DOPPLER STUDY IN MATERNAL FETAL MEDICINE

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1. INTRODUCTION

Nowadays, Doppler assessments are widely used in Obstetrics and have become an important decision-making tool in some clinical conditions. As a technique with high variables, it is important to use standardized and systematic protocols aimed at improving its reproducibility.

Moreover, it is mandatory to acknowledge and understand the physiopathology and hemodynamic changes that occur with the different medical conditions that we want to evaluate, in order to correctly interpret the measurements that are taken. Doppler ultrasound is used to evaluate the hemodynamic changes associated with some pathologic conditions. For instance, the Doppler technique for monitoring foetal chronic hypoxia has been extensively studied in Obstetrics. Foetal chronic hypoxia leads to a gradual worsening of the foetus, generating a sequence of haemodynamic changes in different locations of the foetus, from the initial adaptation to this hostile environment to a progressive foetal surrender. Doppler is also generally used in abnormalities of placental implantation (preeclampsia, foetal growth restriction), and foetal anaemia. Due to physiological fluctuations of the Doppler, more than one observation is required for decision-making.

2. DOPPLER ASSESSMENT OF UTERINE ARTERY

Doppler study of uterine arteries can be performed either transvaginally or abdominally. Transvaginal examination is preferred until the 12th week of gestation, because the flow velocity wave obtained has a better quality and a more optimal insonation angle thanks to its higher proximity. Abdominal examination is preferred after the 20th week of gestation. It is important to use the reference curves created for each approach.

- Transvaginally: the probe should be placed at the anterior fornix of the vagina and then moved laterally through the middle of the uterine cervix to the level of the Internal Cervical Os (ICO). It is important to avoid the upper cervical branch and the lower arcuate artery.

- Abdominally: the probe should be placed longitudinally in the lower lateral quadrant of the abdomen, in parallel with the iliac crest and the uterine wall. A slight medial movement of the probe generates a false image of the uterine artery crossing the external iliac artery. The uterine artery should be ideally studied 1-2 cm distally to this point.

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- The vessel must be first visualized with colour Doppler, using a high-velocity scale (> 60 cm/s) for selective identification of the vessel.
- Adequate zoom should be applied so that the concerned area occupies more than 50% of the screen.
- Insonation angle must be less than 30º, being optimal when aligned with the direction of blood flow (0º).
- Three or more similar waves should be visualized, at an optimal Doppler Pulse Repetition Frequency (PRF). The waveforms should occupy at least 75% of the Doppler screen with the baseline in the lower quarter of the screen.
- The sample volume of the Doppler should be equal to the vessel diameter and should be located at the centre of the vessel.
- Doppler horizontal sweep speed should be fast enough to show 5 to 10 waves on the screen.

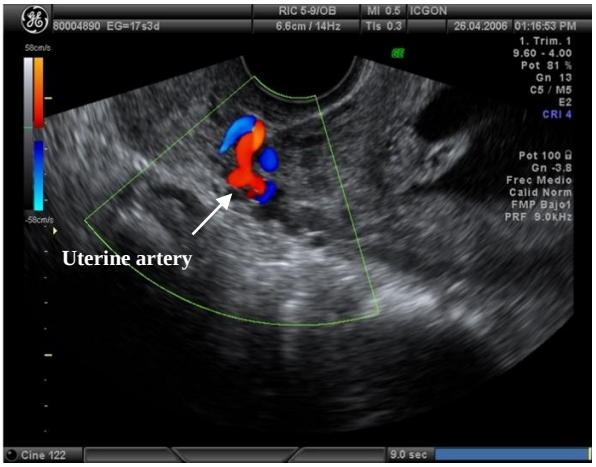

Figure 1: Vaginal view of location of the uterine artery, paramedial to the internal cervical os

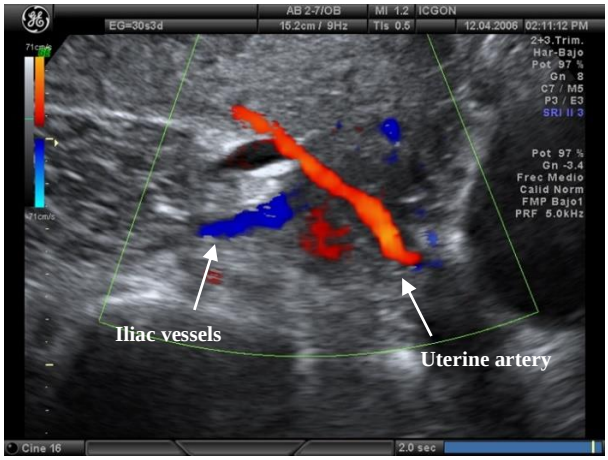

Figure 2: Abdominal view of location of the uterine artery, when it crosses the iliac vessels

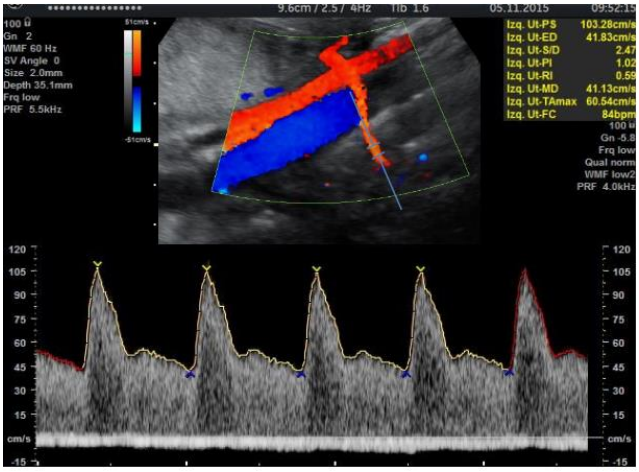

Figure 3: Insonation and obtention of the flow velocity wave of the uterine artery

PARAMETERS USED IN CLINICAL PRACTICE:

- Abnormal uterine flow: The uterine artery can be analysed both quantitatively (pulsatility index, PI) or qualitatively (presence/absence of notching). Notching consists of a lower early diastolic velocity before diastolic velocity increases to its maximum. Since the qualitative analysis has not improved the clinical performance, only the median PI between both uterine arteries should be used (left PI uterine artery + right PI uterine artery /2), analysed according to gestational-age-related reference ranges.

3. DOPPLER ASSESSMENT OF UMBILICAL ARTERY

The umbilical artery (UA) can be studied intraabdominally at the foetal end next to the foetal bladder, at a free loop, or at the placental insertion of the umbilical cord. The nearer to the placenta, the less pulsatility the UA will present. Although reference ranges for each location have been published, it is recommended to perform the Doppler study in a free loop of cord for different reasons: it is an easier technique, the majority of reference curves have been established for this location and all the randomized studies that have validated the utility of this assessment have been performed at this level. In twin pregnancies other sites can be studied, given the difficulty of assigning a loop of cord to a particular foetus, but it is important to always study the same location.

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- The vessel must be first visualized with colour Doppler, using a median velocity scale (between 20 to 40 cm/s) for selective identification of the vessel.
- Adequate zoom should be applied so that the concerned area occupies more than 50% of the screen.
- Insonation angle must be less than 30º, which is easy to do in this vessel. Although Doppler indexes are mathematically independent of this angle, an excessive insonation angle affects its accuracy.

- Both umbilical arteries can present more than 20% of different PI in 30% of the foetus in 2nd trimester, becoming lower as the gestation follows its course. In case of abnormal pulsatility, both arteries should be evaluated, and the best measurement should be reported.
- The measurement should be recorded in the absence of foetal breathing and body movements, since they can simulate an absence of the diastolic flow.
- The assessment of PI can be difficult to evaluate during significant bradycardia or tachycardia, because of the interference in the waveform.
- The sample volume of the Doppler should be equal to the vessel diameter and should be located at the centre of the vessel.
- Three or more similar waves should be visualized, at an optimal Doppler PRF. The waveforms should occupy at least 75% of the Doppler screen with the baseline in the lower quarter of the screen.
- Doppler horizontal sweep speed should be fast enough to show 5 to 10 waves on the screen.
- The study should be performed three times, and the better measurement (less pulsatile) should be chosen.

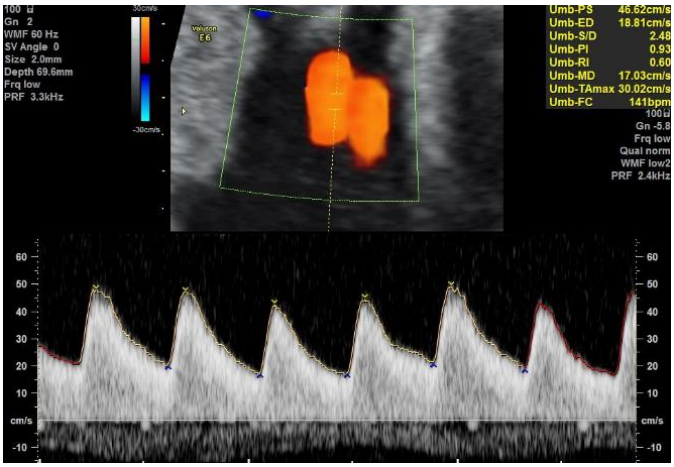

Figure 4: Insonation and obtention of the flow velocity wave of the umbilical artery. Observe the insonation angle close to 0º, the optimization of the colour scale to avoid aliasing and the adjustment of the velocity scale, aiming for the wave to fill 75% of the Doppler screen.

PARAMETERS USED IN CLINICAL PRACTICE:

- Pulsatility index (PI): defined as abnormal when PI is higher than the 95th percentile according to gestational age.
- Characteristics of the diastolic flow:
  - Absent diastolic flow: absent flow at least at some point of the diastole, constantly (more than 50% of the cycles), and persistently (at 2 different measurements separated by at least 12 hours) in both arteries.
  - Reverse diastolic flow: reverse flow at least at some point of the diastole, constantly (more than 50% of the cycles), and persistently (at 2 different measurements separated by at least 12 hours) in both arteries.

When measuring a pathological UA Doppler, both arteries should be measured, and it is the best measurement that should be recorded.

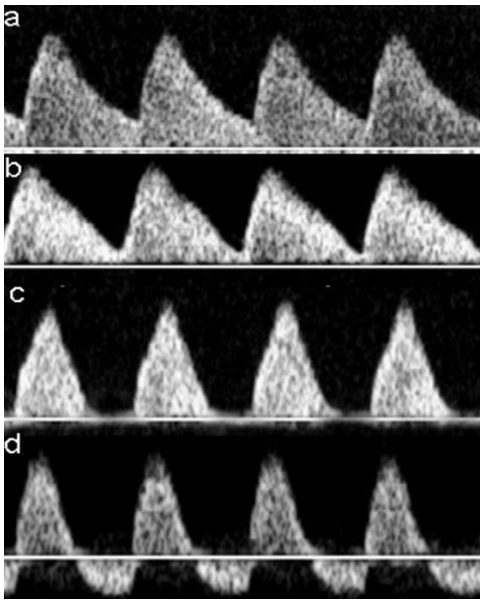

Figure 5: Progressive changes of the flow velocity wave of the umbilical artery when placental insufficiency occurs. (a): Normal diastolic flow; (b): Decreased but positive diastolic flow; (c): Absent diastolic flow; (d): Reverse diastolic flow.

4. DOPPLER ASSESSMENT OF MIDDLE CEREBRAL ARTERY

The middle cerebral artery (MCA) should be identified in an axial section of the brain at the level of the Willis polygon, viewing its trajectory from its origin in the internal carotid artery to its end next to the parietal bone. The more distal from the polygon, the more pulsatility the vessel will present. The vessel is divided distally into two to four branches, which makes its assessment less representative at this level. The assessment should be performed at the proximal portion next to the division from the internal carotid artery.

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- The vessel must be first visualized with colour Doppler, using a median velocity scale (between 20 to 40 cm/s) for selective identification of the vessel.
- Adequate zoom should be applied so that the concerned area occupies more than 50% of the screen.
- Insonation angle must be less than 15º and as close as possible to 0º, which is easy to perform in this vessel.
- The sample volume of the Doppler should be equal to the vessel diameter and be located at the centre of the vessel.
- The measurement should be recorded in the absence of foetal breathing and body movements.
- The assessment of PI can be difficult to evaluate in significant bradycardia or tachycardia, because of the interference in the waveform.
- It is important to avoid excessive pressure to the foetal head since it can increase the pulsatility index (PI) and decrease the peak systolic value (PSV). This phenomenon is more evident in the earlier weeks of gestation since the head is more deformable.

- Three or more similar waves should be visualized, at an optimal Doppler PRF. The waveforms should fill at least 75% of the Doppler screen with the basal line in the lower quarter of the axis.
- Doppler horizontal sweep speed should be fast enough to show 5 to 10 waves on the screen.
- The study should be performed three times, and the best measurement (more pulsatile) should be recorded. The mean value of three different measurements should be considered when evaluating PSV for foetal anaemia.

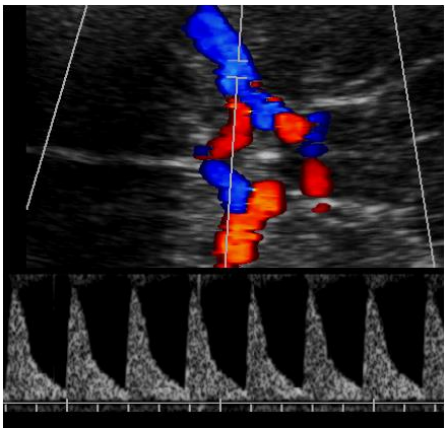

Figure 6: Insonation and obtention of the flow velocity wave of the middle cerebral artery. Observe the zoom, the insonation angle closer to 0º in the most proximal site next to the Willis polygon and the adjustment of the velocity scale aiming for the wave to fill 75% of the Doppler screen

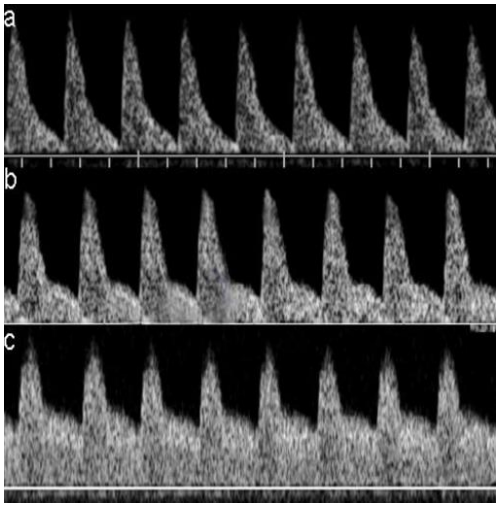

Figure 7: Progressive changes in the flow velocity wave of the middle cerebral artery when hypoxia. (a): Normal flow velocity wave with high resistance; (b): Moderate increase of diastolic velocities with a moderate decrease of pulsatility; (c): Marked increase of diastolic velocities with a marked decrease of pulsatility

PARAMETERS USED IN CLINICAL PRACTICE:

- Pulsatility index (PI): it evaluates cerebral vasodilation when foetal hypoxia is suspected. Cerebral vasodilation is considered when the MCA-PI is persistently lower than the 5th percentile according to the gestational age (in two determinations separated by more than 12 hours).
- Doppler Cerebroplacental Ratio (CPR: MCA-PI/UA-PI): Arterial redistribution of the brain perfusion should be considered when CPR is persistently lower than the 5th percentile according to the gestational age (in two determinations separated by more than 12 hours).
- Maximum velocity (Peak systolic value, PSV): An optimal evaluation requires insonation angles near 0º and never higher than 30º. Increased systolic velocities will be considered when the maximum velocity is constantly higher than 1.5 MoMs according to the gestational age.

5. DOPPLER ASSESSMENT OF THE AORTIC ISTHMUS

The aortic isthmus can be studied both in a sagittal section and in the three vessel-trachea view.

- In a sagittal section of the foetal chest, firstly it is important to identify the left ventricle and the aortic arch. The sample volume of the Doppler should be located some millimeters away from the origin of the left subclavian artery.

Figure 8: Aortic isthmus measured in a longitudinal aorta some millimetres away from the origin of the left subclavian artery

- In the three vessel-trachea view, the sample volume of the Doppler should be located just before the convergence between the aortic isthmus and the ductus arteriosus. It is an easy and fast way to study the aortic isthmus, especially in the last weeks of gestation, when the vertebral column makes the visualization of the aortic arch more difficult.

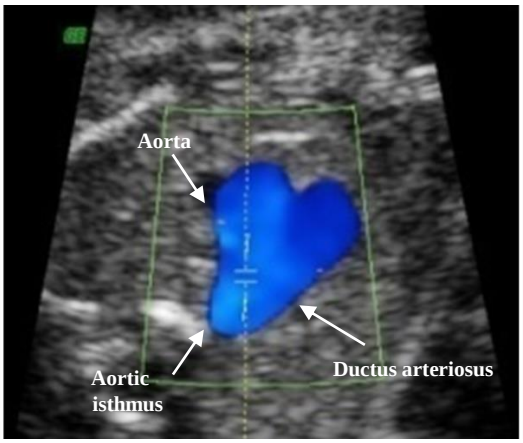

Figure 9: Insonation and flow velocity wave of aortic isthmus in the three vessel-trachea view. Observe the sample volume of the Doppler located just before the convergence between the aortic isthmus and ductus arteriosus

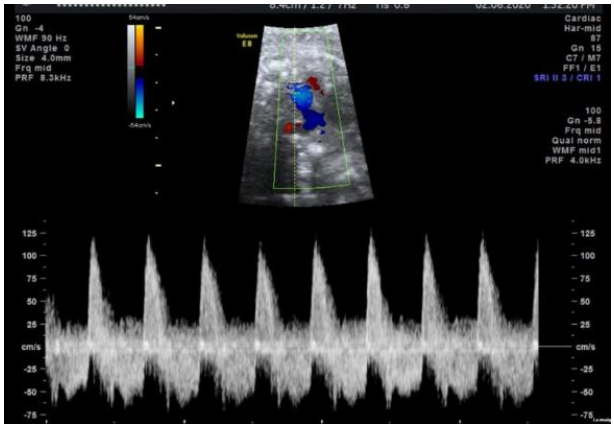

Figure 10: Presence of reverse diastolic flow

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- The vessel must be first visualized with colour Doppler, using a median-high velocity scale (>60 cm/s).
- Adequate zoom should be applied so that the concerned area occupies more than 50% of the screen.
- Insonation angle must be less than 30º, which is easier to perform in the three vessel-trachea view.
- The sample volume of the Doppler should be equal to the vessel diameter and be located at the centre of the vessel.
- The measurement should be recorded in the absence of foetal breathing movements.
- Three or more similar waves should be visualized, at an optimal Doppler PRF. The waveforms should fill at least 75% of the Doppler screen with the baseline in the lower quarter of the axis.
- It is important to differentiate it from the ductus arteriosus flow. In the first place, regarding its morphology, the aortic isthmus presents a protodiastolic notch and a major acceleration of the systole. Secondly, it helps to perform a precise anatomical location.

PARAMETERS USED IN CLINICAL PRACTICE:

- Reverse flow in aortic isthmus: the reverse flow in this vessel is defined when there is a presence of a reverse diastolic component bigger than the anterograde component in more than half of the cycles and at least at three successive measurements.

6. DOPPLER ASSESSMENT OF THE RIGHT VENOUS RETURN

GENERAL CHARACTERISTICS

- As the umbilical vein and inferior vena cava are low-velocity vessels, the wall filter should be fixed at the lower limit allowed for the machine (generally 50Hz), in order to detect low velocities of blood flow.
- In these studies, it is especially important to perform the evaluation when the foetus is not moving. Foetal breathing movements appear more pronounced than in arterial vessels due to the inner vessel wall.
- The sample volume of the Doppler should be equal to the vessel diameter and be located at the centre of the vessel.

6.1 Umbilical vein

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- The study can be assessed both in a free loop and at the intraabdominal portion before the start of the hepatic vein. When measured in a free loop, the waveform can simulate a pulsatile flow because of the proximity of the umbilical artery, which makes the study more feasible at the intraabdominal portion before the start of the hepatic vein. It is important to avoid the study at the umbilical site since the narrowness produced in the vessel generates physiologic pulsatility.
- Low velocities should be used (<20cm/s).
- The insonation angle should be less than 30º.

PARAMETERS USED IN CLINICAL PRACTICE:

- Pulsatile Flow: persistent pulsations (on two occasions separated by more than 12 hours), synchronous with cardiac flow. The pulsation can be bi or triphasic, the triphasic form being the waveform most correlated with foetal acidosis.

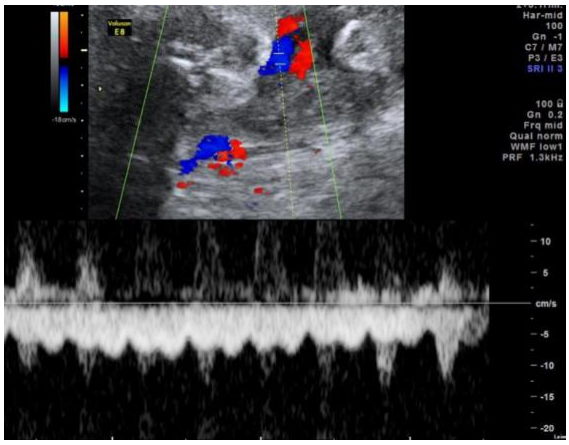

Figure 11: Umbilical venous flow with triphasic pulsations

6.2 Ductus venosus

- The study of the ductus venosus (DV) can be performed at a midsagittal view or in an oblique-transverse view of an abdominal foetus section. The transversus view facilitates insonation angles less than 30º. The ductus venosus starts from the umbilical vein and is easily identified by colour Doppler because it presents high velocities. The colour Doppler of the vessel turns yellow when changing color scales due to the increasing velocity that the blood flow presents.

It is essential to differentiate DV from hepatic veins because the waveform of suprahepatic veins can simulate a pathologic DV. For the differentiation of these two vessels, it is important to have a good knowledge of the foetal anatomy and remember that hepatic veins present lower velocities than DV. Sample volume should be also reduced when studying DV, aiming to avoid any possible contamination produced by adjacent vessels.

TECHNICAL ASPECTS OF THIS MEASUREMENT:

- Adequate zoom should be applied so that the concerned area occupies more than 50% of the screen.
- The Doppler sample has to be located at the most proximal point of the exit of the umbilical vein, which is the point that presents the highest velocities.
- The insonation angle should be less than 30º.
- The measurement should be recorded in the absence of foetal breathing and maternal movements.
- High-velocity scales should be used (40-60 cm/s).
- Three or more similar waves should be visualized, in an optimal Doppler PRF. The waveforms should fill at least 75% of the Doppler screen with the baseline in the lower quarter of the screen.
- Doppler horizontal sweep speed should be fast enough to show 5 to 10 waves on the screen.
- The study should be performed three times (ideally in different planes) and the best measurement (less pulsatile) is the one that should be recorded.

PARAMETERS USED IN CLINICAL PRACTICE:

- Pulsatility index: it will be defined as a pulsatile flow when the PI is higher than the 95th percentile according to the gestational age.

- Presence or absence of flow during the atrial contraction: this finding must be constant (more than 50% of the cycles) and persistent (on 2 occasions separated by more than 12 hours).

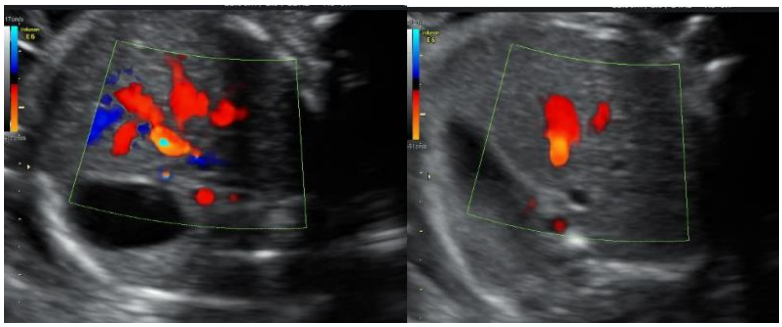

Figure 12: Effect of changing colour scales in the ductus venosus. Observe that adjusting velocities at a high range selectively marks the ductus and allows us to identify the optimal point of insonation, which corresponds with the highest velocity zone

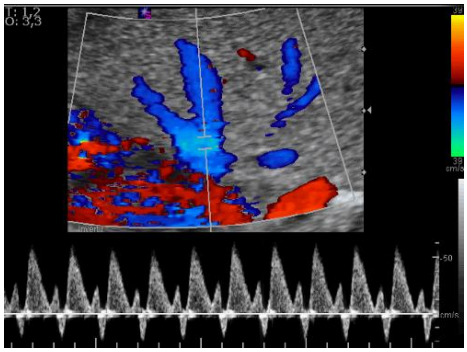

Figure 13: Insonation and flow velocity wave of one hepatic vein. Observe the higher velocities, which are differentiated from the inferior cava and the negative velocities during atrial contraction, which are differentiated from the ductus venosus

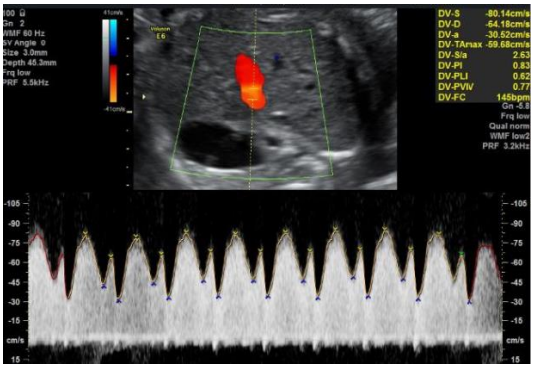

Figure 14: Insonation and obtention of the flow velocity wave of the ductus venosus. Observe the insonation site, which corresponds with the highest velocity identified by the aliasing

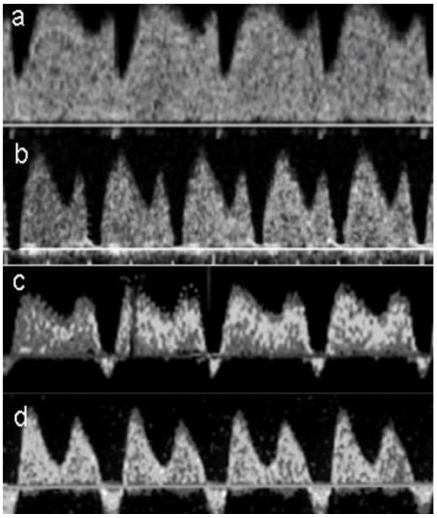

Figure 15: Progressive changes in the flow velocity wave of the ductus venosus in a condition of acidosis. (a): Normal flow velocity wave. (b): Absent flow during atrial contraction; (c): Moderate reverse flow during atrial contraction; (d): marked reverse flow during atrial contraction