Pulsed Wave Doppler of Cardiac Valves

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Abstract

Despite newer techniques like tissue Doppler and speckle tracking, the need for a spectral Doppler still exists. It can give parameters that are not possible by newer techniques like peak systolic velocity and the ratio of time and velocity. In this article, we discuss the technique for doing pulsed wave Doppler for fetal cardiac valves.

Keywords
- fetal cardiac Doppler
- fetal TIE index
- fetal MPI
- fetal echo
- fetal PR interval
- fetal semilunar valves

Introduction

Even after the invention of newer techniques like tissue Doppler and speckle tracking, the need for a spectral Doppler still exists. It can give parameters that are not possible by newer techniques like peak systolic velocity and the ratio of time and velocity. In this article, we will discuss the proper technique for doing pulsed wave Doppler for fetal cardiac valves. The most significant advantage of assessing cardiac valves by pulsed wave Doppler is that the blood flow across these valves can be aligned in standard views with the line of insonation with minimal manipulation from our strandrd views. This gives us absolute values.

The essential step in getting a sound pulse wave Doppler waveform in fetal echocardiography is to have the correct magnification, that is, only the fetal thorax should occupy the whole screen. Blood flow across the valve should align with the insonation line. If this is impossible, an angle correction can be applied, but an angle correction of less than 15 degrees had more reliable and reproducible results than an angle correction of less than 30 degrees.[1,2] The gate size should not be too small to miss out on the velocities, and at the same time, it should not be too big to include endocardial movements. The ideal gate is 2 mm in the second trimester and 3 to 4 mm in the third trimester.[3,4] The ideal view for obtaining the perfect waveform and exact site for the gate placement differs from valve to valve, which we will discuss in detail in this review article.

Atrioventricular Valves

Mitral Valve

Ideal View

Apical or basal four-chamber view. The mitral valve should be perpendicular to the ultrasound beam.

Gate Placement

Place the sample gate into the left ventricle, apical to the mitral valve as shown in ►**Fig. 1**. Switch the color Doppler and place the gate precisely on the brightest point to get peak velocity.[3]

Waveform: diastolic blood flow coming into the ventricle is seen as two waves. The first wave is the E wave, which represents early diastolic ventricular filling because of the passive flow of blood from the left atrium into the left ventricle. The second wave is the A wave, which represents late diastolic ventricular filling because to active left atrial contraction. Since fibrous continuity exists between the mitral and aortic valves, the aortic flow is seen in the mitral

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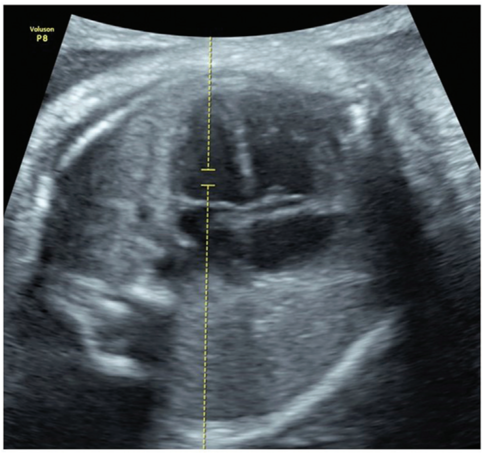


Fig. 1 Correct technique for gate placement for mitral valve spectral Doppler (color Doppler is switched off for better understanding of the position).

wave flow velocity waveform in the opposite direction.[3] (i.e., if the mitral flow is above the baseline, the aortic flow will be below the baseline) This wave is denoted as the S wave in ►**Fig. 2**.

From the beginning of one E wave to the next E wave is one cardiac cycle. In this, E wave plus A wave is an inflow, which should typically contribute to 40 to 50% of the cardiac cycle.

Tricuspid Valve

Ideal View

Apical or basal four-chamber view. The tricuspid valve should be perpendicular to the ultrasound beam.

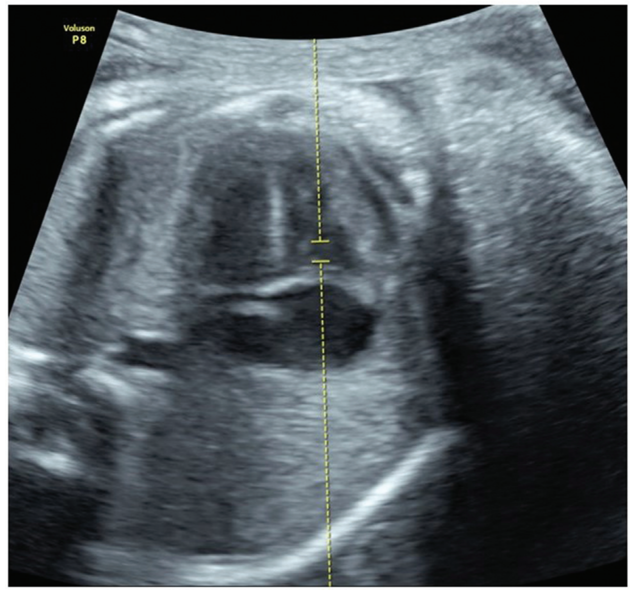


Fig. 3 Correct technique for gate placement for tricuspid valve spectral Doppler (color Doppler is switched off for better understanding of the position).

Gate Placement

Place the sample gate in the right ventricle, apical to the tricuspid valve as shown in ►**Fig. 3**. Switch on the color Doppler and place the gate precisely on the brightest point to get peak velocity.[3]

Waveform

►**Fig. 4** demonstrates the diastolic blood coming into the right ventricle as two waves. The first wave is the E wave,

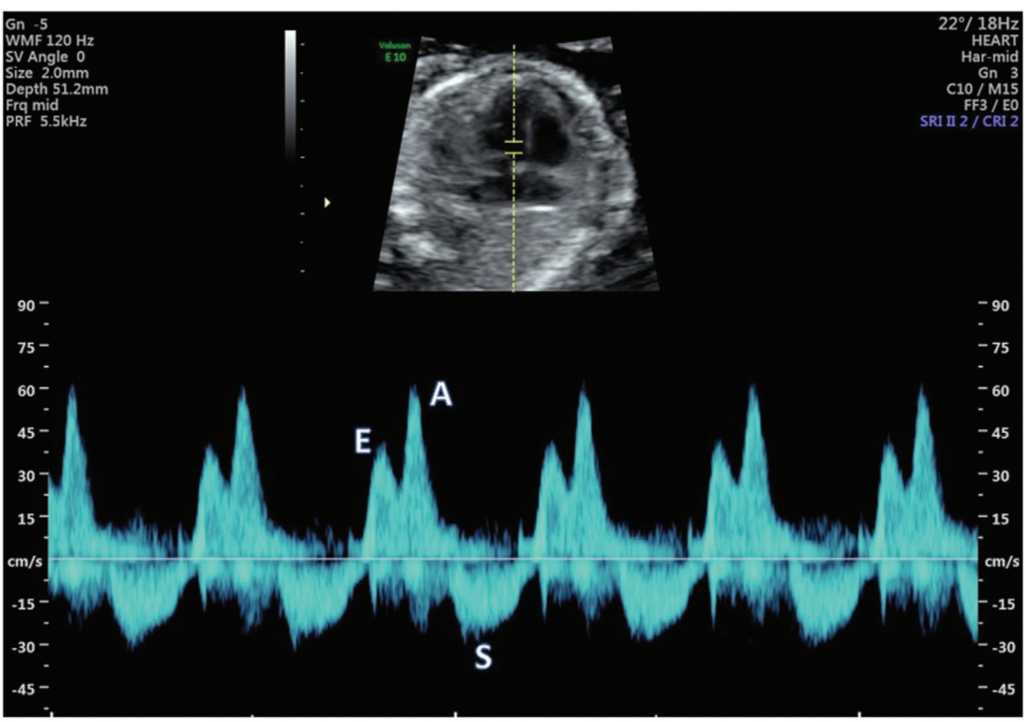


Fig. 2 Normal mitral Doppler wave pattern. E wave denotes the early diastolic ventricular filling. A wave denotes late diastolic ventricular filling. S wave denotes the aortic flow.

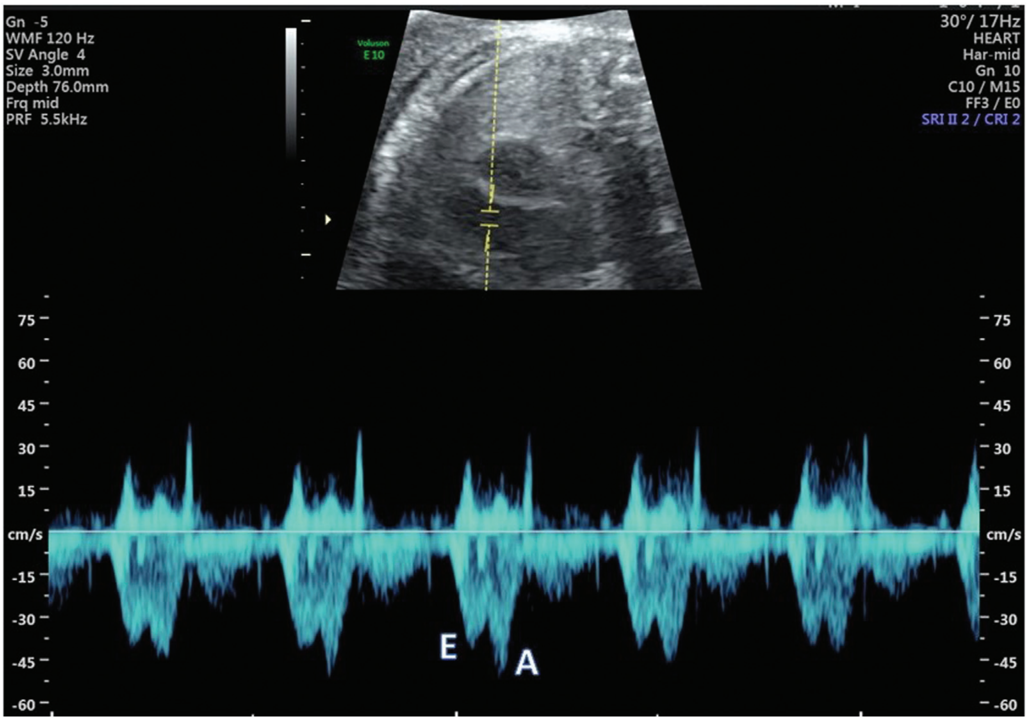


Fig. 4 Normal tricuspid Doppler wave pattern. E wave denotes the early diastolic ventricular filling. A wave denotes late diastolic ventricular filling. (Since it is the basal four-chamber view, the waves are seen below the baseline).

which represents early diastolic ventricular filling because of passive flow of blood from the right atrium into the right ventricle. The second wave is the A wave, which represents the late diastolic ventricular filling due because to active right atrial contraction. Due to the subpulmonary conus, which separates the pulmonary valve from the tricuspid valve, pulmonary flow is not seen in the tricuspid Doppler in the second and third trimester. Due to the close proximity of structures in the first trimester pulmonary flow is seen in the tricuspid valve Doppler.[3]

E/A Ratio

In fetal life, the early ventricular filling is always less than late ventricular filling, that is, the E wave is smaller than the A wave till term. So, the E/A ratio is less than 1, but as the gestation advances, blood shifts from late diastole to early diastole, resulting in an increase in passive ventricular filling (early) compared to active (late) ventricular filling as shown in ►**Fig. 5**. This results in a change in the E/A ratio throughout gestation. There are nomograms available for this.[5]

Common conditions causing abnormal waveforms across the atrioventricular (AV) valves are shown in **Flowchart 1**.

Structural Heart Defects Causing Abnormality in Atrioventricular Valve Doppler

- Abnormal waveform across the mitral valve
  - Hypoplastic left heart syndrome with patent mitral valve
  - Critical aortic stenosis.
- Abnormal waveform across the tricuspid valve
  - Pulmonary atresia with intact septum associated with a hypoplastic right ventricle.
- Abnormal Doppler waveforms in both AV valves
  - Dilated and hypertrophic cardiomyopathies

Even though tricuspid regurgitation or mitral regurgitation is detected in pulse wave Doppler, it is primarily diagnosed by color Doppler. Because of high velocities in these conditions, continuous wave Doppler will be more helpful in looking at the maximum velocity of the regurgitation jet.

Semilunar Valves

Aortic Valve

Ideal View

From the five-chamber view, move the probe laterally, so that the aortic valve should be perpendicular to the ultrasound beam.

Gate placement: place the sample gate in the aorta, distal to the aortic valve, as shown in ►**Fig. 6A**. Switch on color Doppler and place the gate precisely on the brightest point to get peak velocity, as shown in ►**Fig. 6B**.

Waveform: a monophasic waveform is typical of semilunar valves. The flow across the aortic valve is shown in ►**Fig. 7**. Peak systolic velocity increases with gestation from 30 to 40 cm/second in the first trimester to 60 to 80 cm/second in the third trimester, and nomograms are available for this. Throughout gestation, peak systolic flow in

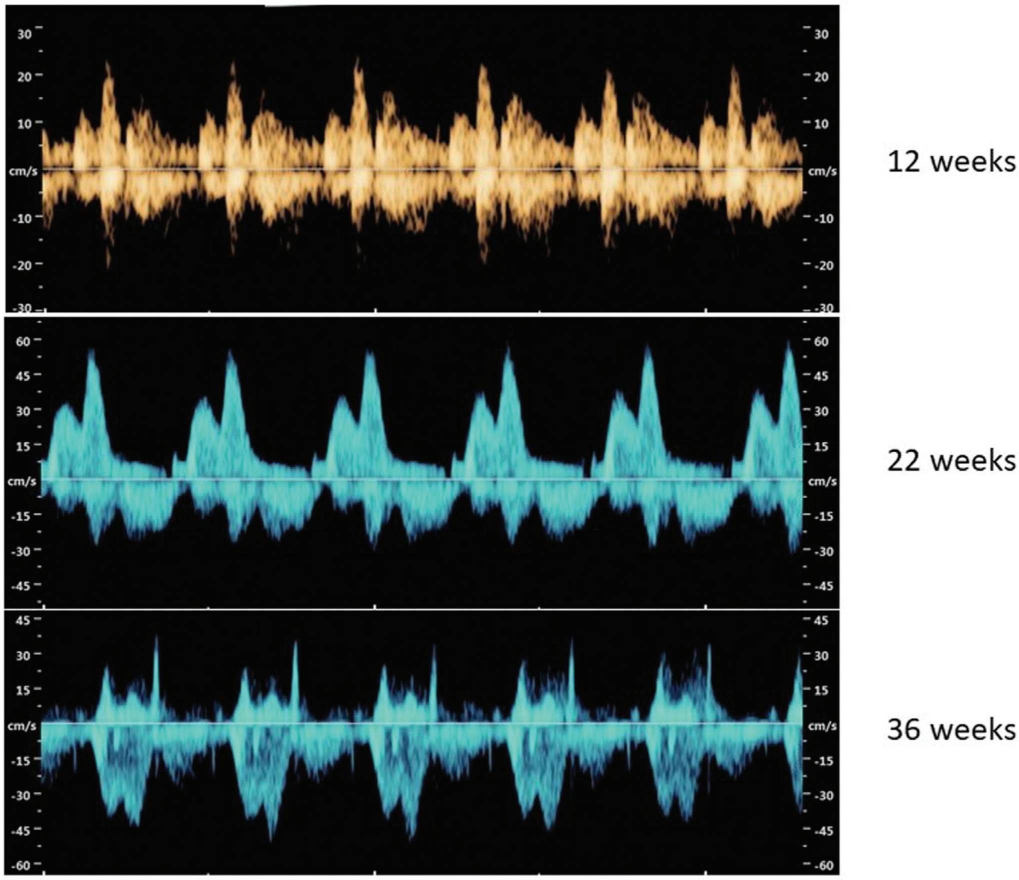
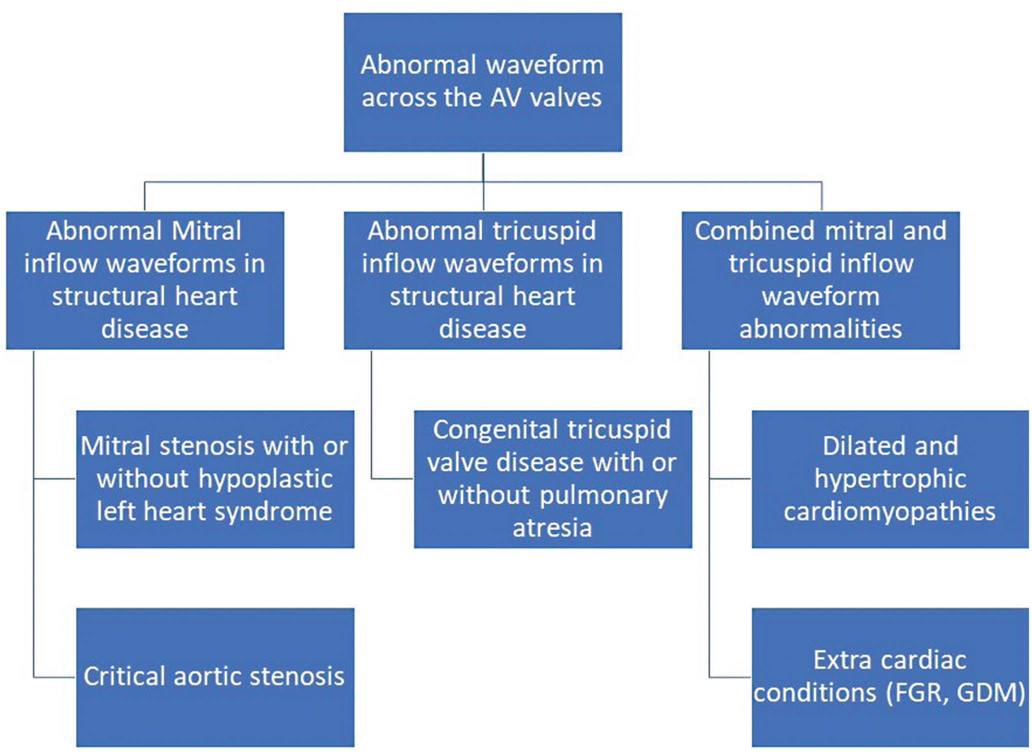


Fig. 5 Change in E/A ratio for every trimester.



Flowchart 1 Abnormal atrioventricular valve (AV) Doppler. FGR, fetal growth restriction; GDM, gestational diabetes mellitus.

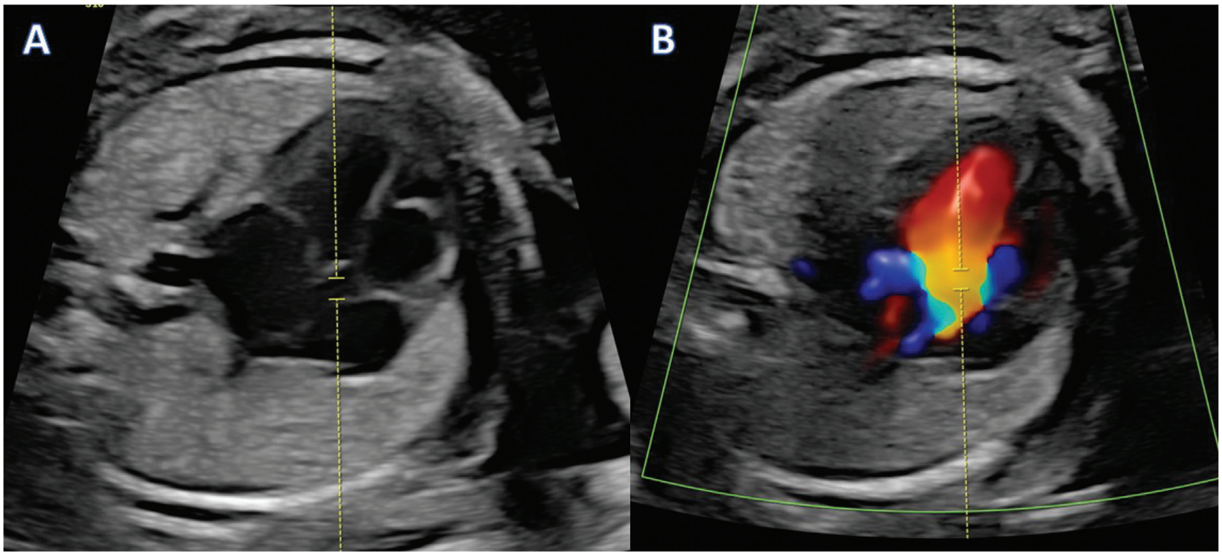


Fig. 6 (A and B) Correct technique for gate placement for aortic Doppler—Here the aortic valve is perpendicular to the line of insonation and the flow across the valve is in line with the line of insonation. After switching on the color Doppler, the gate is placed on the brightest point to get the maximum velocity.

the aorta is higher than in the pulmonary artery, which can be due to the increased pulmonary artery size compared to the aorta[3,6,7]

Pulmonary Valve

Ideal View

Image the pulmonary artery arising from the right ventricle, and then get the pulmonary valve perpendicular to the ultrasound beam.

Gate Placement

Place the sample gate in the pulmonary artery, distal to the pulmonary valve, as shown in ►**Fig. 8A**. Switch on the color Doppler and place the gate on the brightest point to get peak velocity, as shown in ►**Fig. 8B**.

Waveform

Monophasic waveform with peak systolic velocity smaller than the aortic Doppler. The peak systolic velocity increases with gestation from 30 to 40 cm/second in the first trimester

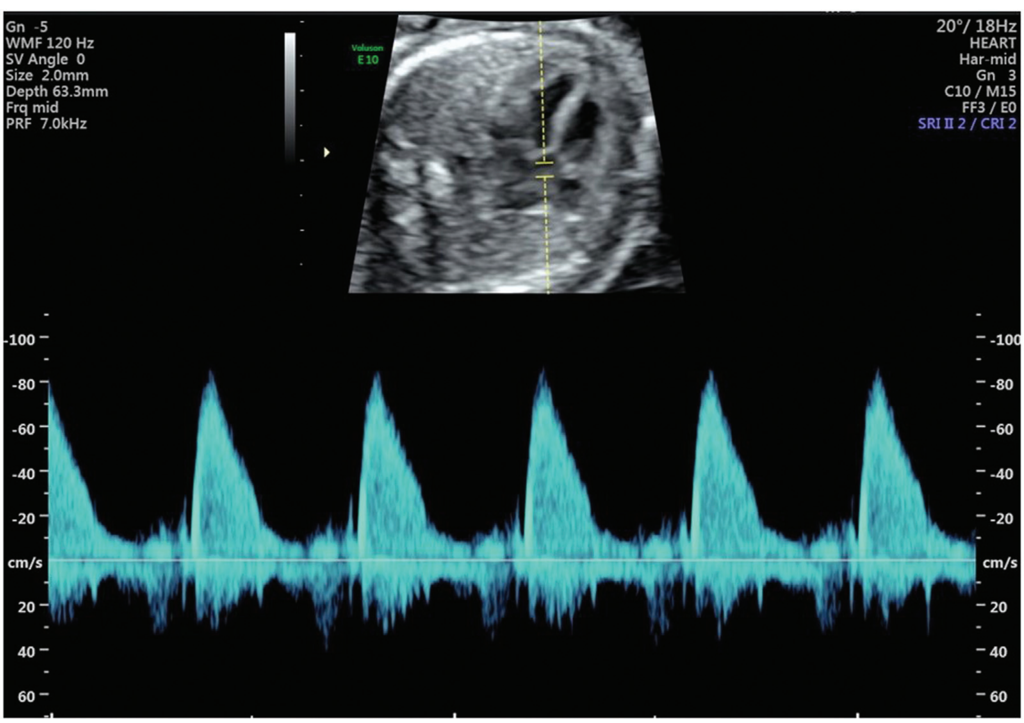


Fig. 7 Normal aortic valve Doppler wave pattern—monophasic waveform.

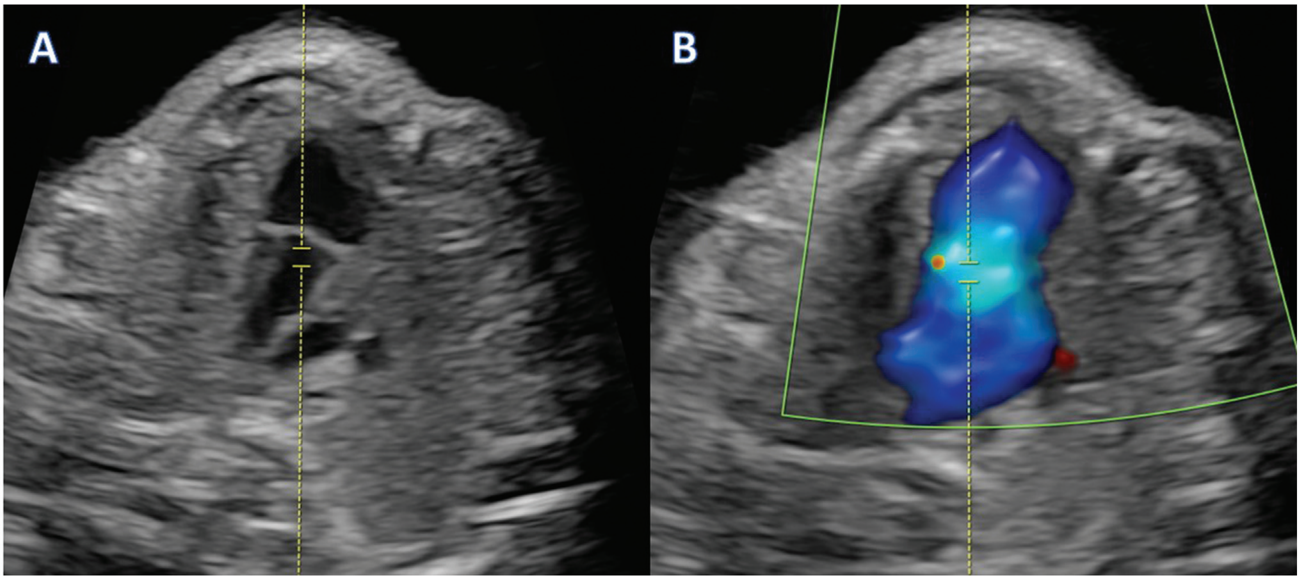


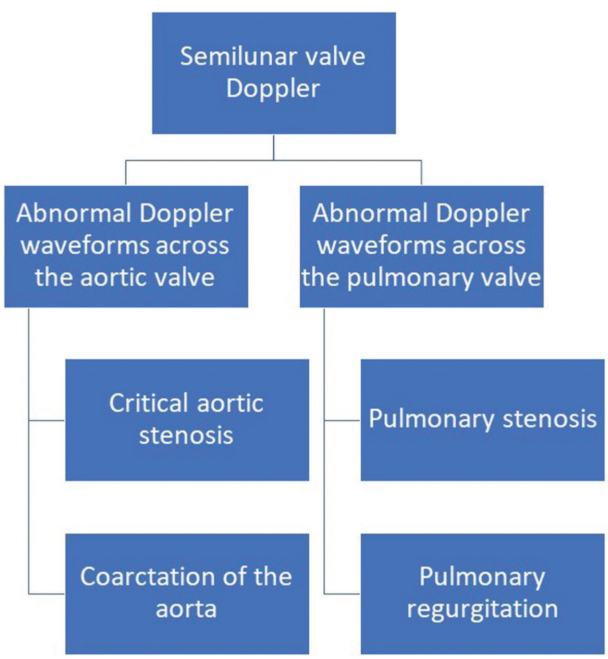
Fig. 8 (A and B) Correct technique for gate placement for pulmonary artery Doppler—Here the pulmonary valve is perpendicular to the line of insonation. After switching on the color Doppler, the gate is placed on the brightest point to get the maximum velocity.

to 60 to 80 cm/second in the third trimester, and nomograms are available for this.[5]

Common conditions causing abnormal waveforms across the semilunar valves are shown in **Flowchart 2**.

Myocardial Performance Index

The myocardial performance index (MPI) or TIE index is a practical, noninvasive index for global myocardial function assessment, and this is possible only with a spectral Doppler.



Flowchart 2 Abnormal semilunar valve Doppler.

Pulsed Doppler Technique for Myocardial Performance Index

Ideal view

From the apical five-chamber view (left ventricular outflow tract view), manipulate the probe so that the mitral and aortic valves should be perpendicular to the ultrasound beam, as shown in ►**Fig. 9B**.

Gate Placement

Place the sample gate in the left ventricle, close to and between the mitral and aortic valves.

Gate Size

This should be big enough to include blood flow from mitral and aortic valves. The ideal size is 2 to 4 mm.

Sweep Speed

Keep the sweep speed high so that only less than two cardiac cycles are seen on the screen.

Myocardial Performance Index Is Calculated by the Formula: Isovolumetric Contraction Time (ICT) + Isovolumetric Relaxation Time (IRT)/Ejection Time (ET)

ET denotes the systolic ejection time, that is, the time taken from the beginning of the S wave to the end of the same S wave.

IVCT denotes the isovolumetric contraction time, that is, the time between the end of an A wave to the beginning of a consecutive S wave.

IVRT denotes the isovolumetric relaxation time, that is, the time between the end of the S wave to the beginning of the E wave.

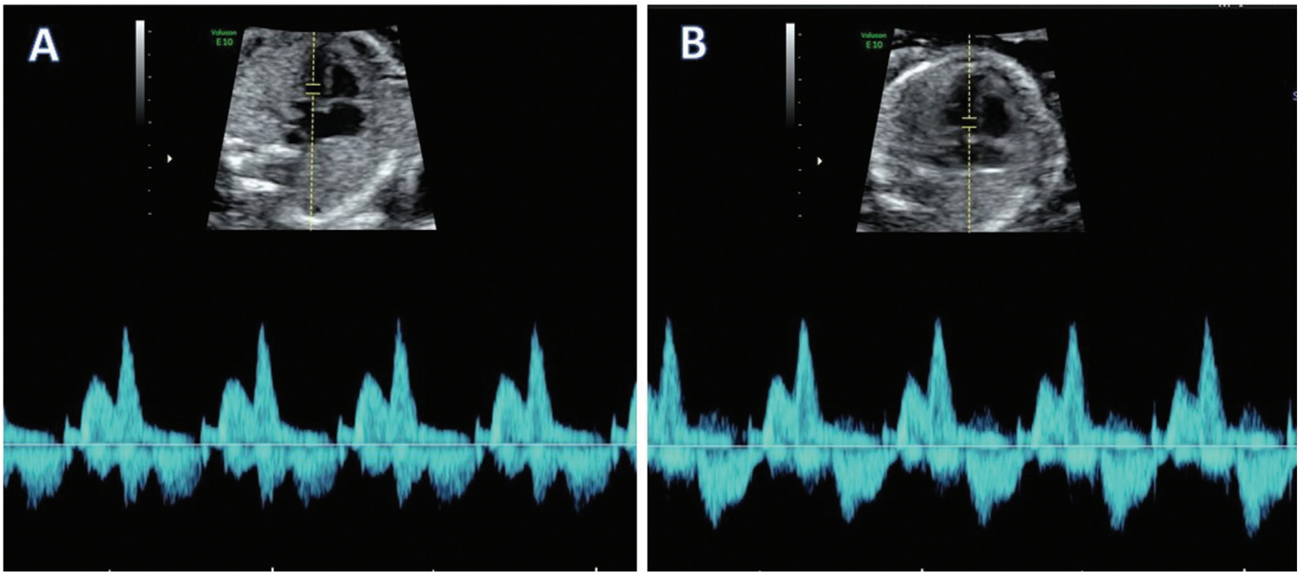


Fig. 9 (**A**) The aortic flow is not so evident in the technique used for the mitral valve Doppler. (**B**) An image obtained by the abovementioned method for a myocardial performance index, where both mitral and aortic Doppler waveforms are seen.

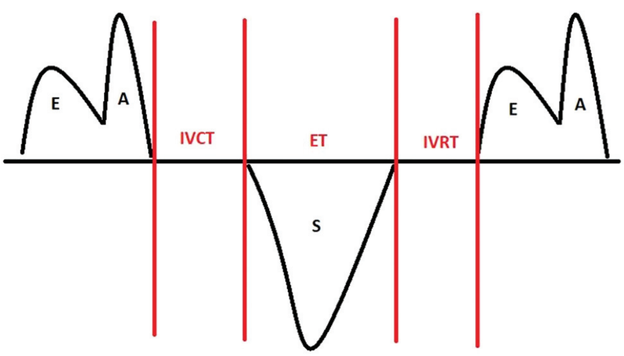
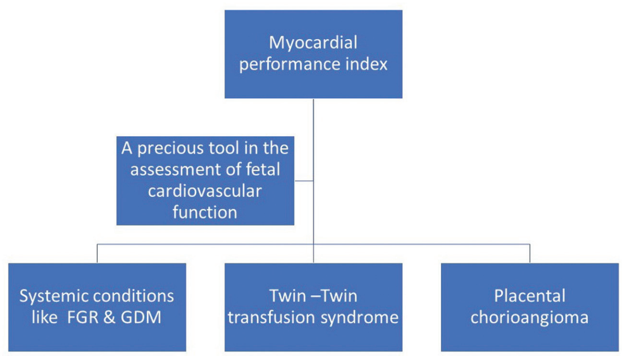


Fig. 10 Pictorial representation of the isovolumetric contraction time (IVCT), isovolumetric relaxation time (IVRT), and ejection time (ET).



Flowchart 3 Clinical implications of myocardial performance index.

►**Fig. 10** shows the spot where IVCT, IVRT, and ET are measured.

Always measure IVCT and IVRT separately and then calculate MPI; otherwise, conditions like long QT syndrome where only IVRT is increased will be missed. MPI can range from 0.28 to 0.44, with a mean of 0.36.[3]

Flowchart 3 shows the clinical implications of MPI

Clinical Implications of Myocardial Performance Index

1. *In precisely pinpointing twin-to-twin transfusion syndrome*: altered cardiac function in the recipient twin seems unique compared to the amniotic fluid or fetal growth discordance, which can be identified early by elevated MPI in the recipient twin.[8,9]
2. *Can help suspect gestational diabetes mellitus in isolated large for gestational age fetuses or fetuses with isolated polyhydramnios*: a systematic review and meta-analysis showed significantly lower mitral and tricuspid E/A ratios and higher MPI in pregnancies with gestational diabetes mellitus than in nondiabetic control pregnancies.[10]
3. *Helps identify fetuses that may develop hydrops due to cardiomyopathy in fetuses with placental chorioangioma*: a recent systematic review and meta-analysis on placental chorioangioma showed that fetuses who develop hydrops are at the highest risk for perinatal death. Hydrop can develop due to fetal anemia or cardiomyopathy in fetuses with placental chorioangioma. While middle cerebral artery Doppler can help evaluate fetal anemia, MPI will help evaluate fetal cardiac function.[11]

PR Interval

The PR interval is the time between the end of early diastolic filling, that is, the E wave, to the beginning of systole, that is, the S wave; this is equivalent to the electric occurrence during electrocardiogram from P to R wave time.

Methods

It can be measured in the five-chamber or superior vena cava—aorta view. We have explained in detail how to do a mitral-aortic Doppler in an apical five-chamber view in the MPI

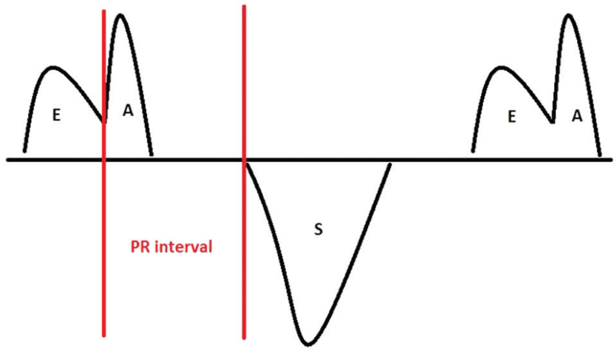


Fig. 11 Pictorial representation of normal PR interval. E wave denotes the early diastolic ventricular filling. A wave denotes late diastolic ventricular filling. S wave denotes the aortic flow. The PR interval is the tune between the end of early diastolic filling to the beginning of systole.

segment. The PR interval can be measured in the same image obtained for MPI.

►**Fig. 11** shows the pictorial representation of the PR interval and ►**Fig. 12** shows the PR interval obtained from a basal five chamber view waveform.

In normal fetuses, the PR interval ranges from 90 to 140 ms. It is gestational age-independent and fetal heart rate-independent, and it is increased in cases of first-degree heart block. It is a valuable tool for following up patients with autoimmune diseases fetuses.[3]

Conclusion

This review article describes the widely used practical and reproducible way to obtain and assess spectral Doppler waveform of valves. The appropriate gate size, gate location, and aligning the line of insonation with the direction of blood flow will help obtain a proper waveform.

Conflict of Interest
None declared.

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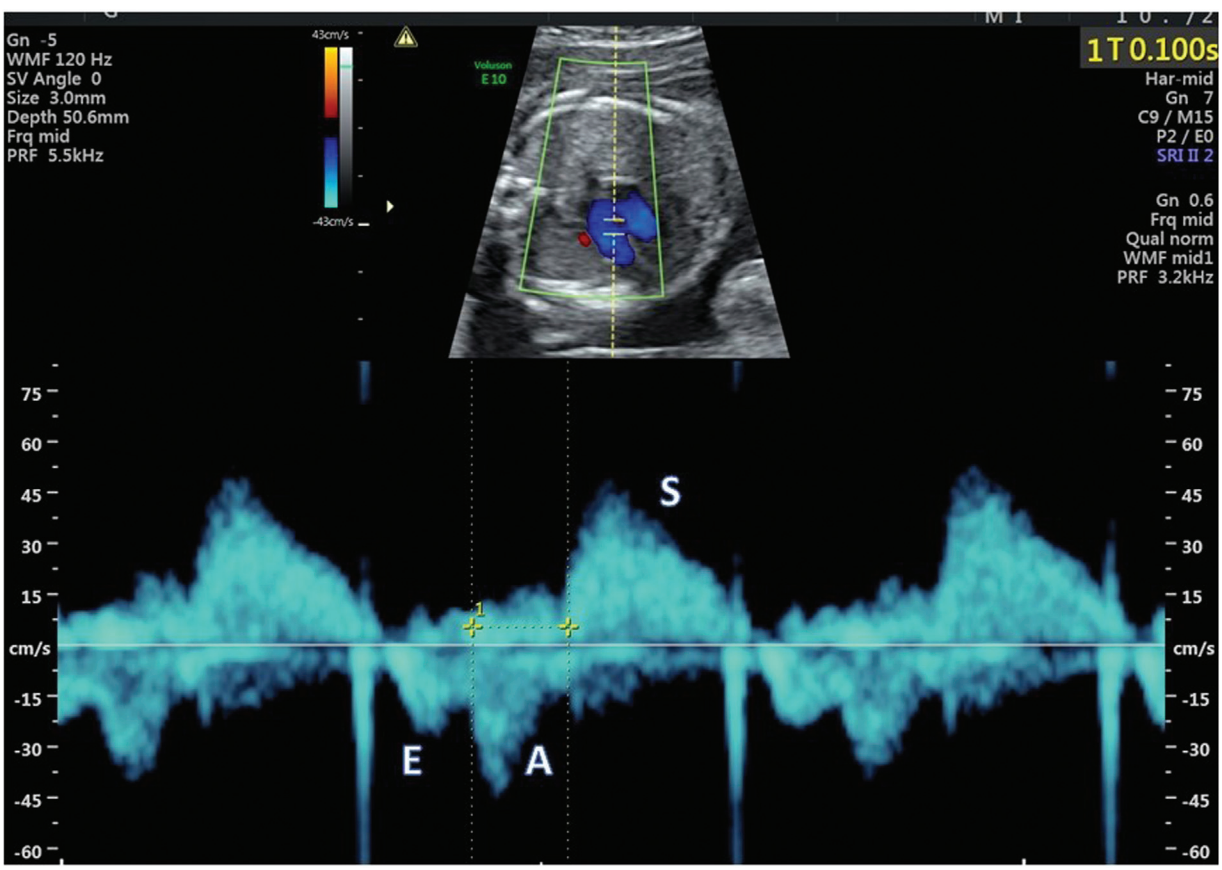

Fig. 12 Normal PR interval. E wave denotes the early diastolic ventricular filling. A wave denotes late diastolic ventricular filling. S wave denotes the aortic flow. PR interval is the time between the end of early diastolic filling to the beginning of systole.

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