Fetal Doppler: Umbilical Artery, Middle Cerebral Artery, and Venous System

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One of the most important applications of Doppler ultrasonography in obstetrics is the detection of fetal anemia in pregnancies complicated by either red-cell alloimmunization or by other causes of fetal anemia. Doppler of the umbilical artery also has prognostic value in pregnancies affected by twin–twin transfusion syndrome undergoing in-utero intervention. Another potential major application is the use of Doppler ultrasound in the management of intrauterine-growth-restricted fetuses. At the present time, there is no single test that appears superior to the other available tests for timing the delivery of the growth-restricted fetus. Therefore, the decision to deliver a fetus, especially at <32 weeks, remains mostly based on empirical management. Doppler may provide a more reliable and systematic basis for timing these deliveries. This review emphasizes the three following concepts: (a) normal and abnormal Doppler of the umbilical artery, middle cerebral artery, mitral and tricuspid valves, umbilical vein, and ductus venosus; (b) some clinical applications of Doppler sonography in obstetrics; and (c) potential future research of Doppler in obstetrics.

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Umbilical Artery

Umbilical artery angle independent indices (pulsatility index or systolic/diastolic (S/D) ratio) decrease with advancing gestation because of a decreased placental vascular resistance, which physiologically occurs with advancing gestation. In pathologic conditions, such as in intrauterine-growth-restricted (IUGR) fetuses, the umbilical artery waveforms change and the angle-independent indices become abnormal (values above their reference ranges). These changes reflect an increased placental vascular resistance. Giles and coworkers demonstrated that the number of placental arteries per high power field is decreased in cases of abnormal umbilical artery Doppler. Only in pregnancies with suspected intrauterine growth restriction and/or hypertensive disease of pregnancy does the use of umbilical artery Doppler reduce the number of perinatal deaths and unnecessary obstetric interventions.

Middle Cerebral Artery

Angle-independent indices differ among the different cerebral arteries. The middle cerebral artery is the most studied cerebral artery because (a) it is easy to sample; (b) it provides information on the cerebral blood flow in normal and IUGR fetuses; and (c) it can be sampled at an angle of 0° between the ultrasound beam and the direction of the blood flow. Therefore, for the middle cerebral artery we are able to determine angle-independent indices (the most used is the pulsatility index) and also the real velocity of blood flow. In IUGR fetuses there is a redistribution of the blood flow from the fetal periphery to the brain. This phenomenon is called the “brain-sparing effect.”

Umbilical Vein

After 15 weeks gestation, the umbilical vein normally has a continuous blood flow but becomes pulsatile in pathological cases, such as in IUGR and hydropic fetuses. For the umbilical vein we use a qualitative assessment: continuous versus pulsatile blood flow.

Atrioventricular Valves

The atrioventricular valves (mitral and tricuspid) are characterized by two peaks—the “E” wave that corresponds to the
rapid filling of the ventricles and the “A” wave that corresponds to the atrial contraction. The “A” wave is taller than the “E” wave, which may suggest that atrial contraction is important in the fetus, and is associated with stiffness of fetal cardiac chambers. With advancing gestation, the E/A ratio increases. By contrast, after birth, and also in the adult, the “E” wave is taller than the “A” wave. In fact, in the adult, 85% of the blood passes from the atria to the ventricles during the first part of the diastole. In IUGR fetuses the two waves become abnormal (the E/A ratio increases) and, in the most severe cases, there is tricuspid and mitral regurgitation.

Ductus Venosus

Ductus venosus waveforms are characterized by two peaks, the S and D, followed by a nadir, the a wave (Fig. 1).

Hemodynamically, these phases reflect the rapid chronologic change in pressure gradients between the umbilical vein and the right atrium. In appropriate-for-gestational-age fetuses, there is forward flow at the ductus venosus, and the pulsatility index for veins (S-D/a) decreases with advancing gestation. However, in IUGR fetuses, the pulsatility index increases, and in the most severe cases, there is “a” wave reversed flow.

Three Clinical Applications of Doppler Sonography in Obstetrics

Diagnosis of Fetal Anemia

The middle cerebral artery (MCA) can be insonated at an angle of 0° between the ultrasound beam and the direction of the blood flow and, consequently, the real velocity of the blood flow can be determined. The lowest intra- and interobserver variability is obtained when the MCA proximal to the transducer is sampled soon after its origin from the internal carotid artery, without the use of an angle corrector, by using a 1- to 2-mm sample volume. A peak systolic velocity (PSV) above 1.50 MoM (Fig. 2), in fetuses at risk for anemia, has a sensitivity for detecting anemia of 100% (CI: 86-100%) in red cell alloimmunization cases as well as in other cases of anemia. The false-positive rate is 12%, but this percentage may decrease when serial MCA values are obtained. In fetuses at risk for anemia because of red cell alloimmunization, we use the curve reported in Figure 3 in the following way. We initially perform three exams, 1 week apart, and then obtain the regression line of the three points. If the curve is to the right side of the dotted line, we perform the next...
MCA Doppler examination between 2 and 4 weeks. For example, if a patient with an anti-D titer of 1:256 is seen at 17 weeks gestation, and her previous pregnancies have not been complicated by fetal anemia, and the regression line of her first three exams is to the right side of the dotted line, we perform the next examination in 4 weeks. However, if the values are between the dotted line and one of the continuous lines, the next examination is performed in 2 weeks. Finally, if the regression line is to the left of one of the continuous lines, and the MCA PSV is below 1.50 MoM, we perform the next examination every 2 to 3 days. After 34 weeks gestation, if we use the 1.50 MoM as the cutoff point, we find that the number of false positives increases. Therefore we look at serial MCA values rather than at one single value. We deliver our patients at risk for fetal anemia at 38 to 39 weeks gestation.

In 1997, we reported that the accuracy of the MCA PSV was at least as good as that of the delta OD450 in the diagnosis of fetal anemia. (We also noted that the MCA PSV had an important advantage in that it is noninvasive.) The accuracy of the MCA PSV was confirmed by Pereira and co-workers in a retrospective study—the same approach we used. More recently, a multicenter prospective study has determined that the MCA PSV is actually more reliable than the delta OD450 in the diagnosis of fetal anemia, which has led workers in a retrospective study—the same approach we used. More recently, a multicenter prospective study has determined that the MCA PSV is actually more reliable than the delta OD450 in the diagnosis of fetal anemia, which has led to the American College of Obstetrics and Gynecology to report that the MCA PSV is an excellent tool for the diagnosis of fetal anemia in the hands of trained people. Retrospective studies have suggested that the MCA PSV can be used for timing the subsequent transfusions, but a randomized trial should be performed to confirm this.

**Twin–Twin Transfusion Syndrome**

Doppler measurements of the umbilical artery are excellent prognostic parameters to assess patients with twin–twin transfusion syndrome. Twin–twin transfusion syndrome patients with absent end-diastolic velocity have a worse prognosis than patients with forward end-diastolic velocity at the umbilical artery in one of the twins, when the twins undergo amnioreduction or laser therapy. The MCA PSV is also another parameter of choice that allows the diagnosis of fetal anemia and indicates the need for transfusions in the recipient following laser therapy.

**Intrauterine Growth Restriction**

Most of the studies that report on IUGR have not differentiated between constitutionally and pathologically small fetuses. Additionally, studies on the pathogenesis of IUGR have been limited by the concept that IUGR fetuses represent a homogeneous group. This has created some confusion and has hampered our understanding of the mechanisms that are at the basis of IUGR. We use the term small for gestational age for those small fetuses with no maternal pathology and with normal umbilical artery and middle cerebral artery Doppler results. In contrast, growth-restricted fetuses are small fetuses with a recognizable maternal pathology or an abnormal umbilical or middle cerebral artery Doppler. When no maternal pathology is present but there is an abnormal fetal Doppler, we define small fetuses as idiopathic IUGR fetuses.

**Placental Insufficiency and Idiopathic IUGR Fetuses**

The concept that placental insufficiency is THE cause of IUGR is a source of confusion. We believe that placental insufficiency is not “THE cause” of the problem but is rather the consequence of a disease process that often we do not understand. We agree with Assali, who defined placental insufficiency as “an umbrella that covers our ignorance in terms of etiology and pathogenesis of the utero-placental chronic dysfunction” (from Bruno Salvadori, personal communication). We have recently reported that placental insufficiency is a “symptom” and it can be compared with the fever seen in patients with bacterial pneumonia. As with pneumonia, there are many agents that could cause it; similarly, with placental insufficiency there may be many underlying causes. If we use an antipyretic in patients with bacterial pneumonia, the fever will temporarily subside; however, to treat the entire condition it is necessary to use antibiotics to target the specific etiologic factor. Similarly, with IUGR, we often view the problem from the wrong direction—as a consequence of placental insufficiency—and we therefore believe that we should treat the placental insufficiency. In reality we should find and treat the specific cause of placental insufficiency. The optimal management, however, would be the prevention of IUGR fetuses.

In many IUGR fetuses there is an underlying maternal pathology, eg, chronic hypertension or advanced stage diabetes mellitus, at the basis of placental insufficiency. In other IUGR cases there is not an identifiable cause of placental insufficiency; these are the cases that we define as “idiopathic” IUGR fetuses.

**What Is New in IUGR Research?**

We and others have reported a temporal sequence in the cardiovascular system of IUGR fetuses. We have also re-
ported that the MCA PSV is increased in IUGR fetuses and that this increase predicts perinatal mortality more accurately than the MCA pulsatility index. In addition, there is a correlation between the MCA PSV and a low pH and high PCO₂ in IUGR fetuses.

Recently, there has been much interest in finding a method to decide when to deliver the IUGR fetus. It has been hypothesized that an abnormal ductus venosus Doppler would be an indication for delivery. Although this could be an indication for delivery after 32 weeks, we do not believe that ductus venosus reversed flow (DVRF) is an indication for delivery early in the third trimester in all cases of IUGR fetuses. This is based on our recent reports that, for each week the fetus remains in utero between 25 and 29 weeks, there is a decreased perinatal mortality of 48%, and that the majority of fetuses with DVRF are not acidic. Therefore, the main goal would be to differentiate between those fetuses with DVRF that require early intervention from those for which delivery can be delayed.

We believe that undertaking a randomized study to determine the optimal timing of delivery of the growth-restricted fetus is premature, because at the current time, there is no study that has demonstrated differentiation among the different IUGR fetuses. Without this information, the results of a randomized study could lead to the adoption of a flawed test to determine the optimal timing for delivery of the growth-restricted fetus. We do not wish to make the mistake of possibly adopting a test determined to be “the best” in such a trial before the full range of observational and randomized studies to evaluate all tests in normal and “at risk and diseased” pregnancies has been completed. To do so would duplicate the history and ensuing controversies of adoption of fetal heart rate monitoring for fetal surveillance. For example, we have learned that idiopathic IUGR fetuses behave in a different way than IUGR fetuses seen in preclamptic patients or in diabetic patients. Therefore, we believe that the first step of future research would be to prospectively learn about the natural history of the different IUGR fetuses. This is a study that we are conducting in our ultrasound laboratory.

References


