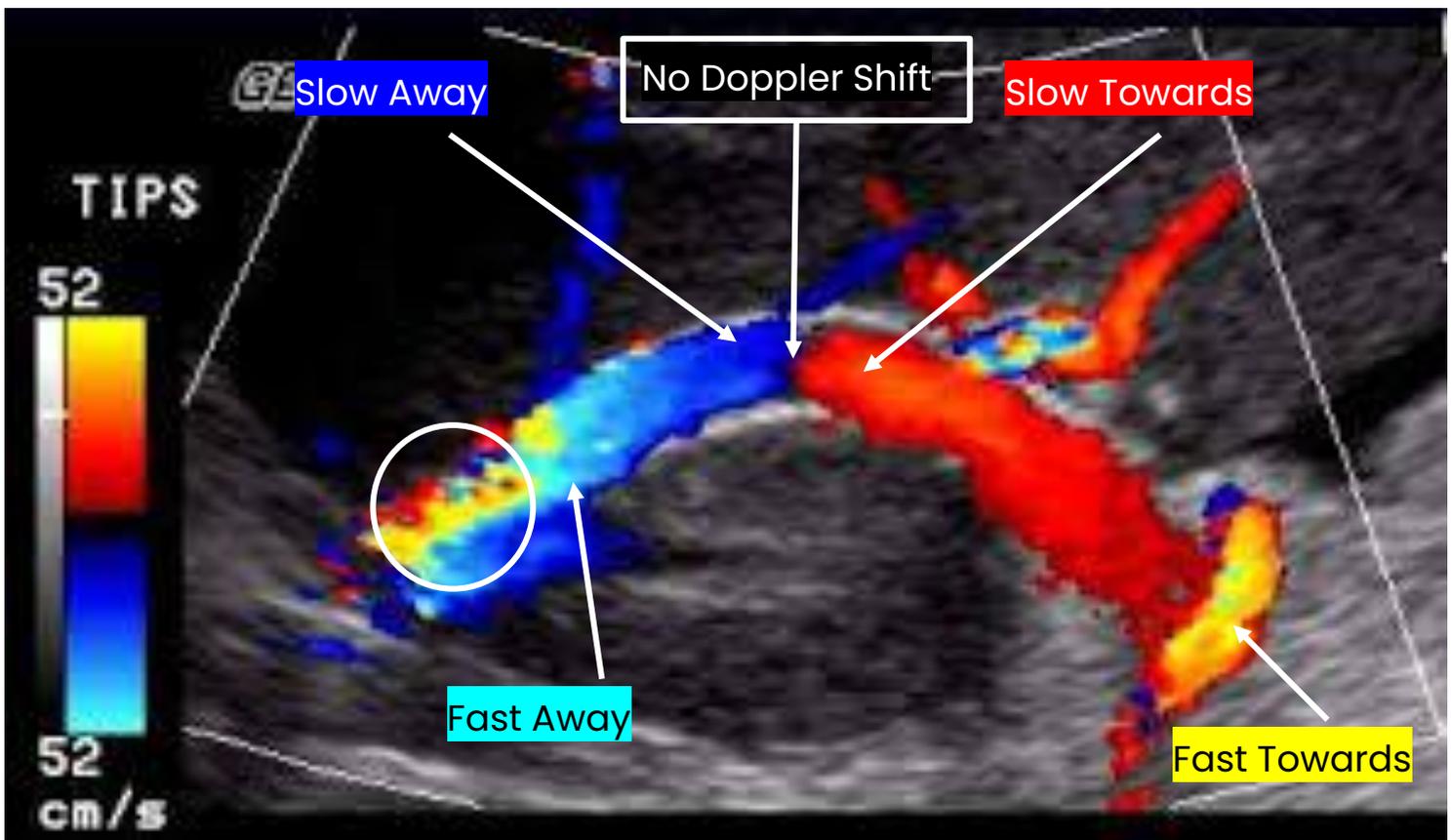
Take a look at the colors that you can see. Do you see the black bar between the red and blue in the center? What does that represent?

What about the yellows and bright blue in the blue side?

## 20.3.4 Color & Velocity

Recall that the colors that are assigned into the image correlate with an average velocity from that area.

- **When colors match up with the colors that are close to the base line, they represent slower moving blood.**
- **When colors match up with the colors that are closer to the edge, they represent faster moving blood**
- **No color means no detectable velocity or Doppler shift (90° Doppler Angle)**



The circled area represents an area of really fast away. It is assigned yellow because it has wrapped around the color scale. This is what color aliasing looks like. (More on this later).

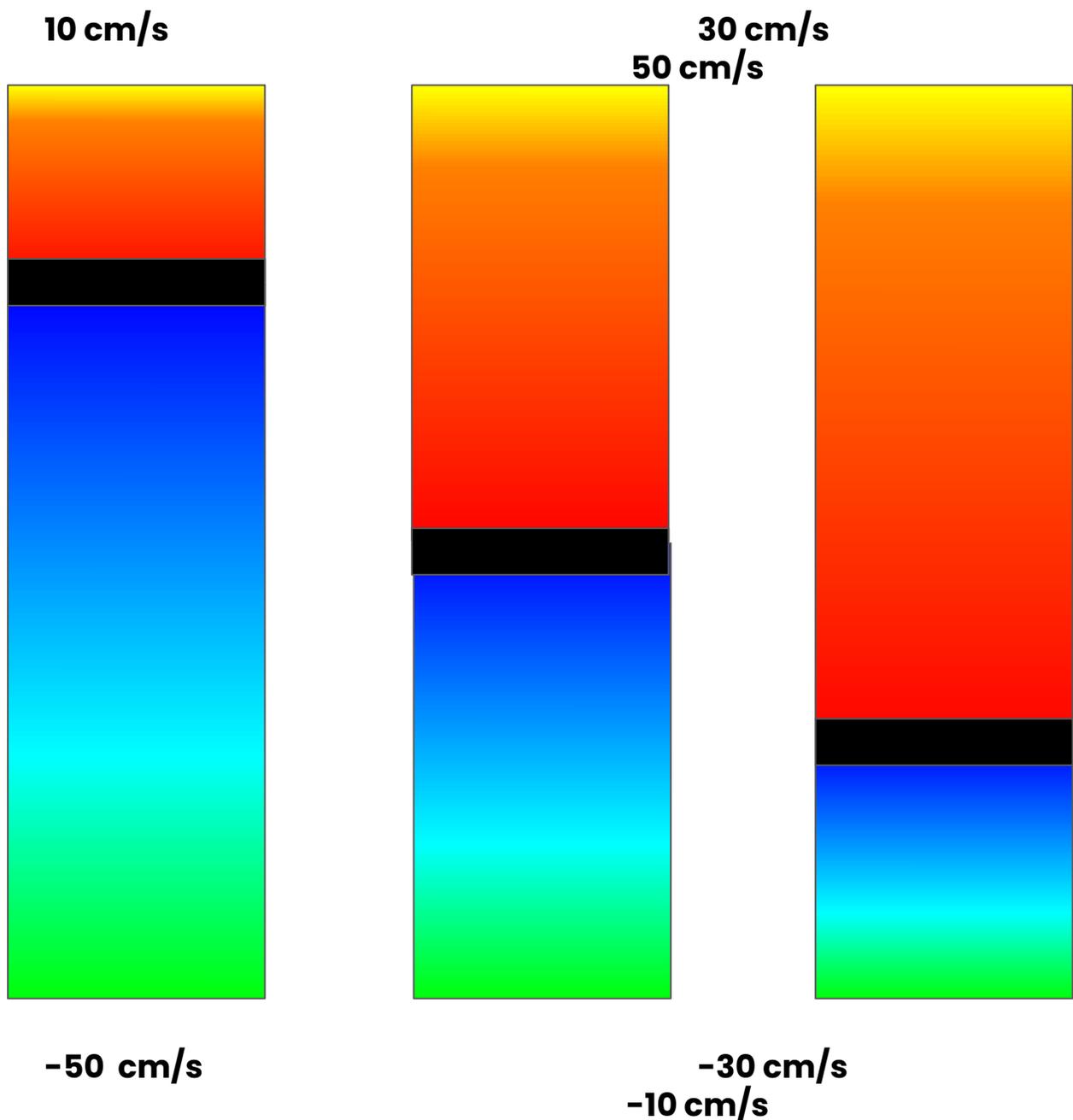
## 20.3.5 Color Doppler Controls

Just like PW Spectral, color Doppler also has some of its own controls. Some of these concepts overlap with PW spectral and will not be covered in as much detail.

### Baseline

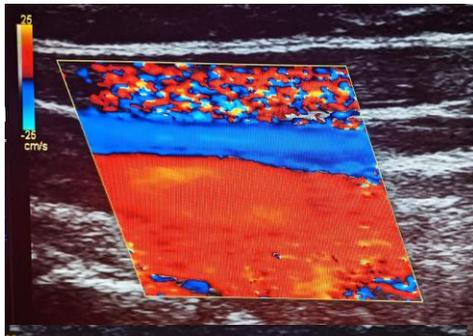
The baseline on the color map *can* be changed, but very rarely is done. The baseline is usually left in the middle with equal velocities represented on either side.

There is a knob that will adjust the baseline up or down.

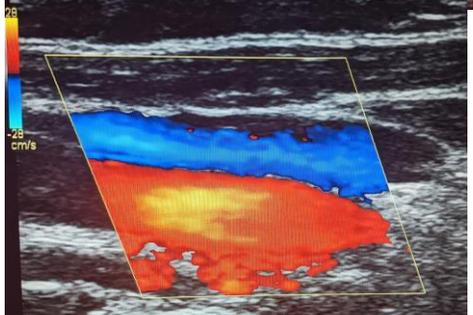


## Gain

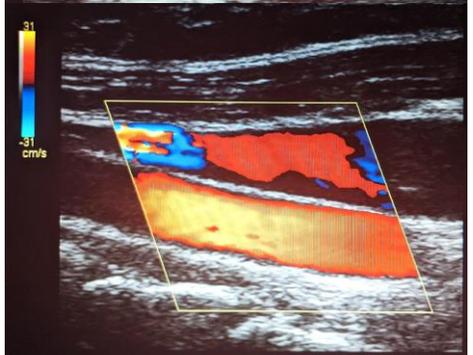
The gain knob for color Doppler increases or decreases the amount of color seen within the color box. Just like all the other gains, color gain can be over gained, causing color to become very flashing and bleed out of the intended area or it can be under gained and make it look like no flow is occurring. There will be a knob/slider to adjust color gain.



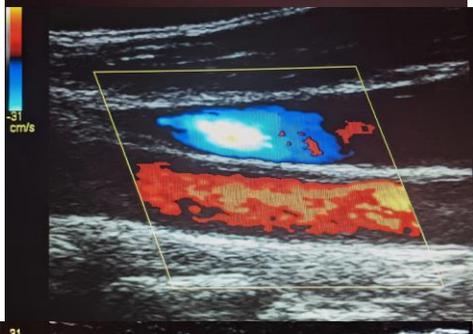
Too much gain - color is all over the place, especially outside of the vessel - looks like confetti



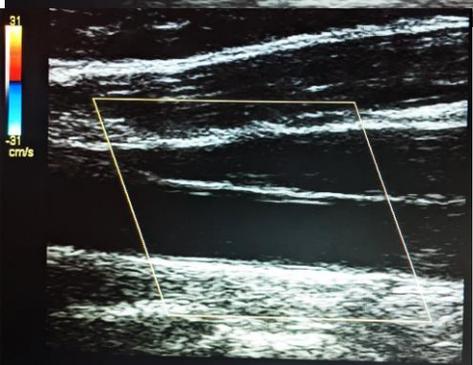
Still too much gain - color is outside of vessel



Gain is just right - color fills wall to wall.



Too little gain - flow is spotty in vessel



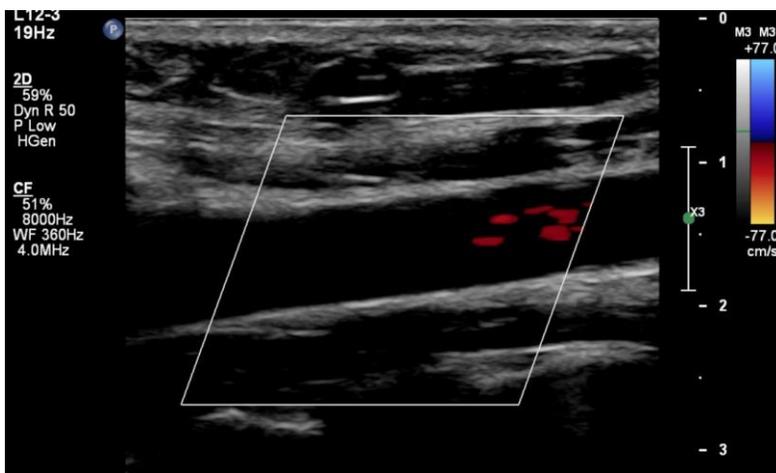
Way too little gain - no color is seen where we would expect normal flow.

## PRF & Scale

Color Doppler is associated with Doppler shifts and average velocities. Since this is a PW subset, it is also dependent on the PRF of the scan lines getting the color Doppler info.

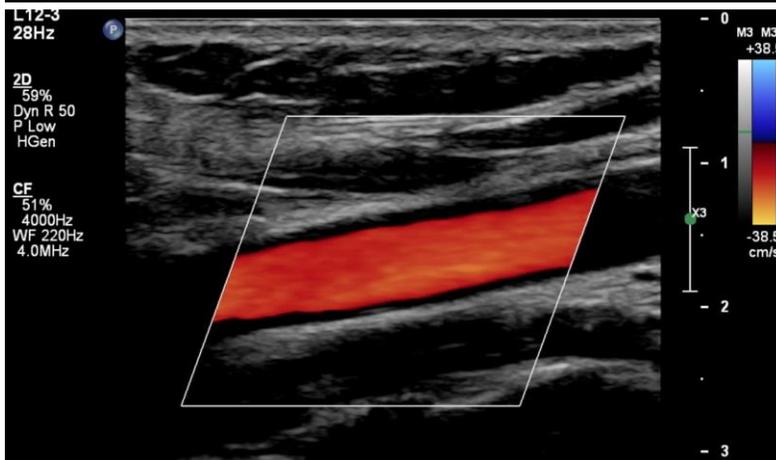
The PRF for color works very similarly to spectral. The PRF can be adjusted up and down, with a max color PRF dependent on the depth of the color box.

- **When color scale / PRF is increased, higher velocity averages can be displayed, but it makes the system LESS sensitive to slow velocities.**
- **When color scale / PRF is decreased, lower velocity averages are used which increases the likelihood of aliasing.**

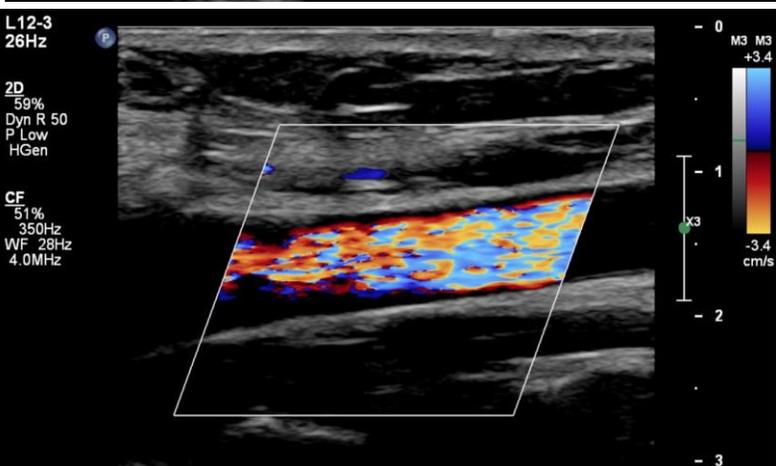


PRF too high - too high to even display normal flow, this will decrease sensitivity to slow flow too.

Notice how the velocities next to the color map changes for each setting.



PRF just right - color is even with just a slight tinge of yellow, which indicates slightly faster velocities

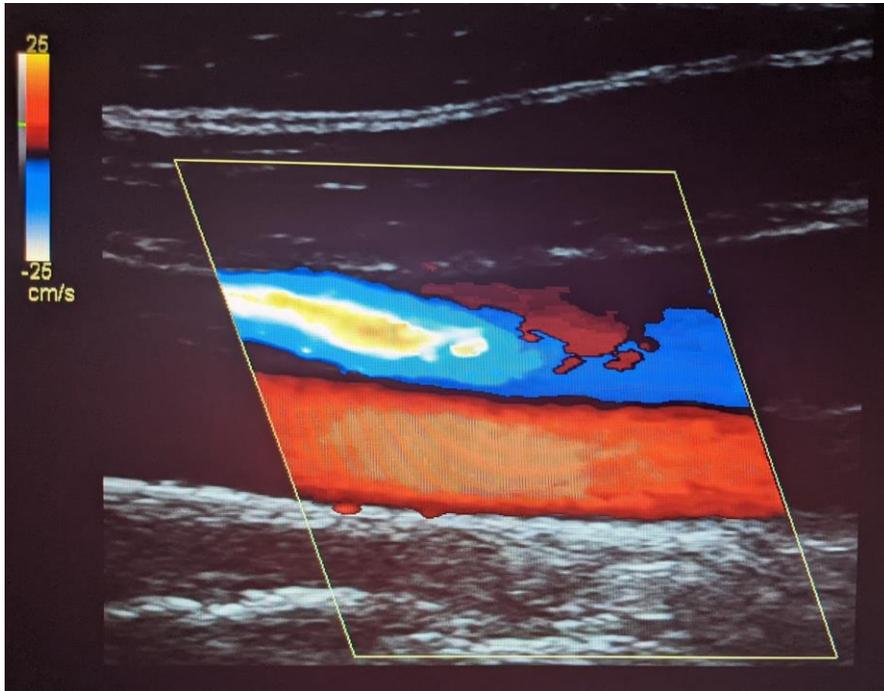


PRF too low - aliasing is occurring because the velocities present are much higher than the average velocity that can be calculated by the PRF setting

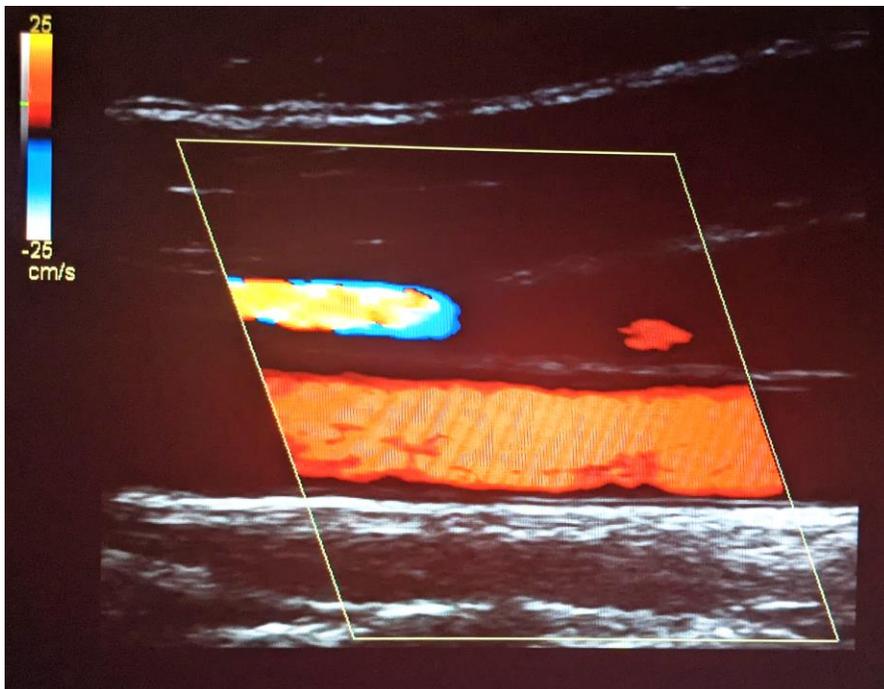
## Color Wall Filter

Also just like PW, color Doppler has its own wall filter. This wall filter can be a little more helpful though. Using the wall filter tells the machine to ignore velocities under a certain range. No color is assigned then to slow velocities.

This can help to “clean” up an image as some color might bleed outside of the vessel, but too much wall filter can completely hide flow that should be present.



Very little wall filter – color fills out to edge and even a little past in parts



Increased wall filter – color doesn't quite make it edges now that slower velocities are excluded

# Section 20.4 Optimizing Color Images

There are artifacts that appear with color Doppler as well, so it is important to know how to recognize them and change machine settings to eliminate them as best as possible.

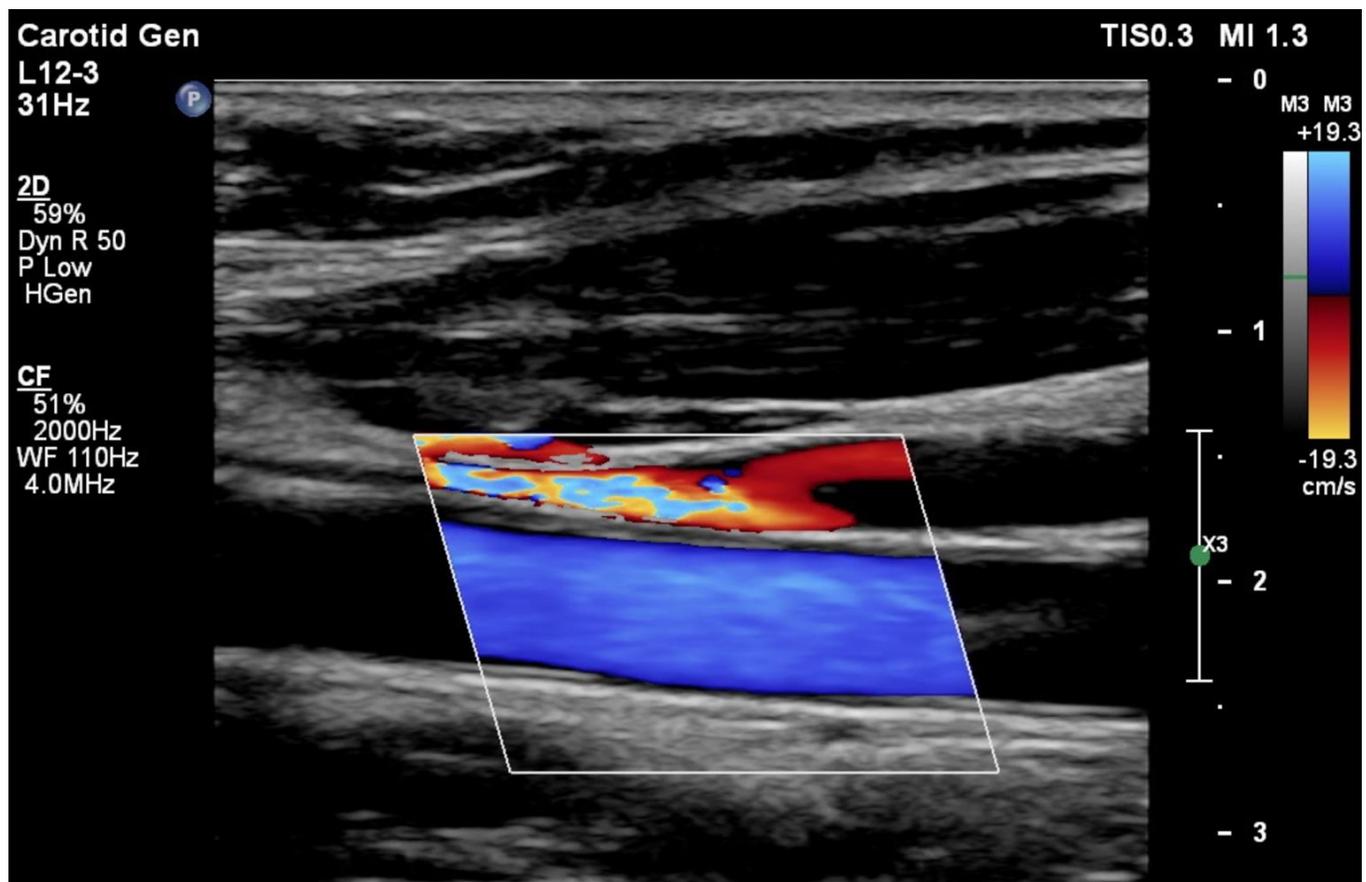
## 20.4.1 Aliasing

Just like PW spectral, color Doppler is prone to aliasing. You need to be able to recognize it and know how to fix it.

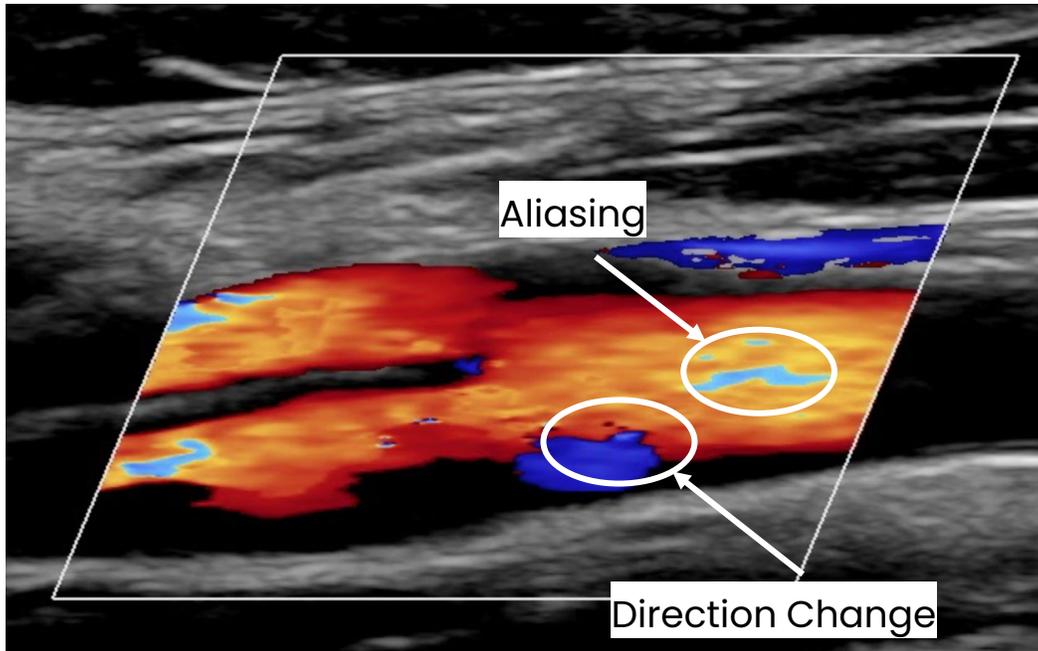
Aliasing in color looks like a mix of colors. You'll notice that it'll go from the fastest velocity color on one side of the map to the fastest velocity color on the other side of the color map.

In the example below, notice how the red vessels goes from red to yellow to cyan. This is aliasing.

The all blue vessel does not exhibit aliasing.



Be careful to not confuse aliasing with true flow reversal. If you see red to black to blue, this flow in different direction next to each other.



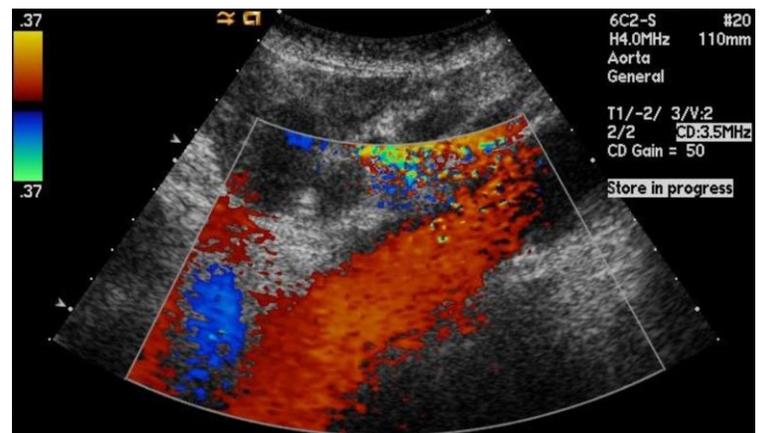
Aliasing is corrected the same way in color as it is in PW Spectral, except that there is not CW option for color.

1. Increase the PRF (most common)
2. Decrease the frequency
3. Decrease the depth of the color box
4. Change the baseline (rare)

## 20.4.2 Other Color Doppler Artifacts

### Ghosting

Ghosting artifacts are the clutter of color Doppler. Color escapes the blood vessel wall and distracts from the true color Doppler. Color wall filters can be helpful to reduce ghosting.



# Section 20.5 Quick Doppler Guides

## What type of Doppler do I want to use?

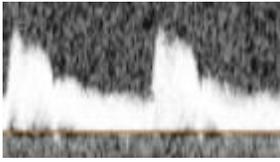
Pulse Wave	<ul style="list-style-type: none"> <li>• I want to know exact location of Doppler sample</li> <li>• I want to be able to detect different types of flow</li> <li>• I want to accurately measure moderate velocities</li> <li>• My waveform isn't aliasing</li> </ul>
Continuous Wave	<ul style="list-style-type: none"> <li>• I need to record VERY HIGH velocities</li> <li>• I can use anatomical knowledge to estimate where I am getting Doppler information from</li> <li>• Switched from PW because of aliasing</li> </ul>
Color	<ul style="list-style-type: none"> <li>• Temporal resolution isn't as big of a deal</li> <li>• I want to see a superimposed image representing flow direction</li> <li>• I want to use this information to help assess where fast areas of flow are located</li> </ul>
Power Doppler	<ul style="list-style-type: none"> <li>• I need to see flow, but am not concerned about direction</li> <li>• Looking for flow in small vessels or where slow flow is suspected</li> </ul>

## PW Transducers vs. CW Transducers

PW	CW
Only need one crystal	Needs at least two crystals
Can create images	Cannot create images
Adjustable Sample Volume	Large, ambiguous sample volume
Prone to aliasing	Will not alias
Backing material	No backing material
Low Q -factor	High Q-factor
Low Sensitivity	High Sensitivity
Wide Bandwidth	Narrow Bandwidth

## How to correct PW Doppler Spectral Tracings

### Too much background noise



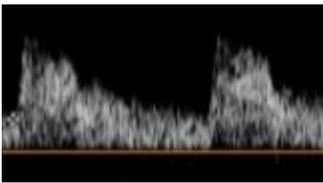
- Reduce PW gain

### PW tracing too faint



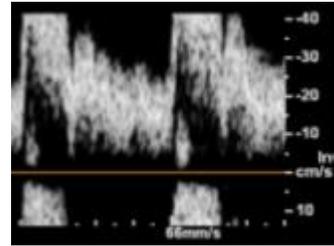
- Get closer to reflectors
- Increase PW gain

### Spectral broadening Loss of spectral window



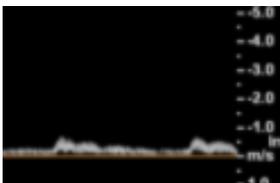
- Might be real if turbulent flow is present
- Reduce PW Gain
- Make gate smaller
- Move gate to middle of vessel, away from slow flow

### Aliasing



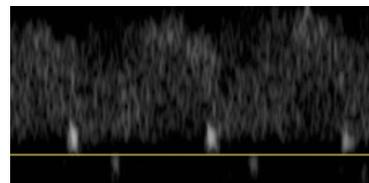
- Increase PW PRF / Scale
- Reduce transducer frequency
- Adjust the baseline
- Move gate to a shallow position
- Switch to CW Doppler

### PW tracing too small



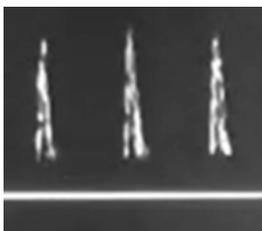
- Decrease PW PRF/Scale

### Cluttering/ Thump Artifact



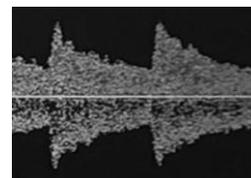
- Increase wall filter

### Floating Waveform



- Decrease wall filter

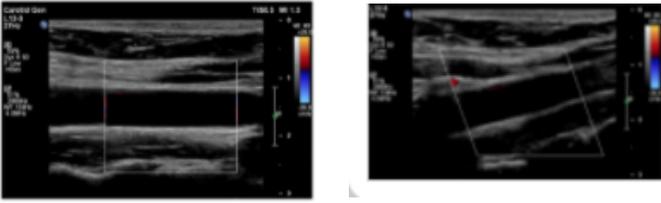
### Crosstalk



- Move away from 90° angle
- Move away from focus of beam
- Decrease PW gain

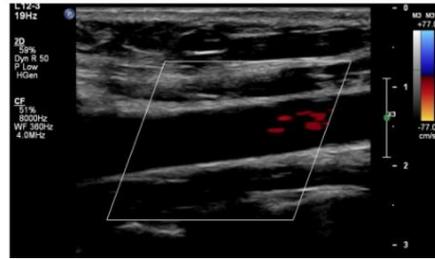
## How to correct Color Doppler Displays

### No color - Bad angle



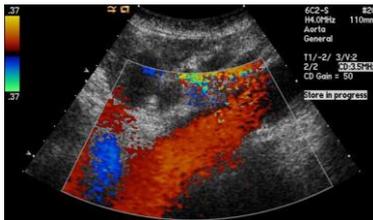
- Steer color box to create anything but a 90° angle
- Angle vessel

### No color - Good angle



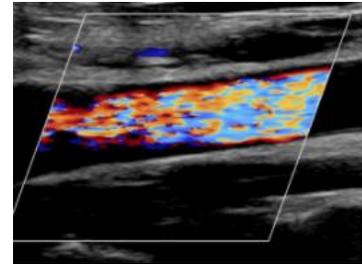
- Increase color gain
- Decrease color PRF/scale
- Decrease wall filter
- Might be real, try Power Color

### Color Outside of Lumen Ghosting



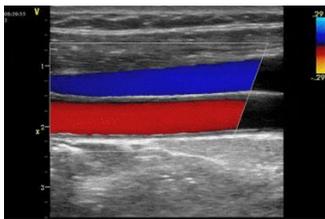
- Increase wall filter
- Increase PRF
- Decrease color gain
- Decrease extra movement, talking, snoring

### Aliasing



- Increase PW PRF / Scale
- Reduce transducer frequency
- Adjust the baseline
- Move gate to a shallow position
- Might indicate area of stenosis

### Poor frame rate with color on



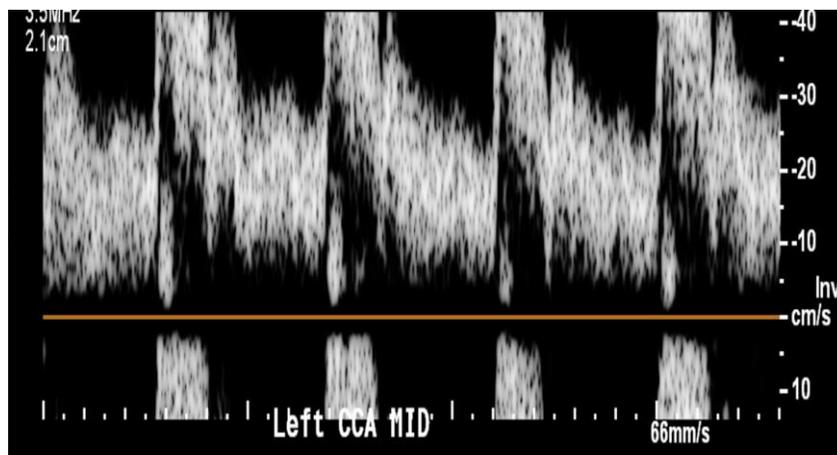
- Make box narrow
- Decrease persistence

### No color, small/deep vessel



- Use power color Doppler

# Section 20.6 Activities ← Link to Answers



What is this image depicting?

Aliasing

What is name of limit this waveform is exceeding?

Nyquist

What is the formula for determining the "limit"

$PRF / 2$

What 5 things can a sonographer do to correct this?

1. Increase PRF
2. Decrease Frequency
3. Move Baseline
4. Decrease Depth
5. Switch to CW

# Will it alias?

$$PRF(\text{hz}) = \frac{77,000 \text{ cm/s}}{\text{depth (cm)}} \quad f_D(\text{kHz}) = \frac{2 \times f_0(\text{kHz}) \times v \left(\frac{\text{cm}}{\text{s}}\right) \times \cos\theta}{c \left(\frac{\text{cm}}{\text{s}}\right)}$$

- 7 MHz Probe
- Gate depth: 15 cm
- Velocity 65 cm/s
- Cosine = 60°

PRF =	<b>5.1</b>	kHz
Nyquist Limit =	<b>2.6</b>	kHz
Doppler Shift =	<b>3</b>	kHz
Will it alias?	<b>YES</b>	

- 7 MHz Probe
- Gate depth: 10 cm
- Velocity 65 cm/s
- Cosine = 60°

PRF =	<b>7.7</b>	kHz
Nyquist Limit =	<b>3.9</b>	kHz
Doppler Shift =	<b>3</b>	kHz
Will it alias?	<b>NO</b>	

- 2 MHz Probe
- Gate depth: 15 cm
- Velocity 65 cm/s
- Cosine = 60°

PRF =	<b>5.1</b>	kHz
Nyquist Limit =	<b>2.6</b>	kHz
Doppler Shift =	<b>0.8</b>	kHz
Will it alias?	<b>NO</b>	

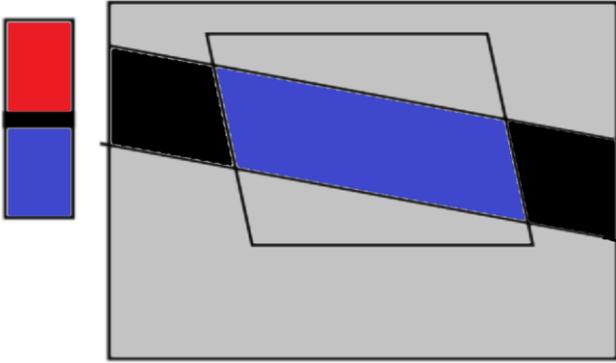
What happened to the Nyquist limit when depth decreased?

Increased

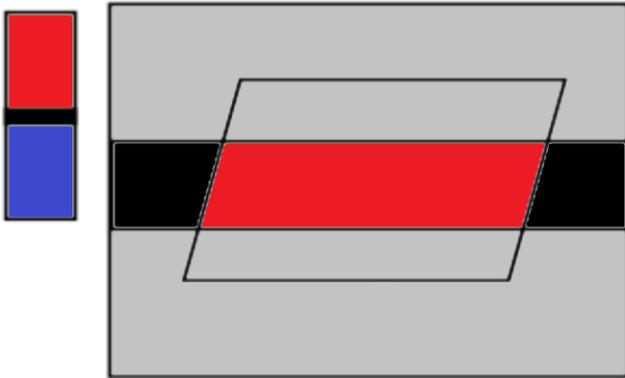
What happened to the Doppler shift when probe frequency decreased?

Decreased

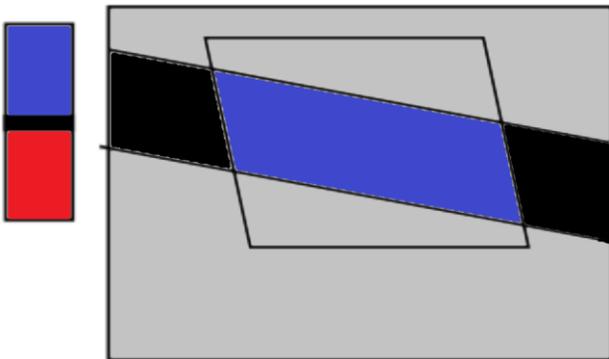
# Left to Right or Right to Left?



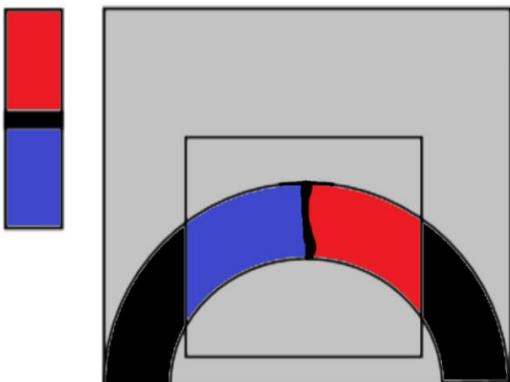
Left to Right



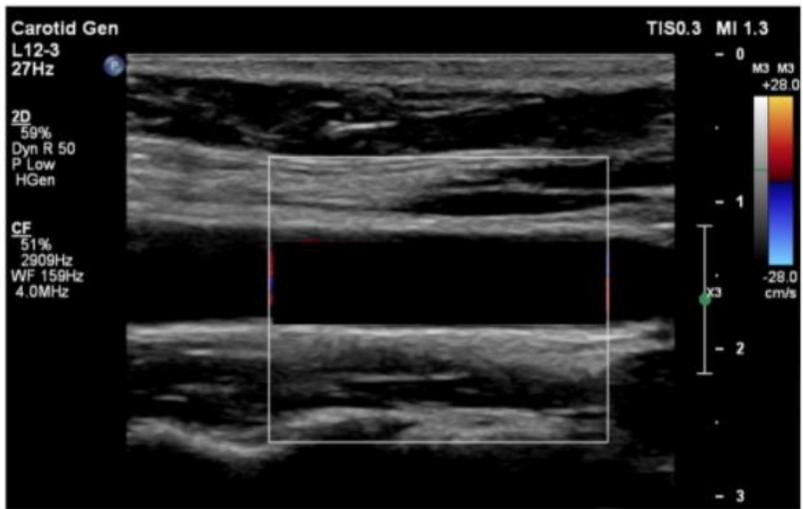
Left to Right



Right to Left



Right to Left

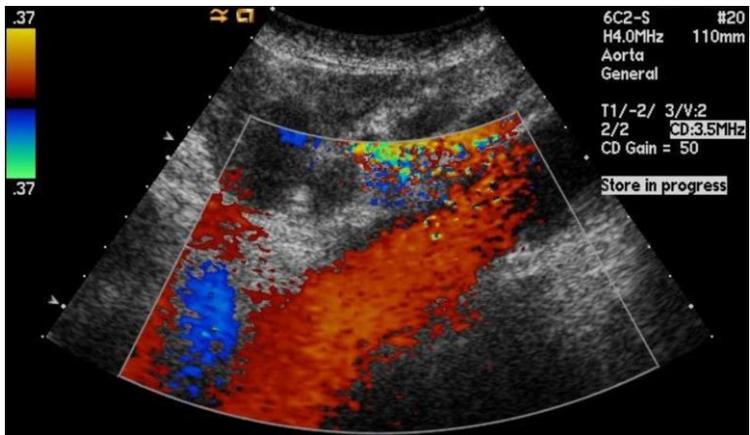


Why is there no color in the vessel?

What should the sonographer adjust?  
( 2 good choices)

The box is at 90 degrees to the vessel. A Doppler shift cannot be detected.

The sonographer can angle the vessel and/or steer the color box.

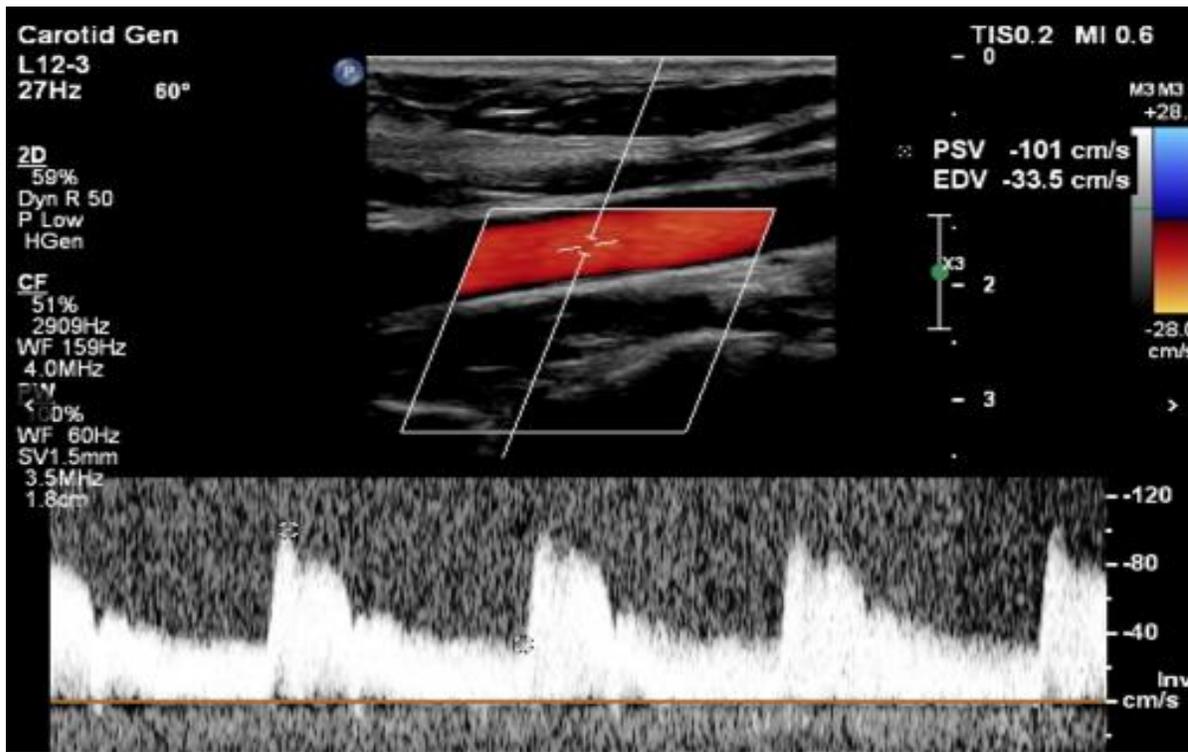


Is there aliasing in the main red vessel?

What should the sonographer adjust?

No.

The sonographer should bring the gain down.  
  
Gain is a better option in this case because bring the PRF down will induce aliasing.



Is this vessel flowing away or towards the transducer?

Away

Does this vessel have a visible stenosis?

No

What should the sonographer adjust?

Spectral gain

This will get rid of the "snow" behind the waveform and clear out the window.

The peak measurement is  $-101$  cm/s, is this correct or over / under estimated?

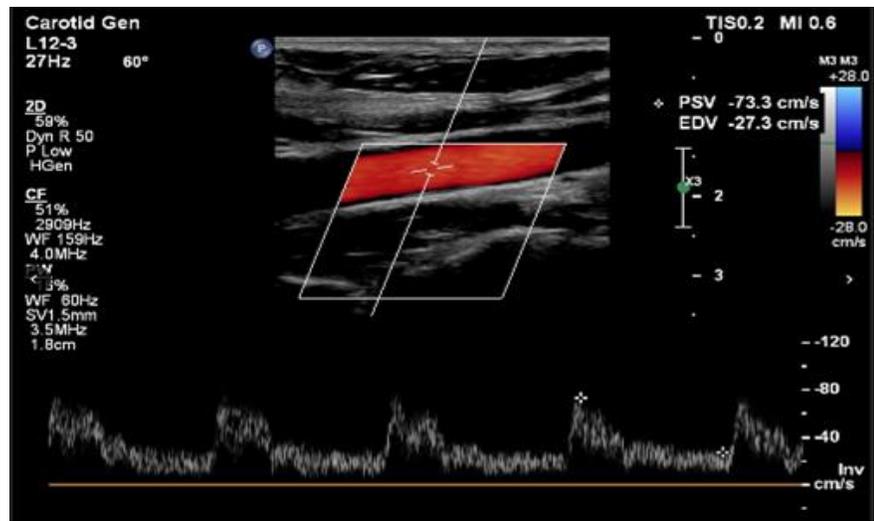
Overestimated.

When spectral gain is too high, false echoes may be measured.

What should the sonographer adjust to make this a better image?

Increase the spectral gain.

The waveform is a little "light"



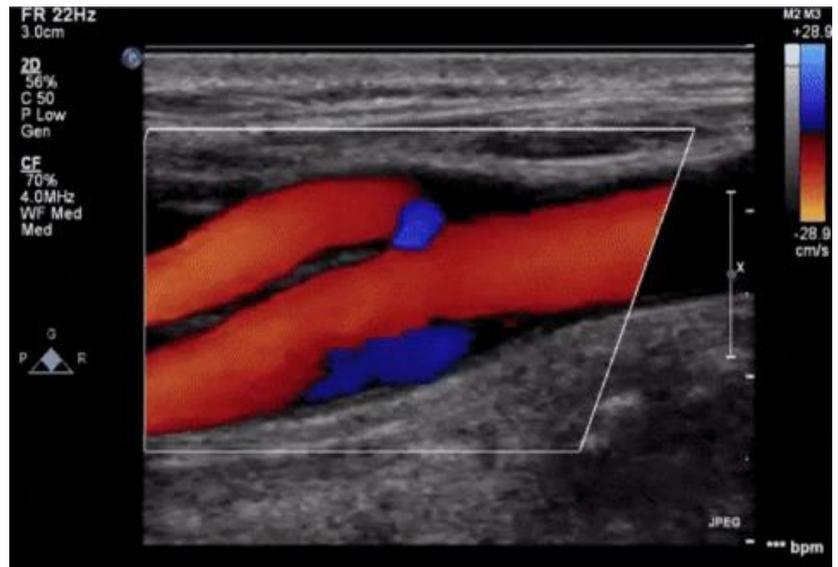
The peak measurement is  $-73 \text{ cm/s}$ , is this correct or over / under estimated?

Underestimated.

If the waveform is too "light" the reflections may not be appropriately displayed which can lead to an underestimate of the velocities.

Is this vessel aliasing or showing a change in flow direction?

Change in Direction



Justify your answer.

The color displayed goes from red to black to blue, meaning that it is crossing over the "0" line and actually changing directions.

What direction is the blood flowing in the top vessel?

Away from the transducer or  
Left to Right

What direction is the blood  
flowing in the bottom vessel?

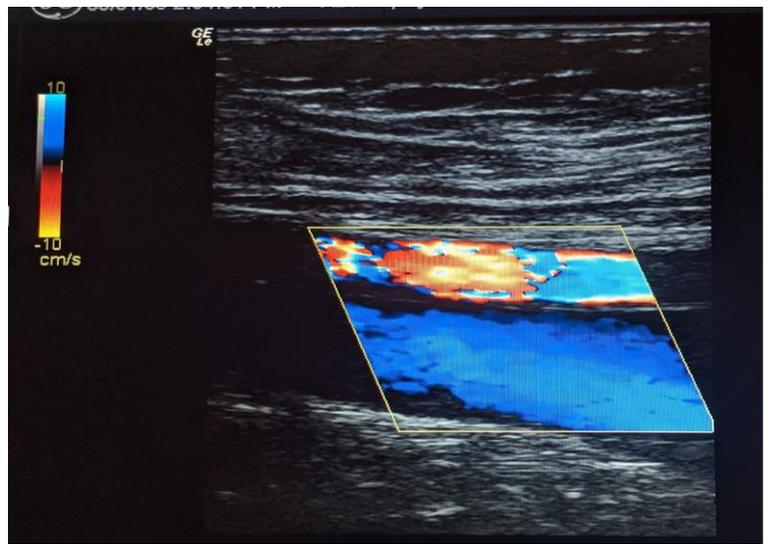
Towards the transducer or  
Right to Left

Is there aliasing or flow  
reversal in the top vessel?

Aliasing

Is there aliasing in the  
bottom vessel?

No



To correct the aliasing, what would  
be a good first this for the  
sonographer to adjust?

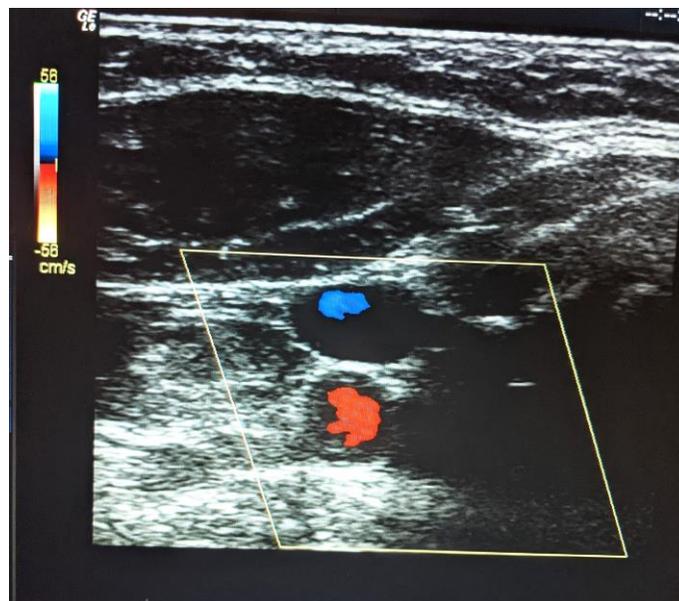
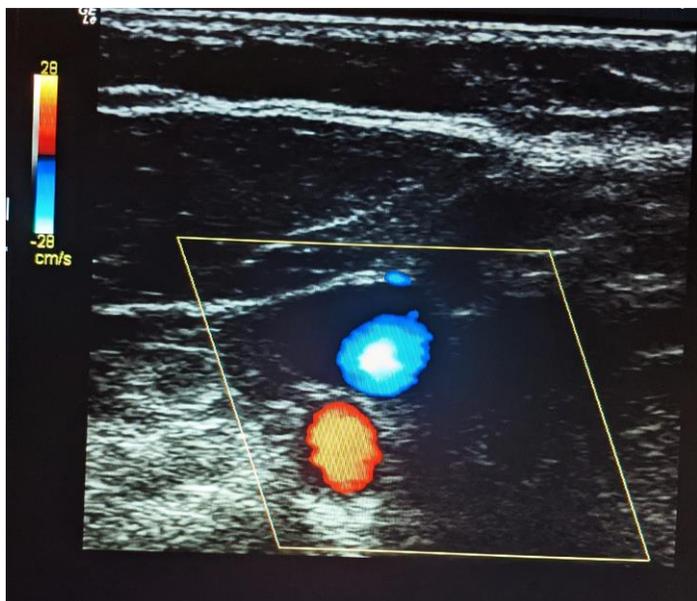
PRF

PRF (or scale) should be  
increased to increase the Nyquist  
limit.

How do you know if it is aliasing  
or flow reversal?

The colors in the top vessel go  
from red to yellow to light blue,  
meaning that they are wrapping  
around the color Doppler map.

The same two vessels are seen in these images. The sonographer did NOT change the PRF or Gain. What else can the sonographer adjust that would reduce color flow visibility?



What did the sonographer adjust to remove most of the flow in the blue vessel?

Rejection or Wall Filter.

By increasing rejection or wall filter, the sonographer can tell the machine to get rid of low level echoes/velocities.



# Section 20.7 Nerd Check!