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GUIDELINES

ISUOG Practice Guidelines: use of Doppler ultrasonography in obstetrics

Clinical Standards Committee

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SCOPE OF THE DOCUMENT

This document summarizes Practice Guidelines regarding how to perform Doppler ultrasonography of the fetoplacental circulation. It is of utmost importance not to expose the embryo and fetus to unduly harmful ultrasound energy, particularly in the earliest stages of pregnancy. At these stages, Doppler recording, when clinically indicated, should be performed at the lowest possible energy levels. ISUOG has published guidance on the use of Doppler ultrasound at the 11 to 13+6-week fetal ultrasound examination[1]. When performing Doppler imaging, the displayed thermal index (TI) should be ≤ 1.0 and exposure time should be kept as short as possible, usually no longer than 5–10 min and not exceeding 60 min[1].

It is not the intention of these Guidelines to define clinical indications, specify proper timing of Doppler examination in pregnancy or discuss how to interpret findings or the use of Doppler in fetal echocardiography. The aim is to describe pulsed Doppler ultrasound and its different modalities: spectral Doppler, color flow mapping and power Doppler, which are commonly used to study the maternal–fetal circulation. We do not describe the continuous wave Doppler technique, because this is not usually applied in obstetric imaging; however, in cases in which the fetus has a condition leading to very high-velocity blood flow (e.g. aortic stenosis or tricuspid regurgitation) it might be helpful in order to define clearly the maximum velocities by avoiding aliasing.

The techniques and practices described in these Guidelines have been selected to minimize measurement errors and improve reproducibility. They may not be applicable in certain specific clinical conditions or for research protocols.

RECOMMENDATIONS

What equipment is needed for Doppler evaluation of the fetoplacental circulation?

- Equipment should have color flow and spectral wave Doppler capabilities with onscreen display of flow velocity scales or pulse repetition frequency (PRF) and Doppler ultrasound frequency (in MHz).
- Mechanical index (MI) and TI should be displayed on the ultrasound screen.
- Ultrasound system should generate a maximum velocity envelope (MVE) showing the whole spectral Doppler waveform.
- MVE should be possible to delineate using automatic or manual waveform traces.
- System software must be able to estimate peak systolic velocity (PSV), end-diastolic velocity (EDV) and time-averaged maximum velocity from the MVE and to calculate the commonly used Doppler indices i.e. pulsatility (PI) and resistance (RI) indices and systolic/diastolic velocity (S/D) ratio. On the tracing, the various points included in the calculations should be indicated, to ensure correctly calculated indices.

How can the accuracy of Doppler measurements be optimized?

Pulsed wave Doppler ultrasonography

- Recordings should be obtained during absence of fetal breathing and body movements, and if necessary during temporary maternal breath hold.

- Color flow mapping is not mandatory, although it is very helpful in the identification of the vessel of interest and in defining the direction of blood flow.
- The optimal insonation is complete alignment with the blood flow. This ensures the best conditions for assessing absolute velocities and waveforms. Small deviations in angle may occur. An insonation angle of 10° corresponds to a 2% velocity error whilst a 20° angle corresponds to 6% error. When absolute velocity is the clinically important parameter (e.g. middle cerebral artery (MCA)) and an angle of > 20° is obtained, angle correction may be used, but this in itself may lead to error. In this case, if the recording is not improved by repeated insonations, a statement should be added to any report stating the angle of insonation and whether angle correction was carried out or that the uncorrected velocity is recorded.
- It is advisable to start with a relatively wide Doppler gate (sample volume) to ensure the recording of maximum velocities during the entire pulse. If interference from other vessels causes problems the gate can be reduced to refine the recording. Keep in mind that the sample volume can be reduced only in height, not in width.
- Similar to gray-scale imaging, the penetration and resolution of the Doppler beam can be optimized by adjusting the frequency (MHz) of the Doppler probe.
- The vessel wall filter, alternatively called 'low velocity reject', 'wall motion filter' or 'high pass filter', is used to eliminate noise from the movement of the vessel walls. By convention, it should be set as low as possible (≤ 50–60 Hz) in order to eliminate the low-frequency noise from peripheral blood vessels. When using a higher filter, a spurious effect of absent EDV can be created (see Figure 4b).
- A higher wall filter is useful for a well-defined MVE from structures like the aortic and pulmonary outflow tracts. A lower wall filter might cause noise, appearing as flow artifacts close to the baseline or after valve closures.
- Doppler horizontal sweep speed should be fast enough to separate successive waveforms. Ideal is a display of four to six (but no more than eight to 10) complete cardiac cycles. For fetal heart rates of 110–150 bpm, a sweep speed of 50–100 mm/s is adequate.
- PRF should be adjusted according to the vessel studied: low PRF will enable visualization and accurate measurement of low velocity flow; however, it will produce aliasing when high velocities are encountered. The waveform should fit at least 75% of the Doppler screen (see Figure 3).
- Doppler measurements should be reproducible. If there is obvious discrepancy between measurements, a repeat recording is recommended. Conventionally, the measurement closest to the expected is chosen for the report unless it is technically inferior.
- In order to increase the quality of Doppler recordings, a frequent update of the real-time gray-scale or color Doppler image should be performed (i.e. after confirming in the real-time image that the Doppler gate is positioned correctly, the two-dimensional (2D) and/or color Doppler image should be frozen when the Doppler waveforms are being recorded).
- Ensure a correct position and optimize the Doppler recording of the frozen 2D image by listening to the audible representation of the Doppler shift over the loudspeaker.
- Gain should be adjusted in order to see clearly the Doppler velocity waveform, without the presence of artifacts in the background of the display.
- It is advisable not to invert the Doppler display on the ultrasound screen. In the evaluation of the fetal heart and central vessels it is very important to maintain the original direction of the color flow and pulsed wave Doppler display. Conventionally, flow towards the ultrasound transducer is displayed as red and the waveforms are above the baseline on the MVE, whereas flow away from the transducer is displayed as blue and the waveforms are below the baseline.

Color directional Doppler ultrasonography

- As compared with gray-scale imaging, color Doppler increases the total power emitted. Color Doppler resolution increases when the color box is reduced in size. Care must be taken in assessing the MI and TI as they change according to the size and depth of the color box.
- Increasing the size of the color box also increases the processing time and thus reduces frame rate; the box should be kept as small as possible to include only the studied area.
- The velocity scale or PRF should be adjusted to represent the real color velocity of the studied vessel. When the PRF is high, low-velocity vessels will not be displayed on the screen. When a low PRF is applied incorrectly, aliasing will present as contradictory color velocity codes and ambiguous flow direction.
- As for gray-scale imaging, color Doppler resolution and penetration depend on the ultrasound frequency. The frequency for the color Doppler mode should be adjusted to optimize the signals.
- Gain should be adjusted in order to prevent noise and artifacts represented by random display of color dots in the background of the screen.
- Filter should also be adjusted to exclude noise from the region studied.
- The angle of insonation affects the color Doppler image; it should be adjusted by optimizing the position of the ultrasound probe according to the vessel or area studied.

Power Doppler and directional power Doppler ultrasonography

- The same fundamental principles as those for color directional Doppler apply.
- The angle of insonation has less effect on power Doppler signals; nevertheless, the same optimization process as for color directional Doppler must be performed.

- There is no aliasing phenomenon using power Doppler; however, an inappropriately low PRF may lead to noises and artifacts.
- Gain should be reduced in order to prevent amplification of noise (seen as uniform color in the background).

What is the appropriate technique for obtaining uterine artery Doppler waveforms?

Using Doppler ultrasound, the main branch of the uterine artery is easily located at the cervicocorporeal junction, with the help of real-time color imaging. Doppler velocimetry measurements are usually performed near to this location, either transabdominally[2,3] or transvaginally[3–5]. While absolute velocities have been of little or no clinical importance, semiquantitative assessment of the velocity waveforms is commonly employed. Measurements should be reported independently for the right and left uterine arteries, and the presence of notching should be noted.

First-trimester uterine artery evaluation (Figure 1)

1. Transabdominal technique

- Transabdominally, a midsagittal section of the uterus is obtained and the cervical canal is identified. An empty maternal bladder is preferable.
- The probe is then moved laterally until the paracervical vascular plexus is seen.
- Color Doppler is turned on and the uterine artery is identified as it turns cranially to make its ascent to the uterine body.
- Measurements are taken at this point, before the uterine artery branches into the arcuate arteries.
- The same process is repeated on the contralateral side.

2. Transvaginal technique

- Transvaginally, the probe is placed in the anterior fornix. Similar to the transabdominal technique, the probe is moved laterally to visualize the paracervical vascular plexus, and the above steps are carried out in the same sequence as for the transabdominal technique.

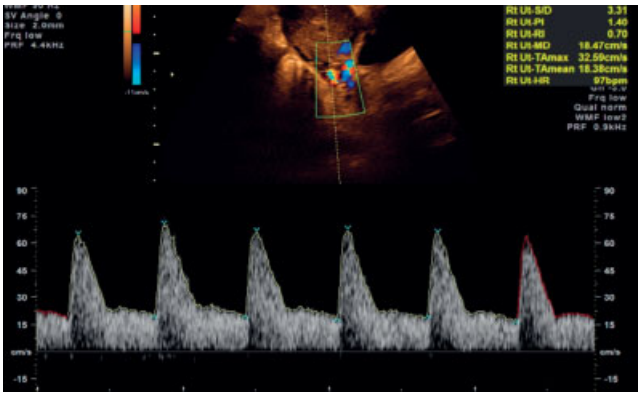

Figure 1 Waveform from uterine artery obtained transabdominally in first trimester.

- Care should be taken not to insonate the cervicovaginal artery (which runs from cephalad to caudad) or the arcuate arteries. Velocities over 50 cm/s are typical of uterine arteries, which can be used to differentiate this vessel from arcuate arteries.

Second-trimester uterine artery evaluation (Figure 2)

1. Transabdominal technique

- Transabdominally, the probe is placed longitudinally in the lower lateral quadrant of the abdomen, angled medially. Color flow mapping is useful to identify the uterine artery as it is seen crossing the external iliac artery.
- The sample volume is placed 1 cm downstream from this crossover point.
- In a small proportion of cases if the uterine artery branches before the intersection of the external iliac artery, the sample volume should be placed on the artery just before the uterine artery bifurcation.
- The same process is repeated for the contralateral uterine artery.
- With advancing gestational age, the uterus usually undergoes dextrorotation. Thus, the left uterine artery does not run as lateral as does the right.

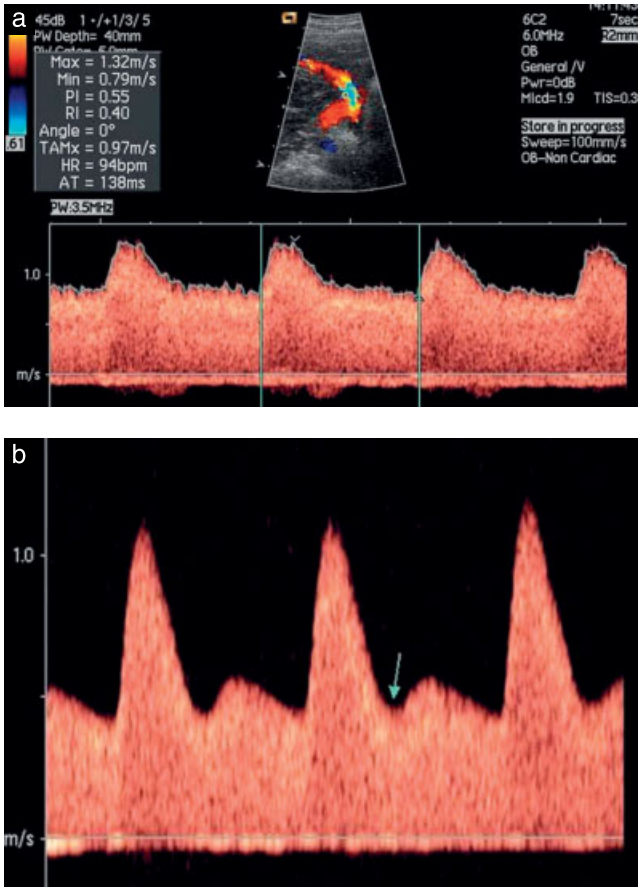

Figure 2 Waveforms from uterine artery obtained transabdominally in second trimester. Normal (a) and abnormal (b) waveforms; note notch (arrow) in Doppler signal in (b).

2. Transvaginal technique

- Women should be asked to empty their bladder and should be placed in the dorsal lithotomy position.
- The probe should be placed into the lateral fornix and the uterine artery identified, using color Doppler, at the level of the internal cervical os.
- The same should then be repeated for the contralateral uterine artery.

It should be remembered that reference ranges for uterine artery Doppler indices depend on the technique of measurement, so appropriate reference ranges should be used for transabdominal[3] and transvaginal[5] routes. The insonation techniques should closely mimic those used for establishing the reference ranges.

Note: In women with congenital uterine anomaly, assessment of uterine artery Doppler indices and their interpretation is unreliable, since all published studies have been on women with (presumed) normal anatomy.

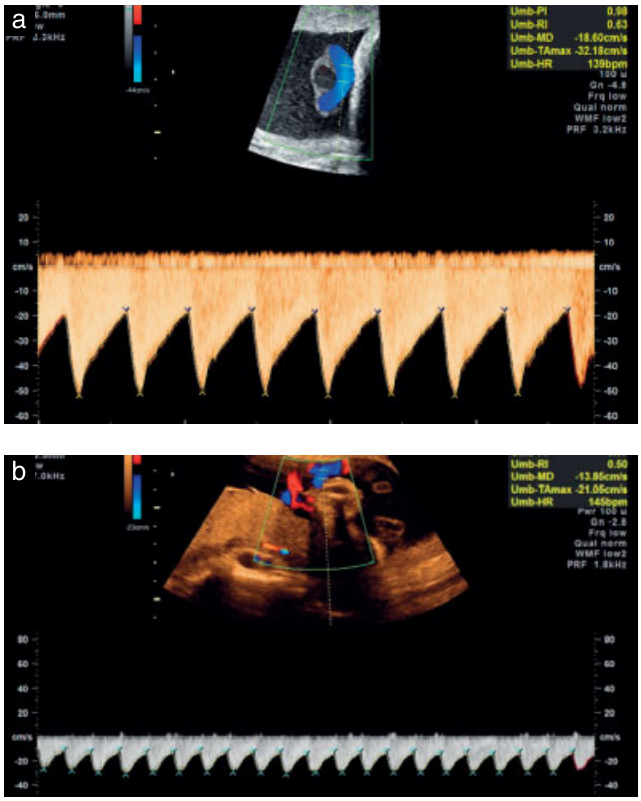

Figure 3 Acceptable (a) and unacceptable (b) umbilical artery waveforms. In (b), waveforms are too small and sweep speed too slow.

What is the appropriate technique for obtaining umbilical artery Doppler waveforms?

There is a significant difference in Doppler indices measured at the fetal end, the free loop and the placental end of the umbilical cord[6]. The impedance is highest at the fetal end, and absent/reversed end-diastolic flow is likely to be seen first at this site. Reference ranges for umbilical artery Doppler indices at these sites have been published[7,8]. For the sake of simplicity and consistency, measurements should be made in a free cord loop. However, in multiple pregnancies, and/or when comparing repeated measurements longitudinally, recordings from fixed sites, i.e. fetal end, placental end or intraabdominal portion, may be more reliable. Appropriate reference ranges should be used according to the site of interrogation.

Figure 3 shows acceptable and unacceptable velocity waveform recordings. Figure 4 shows the influence of vessel wall filter.

Note: 1) In multiple pregnancy, assessment of umbilical artery blood flow can be difficult, since there may be difficulty in assigning a cord loop to a specific fetus. It is better to sample the umbilical artery just distal to the abdominal insertion of the umbilical cord. However, the impedance there is higher than at the free loop and the placental cord insertion, so appropriate reference charts are needed.

2) In a two-vessel cord, at any gestational age, the diameter of the single umbilical artery is larger than when there are two arteries and the impedance is thus lower [9].

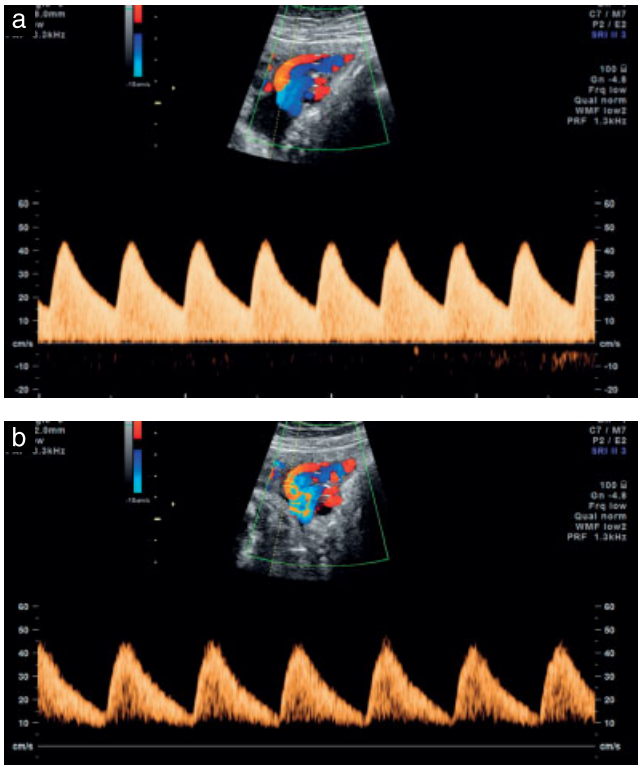

Figure 4 Umbilical artery waveforms obtained from same fetus, within 4 min of each other, showing: (a) normal flow and (b) apparently very low diastolic flow and absent flow signals at baseline, due to use of incorrect vessel wall filter (velocity reject is set too high).

What is the appropriate technique for obtaining fetal middle cerebral artery Doppler waveforms?

- An axial section of the brain, including the thalami and the sphenoid bone wings, should be obtained and magnified.
- Color flow mapping should be used to identify the circle of Willis and the proximal MCA (Figure 5).
- The pulsed-wave Doppler gate should then be placed at the proximal third of the MCA, close to its origin in the internal carotid artery[10] (the systolic velocity decreases with distance from the point of origin of this vessel).
- The angle between the ultrasound beam and the direction of blood flow should be kept as close as possible to 0° (Figure 6).
- Care should be taken to avoid any unnecessary pressure on the fetal head.
- At least three and fewer than 10 consecutive waveforms should be recorded. The highest point of the waveform is considered as the PSV (cm/s).
- The PSV can be measured using manual calipers or autotrace. The latter yields significantly lower medians than does the former, but more closely approximates published medians used in clinical practice[11]. PI is usually calculated using autotrace measurement, but manual tracing is also acceptable.

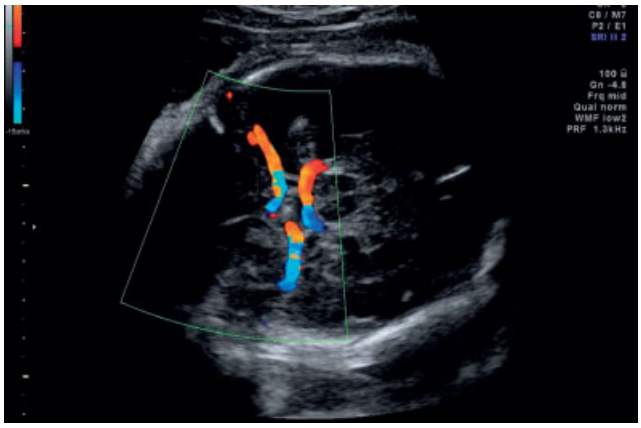

Figure 5 Color flow mapping of circle of Willis.

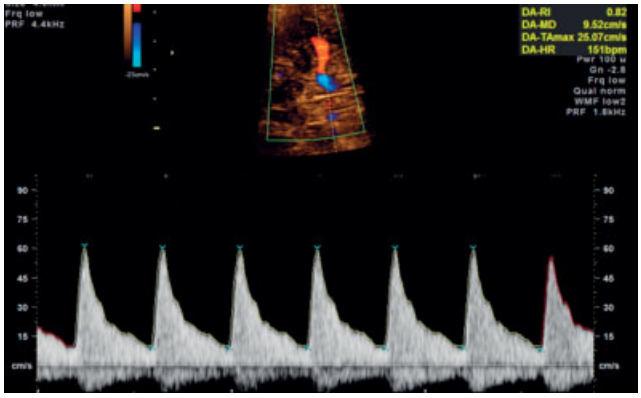

Figure 6 Acceptable middle cerebral artery Doppler shift waveform. Note insonation angle near 0°.

- Appropriate reference ranges should be used for interpretation, and the measurement technique should be the same as that used to construct the reference ranges.

What is the appropriate technique for obtaining fetal venous Doppler waveforms?

Ductus venosus (Figures 7 and 8)

- The ductus venosus (DV) connects the intra-abdominal portion of the umbilical vein to the left portion of the inferior vena cava just below the diaphragm. The vessel is identified by visualizing this connection by 2D imaging either in a midsagittal longitudinal plane of the fetal trunk or in an oblique transverse plane through the upper abdomen[12].
- Color flow mapping demonstrating the high velocity at the narrow entrance of the DV confirms its identification and indicates the standard sampling site for Doppler measurements[13].
- Doppler measurement is best achieved in the sagittal plane from the anterior lower fetal abdomen since alignment with the isthmus can be well controlled. Sagittal insonation through the chest is also a good option but more demanding. An oblique section provides reasonable access for an anterior or posterior insonation, yielding robust waveforms but with less control of angle and absolute velocities.
- In early pregnancy and in compromised pregnancies particular care has to be taken to reduce the sample volume appropriately in order to ensure clean recording of the lowest velocity during atrial contraction.
- The waveform is usually triphasic, but biphasic and non-pulsating recordings, though rarer, may be seen in healthy fetuses[14].
- The velocities are relatively high, between 55 and 90 cm/s for most of the second half of pregnancy[15], but lower in early pregnancy.

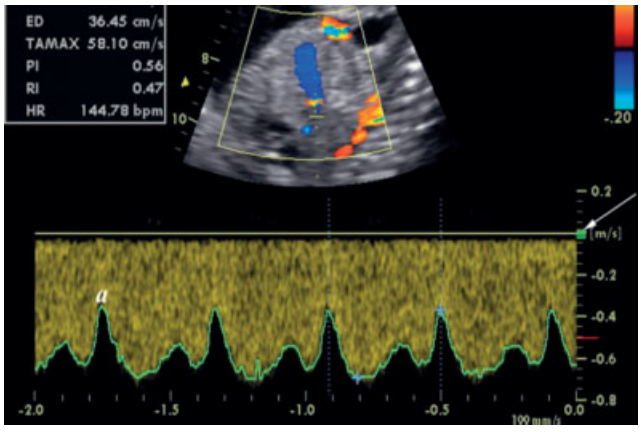

Figure 7 Ductus venosus Doppler recording with sagittal insonation aligning with the isthmic portion without angle correction. Low-velocity vessel wall filter (arrow) does not interfere with a-wave (a), which is far from zero line. High sweep speed allows detailed visualization of variation in velocity.

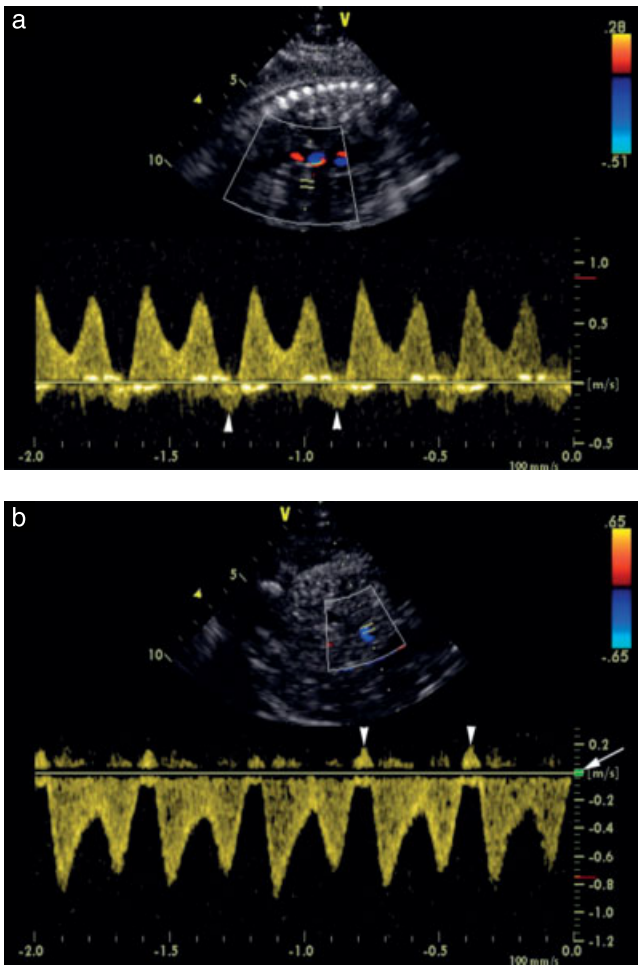

Figure 8 Ductus venosus recording showing increased pulsatility at 36 weeks (a). Interference, including highly echogenic clutter along the zero line, makes it difficult to verify reversed component during atrial contraction (arrowheads). (b) A repeat recording with slightly increased low-velocity vessel wall filter (arrow) improves quality and allows clear visualization of reversed velocity component during atrial contraction (arrowheads).

Which indices to use?

S/D ratio, RI and PI are the three well-known indices to describe arterial flow velocity waveforms. All three are highly correlated. PI shows a linear correlation with vascular resistance as opposed to both S/D ratio and RI, which show a parabolic relationship with increasing vascular resistance[16]. Additionally, PI does not approach infinity when there are absent or reversed diastolic values. PI is the most commonly used index in current practice. Similarly, the pulsatility index for veins (PIV)[17] is most commonly used for venous waveforms in the current literature. Use of absolute velocities rather than semiquantitative indices may be preferable in certain circumstances.

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