

APPLICATION OF DOPPLER ULTRASOUND IN ECHOCARDIOGRAPHY

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INTRODUCTION

Ultrasound is very similar to the sounds we hear everyday. In the same way that sound travels through air, ultrasound travels through tissue in waves. The length of the wave (λ) and the frequency of the wave (f) defines how fast the ultrasound travels through the body. The velocity of ultrasound, which is computed by multiplying these terms λ and f , determines much of what we see and how we see it. These principles are the foundation of understanding how ultrasound permits visualization of blood flow. Ultrasound is transmitted from the transducer into the tissue. When the ultrasound beam is reflected from the moving blood, the frequency changes. This frequency change is called the *Doppler effect*.

The Doppler effect was first described in 1852 by Johann Doppler. He described the changes in color of moving planets. These changes in color were due to the changes in frequency seen in light when planets move toward or away from a point of reference. This effect is used in ultrasound to determine whether blood is moving toward or away from the ultrasound transducer. When the ultrasound signal is sent from the transducer into the body, it is reflected by moving red blood cells. If the blood is moving toward the ultrasound beam, an *increased frequency* is reflected. When the blood is

moving away from the beam, the frequency changes to a *decreased frequency*.

The *Doppler shift* describes the difference between the observed frequency (the reflected frequency coming toward or away from the transducer) and the original frequency. By taking into account the angle of the blood to the transducer, the transmitted frequency, and the speed through the tissue, we can calculate the speed of the blood using the formula in Figure 1.

Blood travels through the heart at different speeds and in various flow patterns. The detected velocity derived from the Doppler equation is received and displayed in several formats in ultrasound imaging. Figure 2 is a color representation of the difference between *laminar* and *turbulent flow*. Flow that is traveling through part of the heart at relatively the same speed is considered laminar. Turbulent flow is caused by many red blood cells traveling at many different speeds in a particular area of the heart. Laminar flow is seen in red and blue, whereas turbulent flow is demonstrated by mosaic colors. The different colors indicate not only how the blood is flowing, but in what direction and generally at what speed. To more accurately assess the blood velocity, *continuous (CW)* and *pulsed wave (PW)* Doppler are used.

CW DOPPLER

CW Doppler detects high-velocity blood flow at all points along the sample cursor beam. The returning velocity signals are presented in a spectral display that includes information on time, velocity, and how many blood cells are traveling at what speed. Figure 3 demonstrates the spectral Doppler display found in both continuous and pulsed Doppler. Flow toward the transducer is seen above the baseline, with flow away from the transducer seen below the baseline. On the *horizontal (X axis)*, velocities over time are displayed. The *vertical*

FIGURE 1. Doppler Equation

$$\text{Velocity} = \frac{F_D (\text{Doppler shift}) \times \text{speed of sound through tissue}}{2F_O (\text{original frequency}) \times \cos \theta (\text{angle of the transducer to the blood flow } \sim 1 \text{ when parallel to flow})}$$

display (Y axis) shows how fast the blood is traveling and in what direction. The brightness of the *blood velocity display* (amplitude) indicates how many blood cells are traveling at that particular speed.

Figure 4 demonstrates how CW Doppler detects velocities all along the sample beam. Both the left ventricular outflow tract (LVOT) velocity, as well as the peak aortic valve velocity, is obtained using the CW transducer. The most accurate CW measurements are received using a *Pedoff* probe. This dedicated transducer (only CW Doppler) has one crystal that sends and another that receives. This results in highly accurate measurements of peak velocities.

PW DOPPLER

In contrast, pulsed wave Doppler only samples blood velocity at one point along the cursor. When using PW Doppler, a sample gate will appear on the screen which identifies the specific area to be interrogated. This single transducer technique sends the signal and waits for the reflected signal before sending another pulse. This time delay is calculated to identify for the system where the blood flow signal is coming from. This technology provides specific information about blood velocity at any certain point in the heart. Unfortunately, the benefit of sampling one point limits the ability to measure high-velocity jets. There is also a maximal depth range that pulsed wave Doppler can sample. Table 1 compares the advantages and disadvantages of continuous and pulsed wave Doppler.

COLOR FLOW DOPPLER

This type of Doppler quickly assesses flow over a large area of the heart or particular blood vessel. It allows the sonographer to assess direction of flow. A common way to remember the direction of blood flow displayed is BART (**B**lue **A**way). Shade of blue corresponds to flow away from the transducer; shades of red identify blood flow moving towards the transducer (**R**ed **T**oward).

Color flow Doppler is accomplished by processing multiple sample areas along multiple scan lines in a two-dimensional image. This Doppler information is calculated very easily by using a method called auto-correlation. Unfortunately, this calculation method is limited, and cannot be used for specific determination of blood flow

velocities. It is most useful in locating and assessing direction of flow. Once a regurgitant or stenotic jet is detected, the PW or CW Doppler sample gate can be placed.

DOPPLER CONSIDERATIONS

Keep in mind that the deeper the sample area, the longer it may take the information to return. Additionally, the sample area is composed of scan lines. A pulse is generated per second for each scan. The number of pulses generated per second is known as the pulsed repetition frequency (PRF). The more pulses necessary to interrogate the sample area, and the deeper in the tissue the pulse must travel and return, the longer it takes to create the picture. The more time necessary to create the sample area, the slower the frame rate, which results in a non-real-time color sampling. A high frame rate permits real-time imaging which enhances the diagnostic accuracy of color Doppler. When the imaging is not real-time (a slow frame rate), portions of the color flow box will not be displayed over time. To avoid this, the sample box should be decreased to a width that allows for a frame rate of at least 15 Hz (frames per second).¹

The *Nyquist limit* is another important consideration that is dependent on the PRF. The Nyquist limit (the maximum frequency shift measurement allowed) is half the sampling frequency. When the blood velocity exceeds the limit of the display, the excess velocity information is displayed incorrectly. In PW and CW Doppler, when the blood velocity exceeds the limit of the display, the information *aliases* and is display as if it were in the opposite direction.² For example, if the blood velocity is away from the transducer and exceeds 4 m/s, but the display only allows 1 m/s below the baseline, the excess velocity will alias and be display above the baseline. Figure 5 demonstrates aliasing with PW Doppler. The picture on the left displays a sampling of mitral regurgitation (MR) with PW from apical four-chamber view. Due to the flow exceeding the limits of the display, the MR is displayed above instead of below the baseline. Using CW Doppler and adjusting the baseline appropriately can resolve this problem.

In color flow imaging, when the blood velocity exceeds the range of the color bar, the color also aliases. The blood will be displayed as if it were going in the opposite direction. Figure 6 shows the acceleration of blood through the LVOT. Notice that the Nyquist limit is set at 61cm/s. Blue

TABLE 1. Comparison of the Advantages and Disadvantages of Pulsed and Continuous Wave Doppler

	Pulsed Wave	Continuous Wave
Advantages	Assess blood flow in a specific area (range resolution)	Assesses the peak area velocity
Disadvantages	Flow aliases when blood flow is too high	Cannot assess velocity in a specific point in the blood pool

demonstrates blood moving away from the transducer, but flow accelerates faster than the color flow can demonstrate. Therefore, when the velocity accelerates higher than 61 cm/s, the displayed color aliases and is displayed as a red color. To be clear that the blood is still going away from the transducer, notice that the colors change from shades of blue to white, then to shades of red. When the velocity changes directions, the color change will go from blue to black, then red.

DOPPLER CONTROLS

There are many controls that can be used to optimize the Doppler signals. Many of these controls are used in color, PW and CW Doppler.

GAIN

Gain increases the amplitude of the returning echoes. This is accomplished in PW and CW Doppler. Figure 7 demonstrates the importance of setting the gain correctly, especially in color Doppler. On the left, the gain setting is too high, which results in extraneous color artifact. On the right, the gain setting is too low, which results in a missed mitral regurgitation jet.

FOCUS

The focus is the beam area where the signal is concentrated. Place at or below the level of interest.

FILTER

The filter eliminates the display of low- or high-velocity frequency shifts. The setting should be at a mid-level.

VARIANCE

Variance represents the distribution of Doppler signals across a bandwidth. This is displayed as a variation from the mean velocity sometimes displayed in shades of green.

LINE DENSITY

Line density represents the number of lines within a sector angle.

SPECTRAL DISPLAY

Overall, the Doppler controls which change the spectral image are very important. Figure 8 demonstrates a *spectral display* of mitral inflow with variations in the gain, sweep speed, and scale. In the upper right, the Doppler gain is set so low that Doppler velocities, including the peak velocity, is misrepresented. The scale is set very high in the lower left corner, which results in a very small waveform that makes it difficult to assess which is the peak velocity. In

the lower right corner, the sweep speed is set very slow, displaying many inflow velocities placed too closely together for routine mitral valve inflow assessment.

SAMPLING TIPS

When performing Doppler ultrasound, techniques can be used to optimize the Doppler signal. Placing the color box over the area of interest aids in focusing the cursor within the jet for a more accurate sampling of blood. To optimize color flow Doppler detection of blood flow, narrow the sector to include only a small area of interest.

After placing the sample gate in the specific area of interest, listening for a strong audible signal will confirm accurate sample volume placement. Normal laminar flow will have a medium- to high-frequency sound, which is clear and smooth. Turbulent flow will be more high-pitched with harsh, multiple frequencies. When using the Doppler equation, the angle of flow is taken into consideration. Because of this, it is very important to align the Doppler sample as parallel to the flow as possible. Throughout a normal echocardiographic examination, Doppler is used to assess blood flow velocities throughout the heart. Table 2 presents a typical Doppler protocol that includes using color as well as PW and CW Doppler in each view. All three of these Doppler modalities will also be used to assess blood flow through each valve.

AORTIC STENOSIS

Aortic valve area is calculated using Doppler assessment of PW wave left ventricular outflow, CW aortic valve Doppler, and the two-dimensional measurement of left ventricular outflow diameter.^{3,4} These measurements are inserted into an equation called the *continuity equation* to accurately calculate the aortic valve area. Peak Doppler velocities of the aortic valve in aortic stenosis range from 1.8 m/s to 4+ m/s. These peak Doppler velocities are high-velocity, pulsatile, and systolic blood flow.⁵ Assessment of aortic stenosis (AS) by Doppler requires interrogation of multiple imaging windows.⁶ Apical four-chamber, suprasternal notch, and right sternal border views are used to evaluate AS. Figure 9 demonstrates the additional necessary view of right sternal border.

LEFT VENTRICULAR OUTFLOW TRACT (LVOT)

PW Doppler is used to place a sample volume into the LVOT to assess flow in that specific area. As just mentioned, this flow measurement is necessary when using the continuity equation to calculate AS. In addition, it is used in patients with left ventricular outflow obstruction. Although flow is going through the same place, the increased flow is displayed differently if the flow is dynamic (LVOT obstruction) or fixed (AS). Figure 10 also demonstrates the difference between a stenotic aortic valve and a dynamic left ventricular outflow obstruction.

TABLE 2. Typical Doppler Protocol

Parasternal long axis views:
<ul style="list-style-type: none"> • Color aortic valve for aortic stenosis/aortic insufficiency • Color mitral valve for mitral stenosis/mitral regurgitation • Angle to tricuspid inflow, place color Doppler over the right atrium, tricuspid valve, use continuous wave if tricuspid regurgitation is present • Angle to pulmonic outflow, place color Doppler sample to identify pulmonary outflow, use pulsed wave or continuous wave as necessary
Parasternal short axis views:
<ul style="list-style-type: none"> • Put color Doppler over the right atrium, use pulsed wave Doppler to measure tricuspid regurgitation velocities • Place color Doppler over the right ventricular outflow tract, use pulsed or continuous wave Doppler right ventricular outflow tract • Image aortic valve, place color Doppler sample to identify flow through the aortic valve
Apical views:
<ul style="list-style-type: none"> • Apical four-chamber view, color each valve for stenosis or regurgitation • Place color Doppler over mitral valve, use continuous wave if mitral regurgitation is present • Increase depth to visualize pulmonary veins, use pulsed wave to sample the pulmonary veins • Place color Doppler over the mitral valve inflow, use continuous wave if mitral stenosis is present, pulsed wave for diastolic function • Place color Doppler over the left ventricular outflow tract, use pulsed wave Doppler to sample flow • Place color Doppler over the aortic valve, use continuous wave Doppler to assess peak velocity • Place color Doppler over the right atrium, use pulsed wave Doppler to sample the tricuspid valve inflow • Place color Doppler over the tricuspid valve, measure tricuspid regurgitation with continuous wave if present • Rotate to two-chamber view, place color Doppler over the mitral valve, use continuous wave Doppler if mitral regurgitation is present • Rotate to three-chamber view, place color Doppler over the mitral valve, place color Doppler over the aortic valve, use continuous wave if mitral regurgitation or aortic insufficiency is present, rotate back to four-chamber view
Subcostal views:
<ul style="list-style-type: none"> • Image the subcostal four-chamber view • Image atrial septum, use pulsed and/or continuous wave Doppler • Place color Doppler over the right atrium and left atrium to include the interatrial septum. • Place color Doppler over the right and left ventricle to include the ventricular septum • Pulsed wave Doppler hepatic veins when necessary
Suprasternal views:
<ul style="list-style-type: none"> • Place color Doppler over the aortic arch, use pulsed wave, and/or continuous wave Doppler when necessary • Use right parasternal, as needed, especially in aortic stenosis

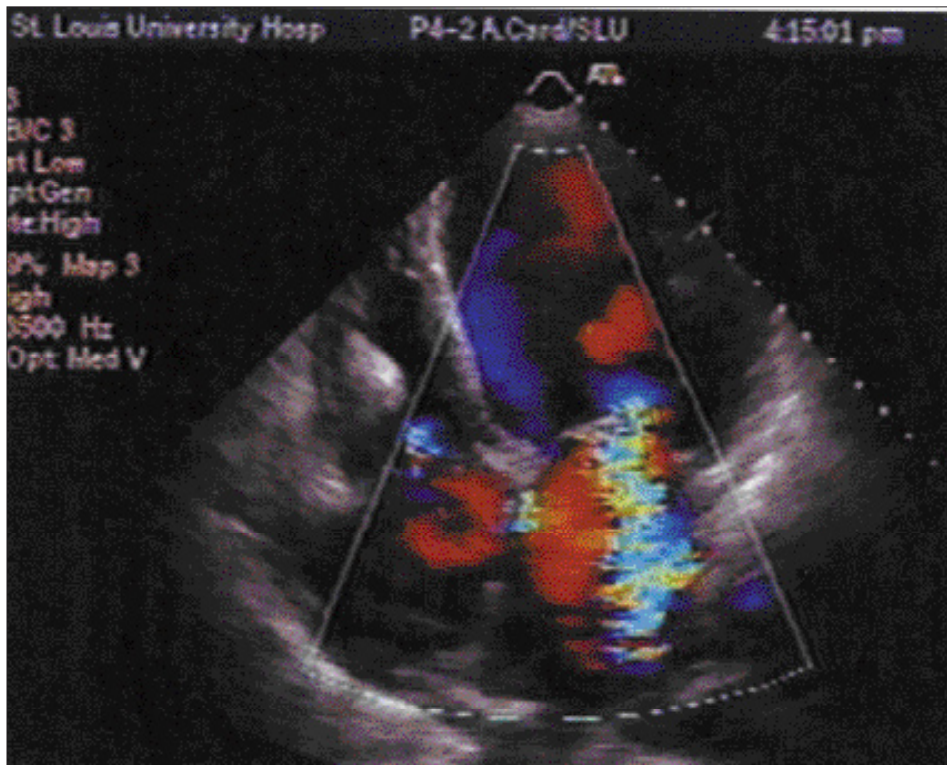
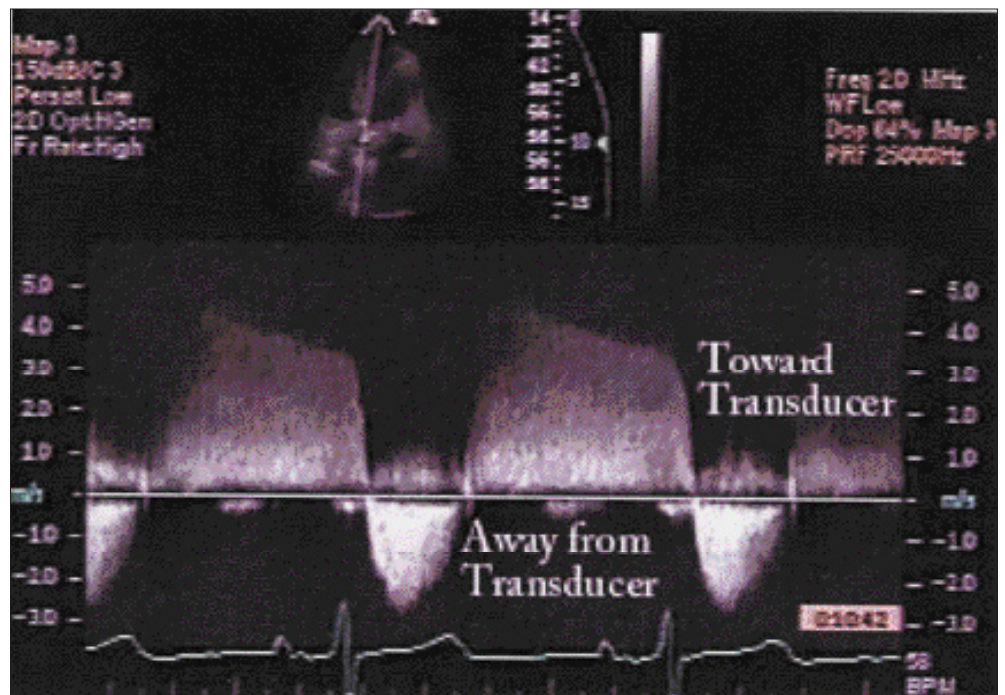


FIGURE 2. Color Doppler Demonstration of Laminar Versus Turbulent Flow. Laminar flow is seen in red and blue, with turbulent flow demonstrated by aliased mosaic colors.

FIGURE 3. In continuous (as seen here) and pulsed spectral Doppler, flow toward the transducer is seen above the baseline, with flow away from the transducer seen below the baseline.



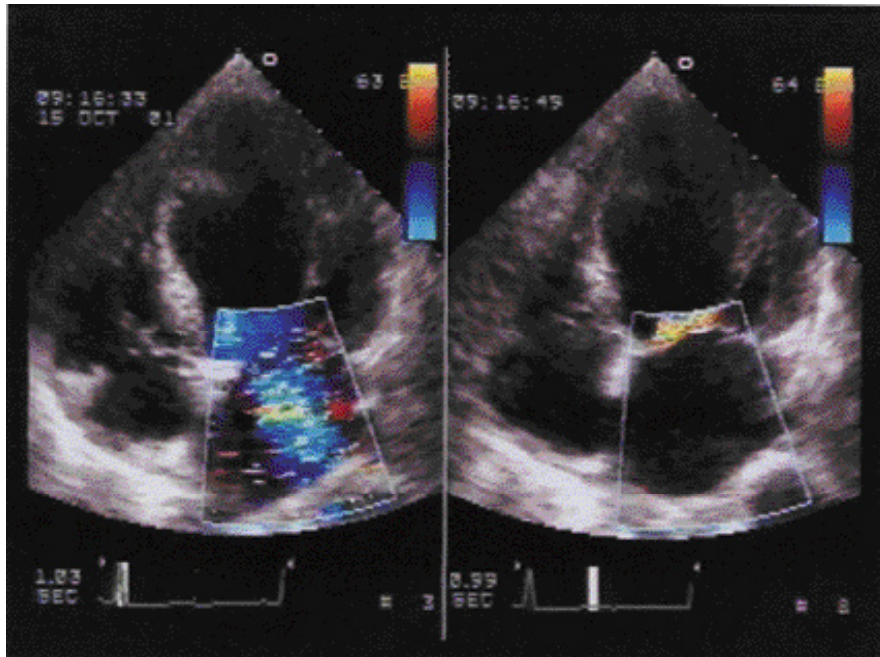


FIGURE 7. Gain control is an important setting when using color Doppler. On the left, the gain setting is too high, resulting in extraneous color artifact. On the right, the gain setting is too low, resulting in a missed mitral regurgitation jet.

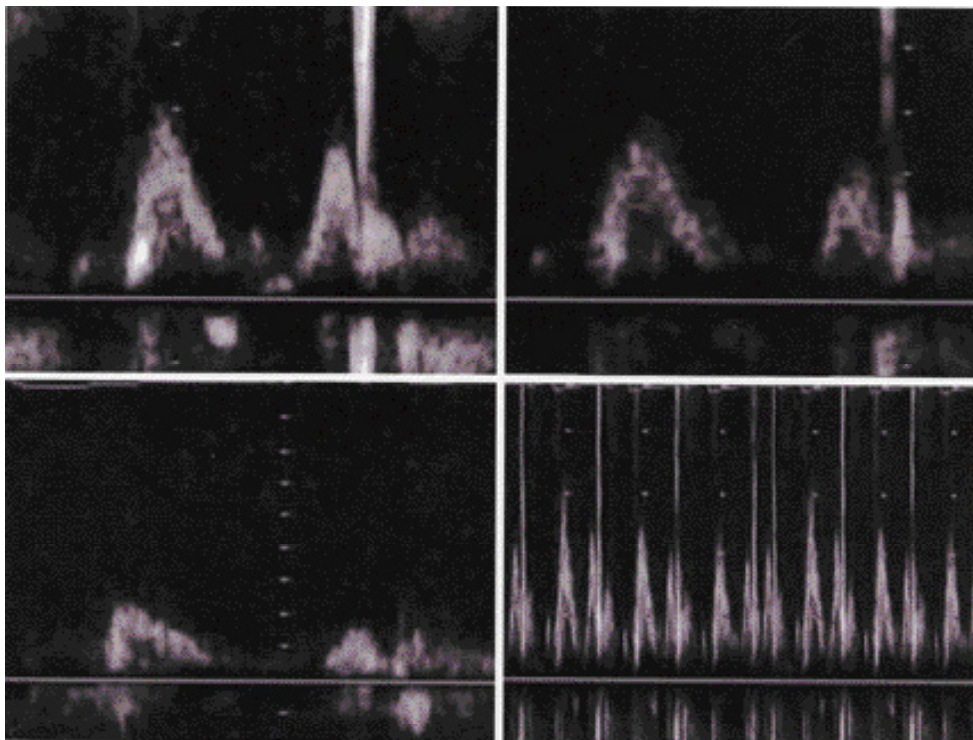


FIGURE 8. Spectral display of mitral inflow can be manipulated to optimize Doppler flow velocities, as seen in the upper left. In the upper right, the Doppler gain is set so low that Doppler velocities, including the peak velocity, are misrepresented. The scale is set very high in the lower left corner, which results in a very small waveform, making it difficult to assess which is the peak velocity. In the lower right corner, the sweep speed is set very slow, displaying many inflow velocities placed too closely together for routine mitral valve inflow assessment.

FIGURE 9. This aortic valve flow view is taken with a dedicated CW Doppler probe (Pedoff) from the right parasternal window. Notice the increased velocities common in the situation of aortic stenosis.

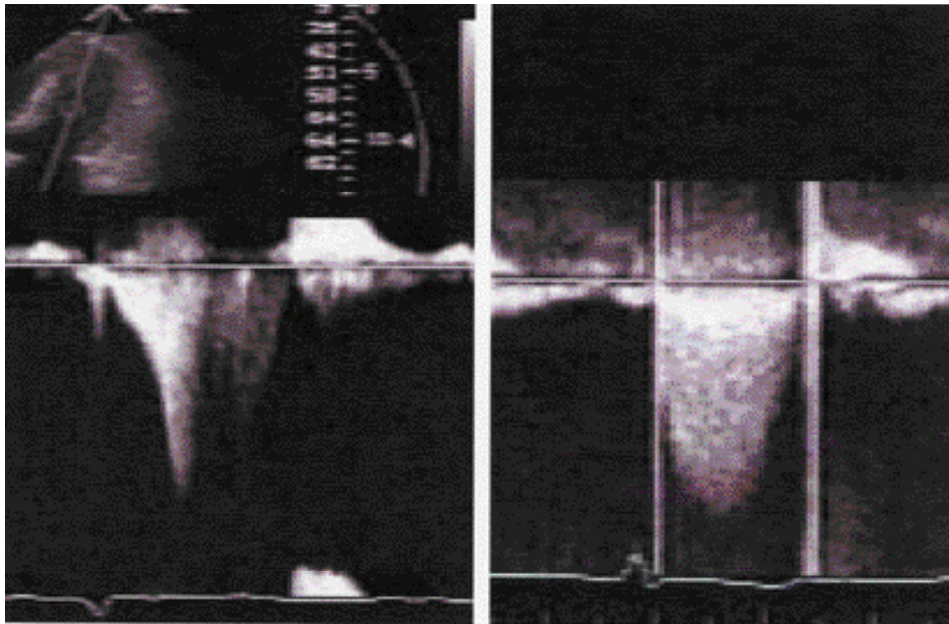
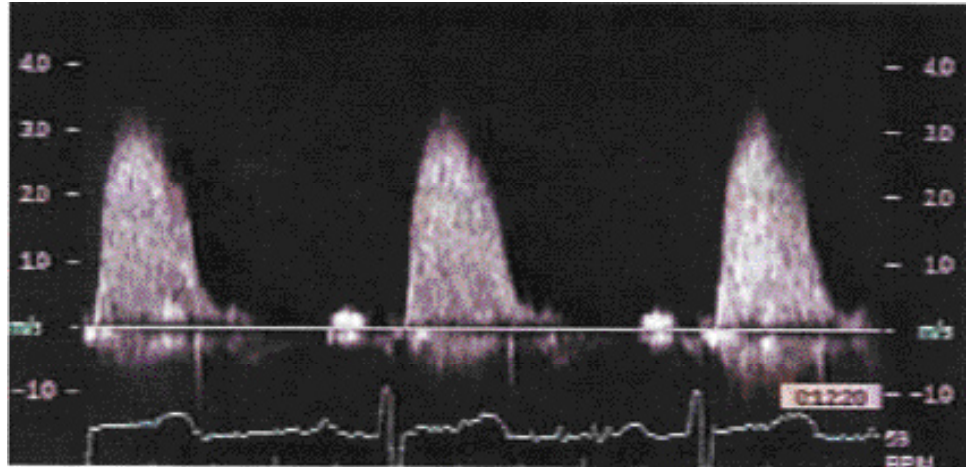
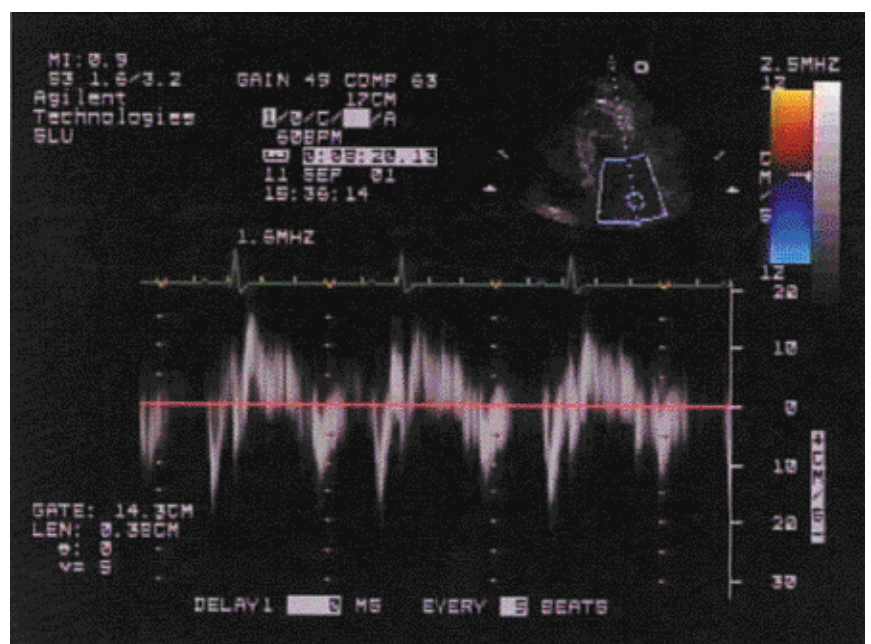


FIGURE 10. Continuous wave Doppler displays stenotic lesions differently if they are dynamic or fixed obstructions. On the left, a dynamic obstruction as seen in a left ventricular outflow tract obstruction caused by systolic anterior motion of the mitral valve. On the right, a fixed obstruction as commonly seen in aortic stenosis.

FIGURE 11. Tissue Doppler imaging is a relatively new technique used to assess myocardial velocity while suppressing blood flow signals.



On the left, we see a dynamic obstruction as would occur in a LVOT obstruction caused by systolic anterior motion of the mitral valve. On the right, a fixed obstruction is displayed as commonly seen in AS. Using CW Doppler for dynamic obstructions in hypertrophic cardiomyopathy have been well described.⁷⁻⁹

AORTIC REGURGITATION/INSUFFICIENCY (AR/AI)

Color flow interrogation of AI can be visualized from parasternal long, parasternal short, apical four-chamber view, and apical three-chamber view. Jet width measured from the parasternal long and short axes aids in assessing the severity of AI. From the apical windows, AI is displayed as a diastolic velocity above the baseline measuring at least 3.5 to 4 m/s. Measuring the slope of the CW AI jet using the pressure half-time measurement is another method of grading AI.¹⁰ PW Doppler sampling of the descending aorta aids in grading the severity. If significant diastolic reversals are seen, this indicates at least moderate-to-severe aortic regurgitation.

MITRAL STENOSIS

Both color and CW Doppler can be used to effectively evaluate mitral stenosis.¹¹ The spectral display measured by continuous wave Doppler shows mitral stenosis as a diastolic high-velocity jet above the baseline. Pressure half-time and mean pressure gradient analysis techniques are used to calculate mitral valve areas in mitral stenosis. Doppler velocities of mitral stenosis range from 1 m/s to greater than 2.5 m/s. Because this waveform which represents mitral stenosis is displayed above the baseline in diastole, the spectral Doppler display velocity looks very similar to aortic insufficiency (AI). To avoid this mistake, note that AI velocities are greater than 4 m/s, and AI begins immediately after the aortic valve closes, whereas the mitral stenosis waveform begins later after the no-flow time of isovolumic relaxation time.

MITRAL VALVE INFLOW

Flow velocities through the mitral valve in situations without mitral stenosis are measured using PW Doppler. This enables the flow only at the tips of the mitral valve to be used to assess diastolic function and filling patterns.¹²⁻¹⁵ This technique has become increasingly important because it allows the cardiologist to interpret information about left ventricular filling patterns and early diastolic dysfunction.

Additional measurements of *isovolumic relaxation time* and *pulmonary vein waveforms* can also aid in the assessment of diastolic function. CW from the apical four-chamber window with the cursor placed between the mitral and aortic valves allows interrogation of the isovolumic relaxation time.

PW Doppler 1 cm into the pulmonary veins from the

apical four-chamber window provides information about diastolic function and MR. The systolic, diastolic, and atrial reversal components of pulmonary veins indicates left ventricular filling patterns associated with measures of diastolic dysfunction. Pulmonary vein reversals are indications of severe mitral regurgitation.

MITRAL REGURGITATION

CW Doppler assessment of MR provides an indication of the severity of this condition and velocity of the blood. The color Doppler used in Figure 1 displays the typical presentation of MR in a mosaic color pattern. The spectral display shows MR below the baseline that usually measures at least 4.5 to 5 m/s. The more severe the MR, the brighter the spectral MR jet will appear. On the right side of Figure 5, severe MR is demonstrated by a very bright spectral display of MR seen below the baseline. Measurements of mitral inflow, pulmonary veins, regurgitant fraction, regurgitant orifice area, and proximal iso-velocity surface area (PISA) help to quantitate MR.

TRICUSPID STENOSIS (TS)

Doppler assessment of TS is achieved using both color and CW Doppler. The spectral display of TS is similar to mitral stenosis, that is, above the baseline and in diastole.

TRICUSPID REGURGITATION (TR)

Assessing TR in multiple views is important to accurately measure the highest velocity. CW Doppler measurement of TR measures peak velocity and is displayed below the baseline in systole. This Doppler measurement aids in predicting right ventricular systolic pressure.¹⁶ Color and PW Doppler measurements of hepatic veins aid in grading the severity of TR.

PULMONARY STENOSIS (PS)

CW Doppler assessment of PS is displayed below the baseline in systole when measured from the parasternal views. Peak velocity and measurement of peak gradient aid in assessing the severity of PS.

PULMONARY INSUFFICIENCY (PI)

Color Doppler visualization of PI is seen commonly. CW interrogation provides a spectral waveform similar to that of AI, except that PI is of lower velocity. The end-diastolic velocity reflects the right ventricular diastolic pressure. Table 3 presents the normal velocity values with increasing stenosis (m/sec) of the mitral, aortic, tricuspid, and pulmonic valves.

TABLE 3. Normal Velocity Values with Increasing Stenosis (m/sec) of Mitral, Aortic, Tricuspid, and Pulmonic Valves

Valve	Normal Velocities (m/sec)	Mild Stenosis	Moderate Stenosis	Severe Stenosis
Mitral Inflow	0.6 - 1.0	1.0 - 1.5	1.6 - 2.5	2.5 +
Left Ventricular Outflow	0.7 - 1.2			
Aortic Outflow	1.0 - 1.8	2.0 - 3.0	3.0 - 4.0	4.0 +
Tricuspid Inflow	0.3 - 0.7	0.7 - 1.2	1.3 - 2.0	2.0 +
Pulmonic Outflow	0.6 - 0.9	1.0 - 2.7	2.7 - 4.0	4.0 +

CONCLUSION

From the early days of mapping regurgitant jet velocities, Doppler has progressed to using color flow mapping for a more broad assessment of blood flow. New techniques continue to develop within the field of Doppler. A more recent use of Doppler involves a new way of assessing the myocardial velocities (Figure 11). Using tissue Doppler imaging, the low velocity (<25 cm/s) and high-amplitude signals of myocardial walls are displayed with the excess information filtered out. This technique reduces the detection of blood flow velocities to enhance only myocardial velocities. This also allows additional information about how the ventricle relaxes and contracts in both normal and abnormal cardiac conditions.

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APPLICATION OF DOPPLER ULTRASOUND IN ECHOCARDIOGRAPHY POST TEST

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1. **What defines the speed that ultrasound travels through the body?**
 - a. Changes in color
 - b. The length and frequency of the wave
 - c. The Nyquist limit
 - d. The spectral display
2. **Multiplying the length of the wave and the frequency of the wave will compute the wave's**
 - a. velocity.
 - b. laminar flow.
 - c. turbulent flow.
 - d. Doppler shift.
3. **The Doppler effect describes the**
 - a. gain changes necessary when moving from continuous wave transducers to pulsed wave transducer information.
 - b. artifact common in Doppler ultrasound, which is most often observed in color Doppler.
 - c. frequency changes seen in ultrasound from the interaction of the beam with blood cells that is moving toward or away from the ultrasound transducer.
 - d. effect of the transducer beam changing the speed of the blood cells as it moves through tissue.
4. **The Doppler shift describes**
 - a. artifacts.
 - b. the difference between laminar and turbulent flow.
 - c. the difference between the observed frequency and the original frequency.
 - d. blood velocity over the limit of the display.
5. **To assess the Doppler shift in blood flow, the formula takes into account**
 1. the angle of the blood to the transducer.
 2. laminar versus turbulent flow.
 3. whether detection is from pulsed or continuous.
 - a. 1 only
 - b. 2 only
 - c. 3 only
 - d. 1, 2, and 3
6. **Turbulent flow**
 - a. results from blood cells traveling at a uniform speed.
 - b. is synonymous to laminar flow
 - c. is demonstrated by red and blue.
 - d. is demonstrated by mosaic colors.
7. **The returning velocity signals of CW Doppler offers information on**
 1. time.
 2. velocity.
 3. the number of blood cells.
 4. the speed at which blood cells travel.
 - a. 2 only
 - b. 1 and 2
 - c. 2 and 4
 - d. 1, 2, 3, and 4
8. **The most accurate measurement of peak blood flow is obtained with**
 - a. continuous wave Doppler.
 - b. pulsed wave Doppler.
 - c. color Doppler.
 - d. spectral Doppler.
9. **A sampling of blood flow at one specific point in the heart is achieved using**
 - a. continuous wave Doppler.
 - b. pulsed wave Doppler.
 - c. color Doppler.
 - d. spectral Doppler.
10. **Which is an advantage of pulsed wave Doppler?**
 - a. It assesses the peak velocity.
 - b. The flow aliases when blood flow is too high.
 - c. It assesses blood flow in a specific area.
 - d. It detects high-velocity blood flow at all points along the sample cursor beam.
11. **In color flow Doppler, direction of flow is demonstrated with what colors?**
 - a. Blue toward, red away
 - b. Blue away, red toward
 - c. Green toward, yellow away
 - d. Yellow toward, green away
12. **The Doppler information is calculated by a method called**
 - a. volume averaging.
 - b. interpolation.
 - c. isovolumic relaxation.
 - d. auto-correlation.
13. **As a rule, the deeper the sample area, the**
 - a. more accurate the data acquired.
 - b. less information acquired.
 - c. shorter the time for the information to return.
 - d. longer the time for the information to return.
14. **To avoid missing a portion of the color flow box, the sample box should be**
 - a. less than 5 Hz.
 - b. less than 10 Hz.
 - c. at least 15 Hz.
 - d. at least 80 Hz.
15. **The Nyquist limit is dependent on the**
 - a. PRF.
 - b. focus.
 - c. filter.
 - d. BART.
16. **Aliasing occurs when the**
 - a. gain is set too high.
 - b. color box is too large.
 - c. filter is set too low.
 - d. nyquist limit is exceeded.

- 17. To optimize color flow Doppler detection of blood flow,**
- the color box should encompass the entire screen.
 - the gain should be very low.
 - narrow the sector to include only a small area of interest.
 - the filter should be high.
- 18. After placing the sample gate in the specific area of interest, listening for a strong audible signal will**
- provide an accurate diagnosis.
 - confirm accurate sample volume placement.
 - indicate poor placement.
 - not be of value.
- 19. Aortic valve area is calculated using Doppler assessment of**
- pulsed wave left ventricular outflow.
 - continuous wave aortic valve Doppler.
 - two-dimensional measurement of left ventricular outflow diameter.
- 1 only
 - 2 only
 - 3 only
 - 1, 2, and 3
- 20. Using continuous wave Doppler, aortic stenosis should be evaluated from each view except**
- parasternal short axis.
 - apical four-chamber.
 - suprasternal notch.
 - right sternal border.
- 21. The severity of aortic regurgitation/insufficiency may be graded with**
- PW Doppler.
 - CW Doppler.
 - Color Doppler.
 - any of the above.
- 22. AI velocities are greater than**
- 1 m/s.
 - 2.5 m/s.
 - 4 m/s.
 - 10 m/s.
- 23. Interrogation of the isovolumic relaxation time is allowed by**
- imaging the subcostal four-chamber view.
 - continuous wave Doppler from the apical four-chamber window with the cursor placed between the mitral and aortic valves.
 - apical four-chamber, suprasternal notch and right sternal border views.
 - pulsed wave Doppler from the four-chamber view.
- 24. The spectral display of tricuspid stenosis is similar to that of mitral stenosis**
- below the baseline and in diastole.
 - below the baseline and in systole.
 - above the baseline and in diastole.
 - above the baseline and in systole.

25. Doppler imaging is used to

- assess myocardial velocities.
 - gain additional information about how the ventricle relaxes and contracts in both normal and abnormal cardiac conditions.
 - make a broad assessment of blood flow.
- 1 only
 - 2 only
 - 3 only
 - 1, 2, and 3



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APPLICATION OF DOPPLER
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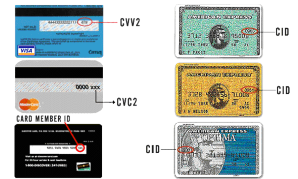
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