

## MASTER CLASS

# Doppler Technology



BY E. ALBERT REECE, M.D., PH.D., M.B.A.

**D**oppler technology embraces a common phenomenon and a familiar part of our world. We all come to appreciate its principles when we are stopped at a train crossing: We hear the train's horn at one tonal pitch as the train approaches, and at a lower tonal pitch as it passes us and moves away. The change in pitch is a manifestation of the change in sound-wave fre-

quency that our ears can detect, and—when it is transformed into mathematical equations and scientific formulas—the change in frequency is what forms the basis of Doppler technology.

Blood flow is like the moving train that passes a particular point, which in a clinical context is an ultrasound transducer. As blood rushes past it, the transducer detects changes in frequency.

The speed of blood flow, or the resistance the blood encounters downstream, can thus be assessed using these universal Doppler principles.

Doppler technology has been used quite effectively in medicine for a variety of clinical circumstances, from the assess-

ment of thrombi to the assessment of blood flow to the fetus or resistance in the placenta.

Over the past few decades, this technique has been applied to both normal and problem pregnancies with the expectation that as blood-flow changes are detected by Doppler techniques, such detection might be effective in the assessment of fetal well-being and, more importantly, the loss of fetal well-being. The question, however, is how we can best apply Doppler technology in our general practice.

This month's guest professor is Dr. Christopher Harman, who is a well-known international expert in the area of

ultrasound and Doppler technology.

Dr. Harman is professor and vice chairman of the department of obstetrics, gynecology, and reproductive sciences at the University of Maryland, Baltimore, as well as director of the school's maternal-fetal medicine division. He will discuss the application of Doppler in general obstetric practice. ■

DR. REECE, who specializes in maternal-fetal medicine, is vice president for medical affairs, University of Maryland, as well as the John Z. and Akiko K. Bowers Distinguished Professor and dean of its school of medicine in Baltimore. He is the medical editor of this column.

## Roles and Limitations of Doppler Ultrasound

As ob.gyns., we are increasingly exposed—in the literature and at national and international meetings—to the potential roles and limitations of Doppler ultrasonography. Although specialized applications seem clear, it can be difficult to discern what Doppler's real day-to-day value is or can be.

What is Doppler good for, many of us wonder. And how might it be useful in routine obstetric care and the general, uncomplicated pregnancy?

To answer these questions, it's helpful to understand the basis for Doppler abnormalities, as well as the ways in which this technology is useful in detecting and managing specific clinical problems.

The evolution of Doppler has significantly expanded our understanding of many fetal disease processes, and it is now clear that Doppler is a useful tool for both evaluation and diagnosis. As part of an integrative, contextual approach to evaluation, it has earned a broad role that is not limited to application in intrauterine growth restriction.

### Underlying Principles

The Doppler parameters that are used to evaluate pregnancies at risk for placental problems focus on the relationship between resistance in the blood vessels and its effect on blood flow. Especially important is Doppler's depiction of resistance and flow through the maternal uterine arteries and the fetal umbilical arteries.

When the placenta is developing properly, blood-flow resistance on both sides of this exchange surface falls significantly with advancing gestational age. In the uterine arteries, this phenomenon involves both direct mechanical change in the arteries themselves—the vessels lose their muscular coats and their reactive capability—and a change in the volume of blood that's able to run through them into a low-resistance placental bed.

These changes, signifying normal development of the uterine artery circulation, are easily depicted by Doppler ultrasound. The technology shows progressively lower speeds required to perfuse the uterine arteries, as well as significantly more blood flow during diastole. (See Figure 1.) It also shows the disappearance in early pregnancy of a diastolic "notch" in the uterine arteries, which is a sort of elastic recoil that occurs in the vessels, in the non-pregnant state, after a pulse travels through them. When uterine artery circulation develops normally, the notch is lost as elastic resistance drops.

Blood-flow resistance on the other side of the placenta—that is, in the fetal umbilical arteries—begins its progressive drop a little later than does resistance in the maternal uterine arteries. High resistance on the fetal side is a normal fea-

ture of first-trimester fetal circulation. (See Figure 2.)

Ultimately, however, the development of successive generations of villous vessel branching offers more area for blood to run through, and resistance in the fetal umbilical arteries drops progressively. Much work has been done correlating the anatomical and structural elements of placental development with blood-flow resistance, and Doppler has been shown again and again to be an excellent method of evaluating the function of the placenta.

### Specific Clinical Roles

Elevated resistance and persistence of notching in the uterine arteries throughout pregnancy signify a placenta that is not developing well—and often, an intrauterine growth-restricted fetus that has to cope with and invoke compensations for this placental insufficiency.

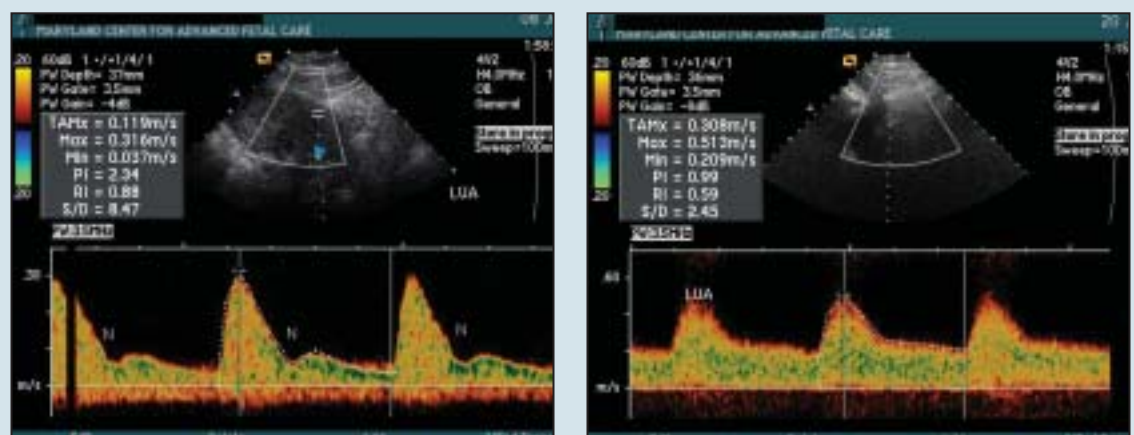
These compensations can at least in part be depicted by Doppler ultrasound through

a more detailed evaluation of the fetal circulation. Here we must examine two additional vascular beds: the middle cerebral artery (MCA), which is used to evaluate brain blood flow, and the ductus venosus (DV), a unique fetal vessel that funnels a proportion of nutrient-rich umbilical venous return directly into the right atrium. Because this direct connection allows reflection of the atrial impulse, we can use the DV to evaluate cardiac status. Because the DV is very sensitive to fetal oxygen status, we can also use it to evaluate fetoplacental respiratory status.



BY CHRISTOPHER HARMAN, M.D.

Figure 1



Uterine artery Doppler in the first trimester (left) shows high resistance (difference between systolic peak and diastolic level) and diastolic notching (N). On the right, normal placental invasion yields low resistance (note much increased diastolic velocity) and loss of notching. If the left panel persists into the third trimester, it is frequently associated with maternal hypertensive disorder.

PHOTOS COURTESY DR. CHRISTOPHER HARMAN

### Screening Potential

In the regular ob.gyn. practice, then, Doppler ultrasound can certainly be employed in cases of inadequate fetal growth and in cases in which we want to know directly how the placenta is doing—in a patient who had a previous stillbirth or previous IUGR baby, for instance,

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or in patients for whom we have reason to suspect fetal anemia.

We can extrapolate this further, and ask whether there is a role for Doppler screening. Should everyone receive a Doppler evaluation to detect IUGR and other problems?

A significant amount of research has been done, and is ongoing, to determine Doppler's screening roles. In this context, it is important to consider individual vessels separately. There probably is no role for screening with MCA Doppler (Figure 3), because fetal anemia in the absence of specific risk factors is rare. Doppler screening of the DV has limited application in the second half of pregnancy, but can have a useful role in identifying fetuses at risk for cardiovascular problems when it is performed earlier in pregnancy.

Ductus venosus Doppler can easily be done, in fact, in the context of the first-trimester ultrasound examination. In a study we recently completed at the University of Maryland, abnormal first-trimester DV Doppler findings were predictive of adverse outcomes—including cardiovascular defects, fetal growth restriction, and aneuploidy—in fetuses with normal nuchal translucency. (See Figure 4.)

(Doppler assessment had been known previously to increase the predictive accuracy for Down syndrome when NT is increased. In this study we looked at cases with normal NT.) With respect to the uterine artery and umbilical artery, Doppler's screening applications (in the first half of pregnancy) is not as reliable as its diagnostic role. Patients showing abnormal placental blood-flow resistance before 20-22 weeks may still show normal blood-flow patterns in the third trimester, with a normal mother and normal fetus, so we should not base major clinical management decisions or therapies on early Doppler screening.

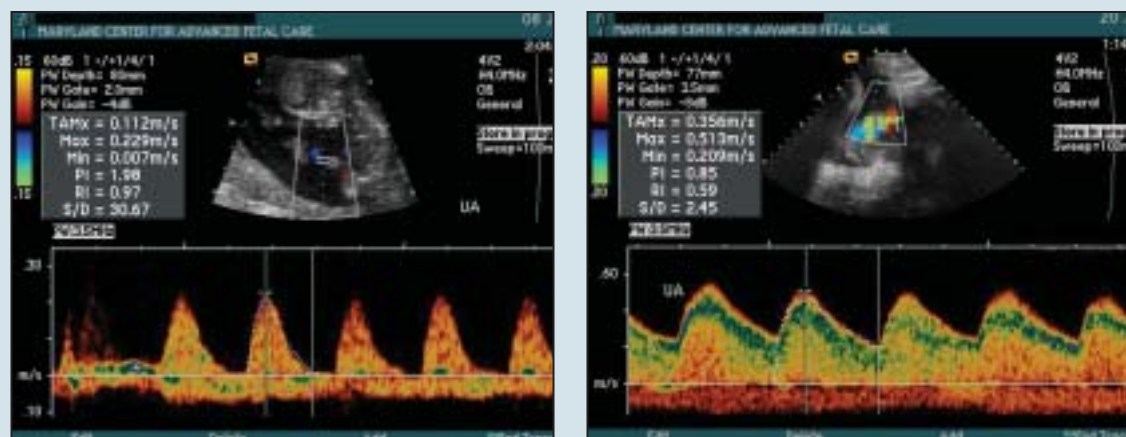
Although there is not perfect correlation, there does appear to be potential value in Doppler screening in the first half of pregnancy. Uterine artery screening has been used in the first and second trimesters to detect cases in which placental development is deficient enough to put mothers at high risk for developing preeclampsia or isolated hypertension, and it turns out that elevated resistance and persistent notching are significantly predictive of the onset—and even, in some trials, the severity—of hypertensive complications.

Evidence has also suggested that detection of these abnormalities at 11-12 weeks, followed by the administration of low-dose aspirin (ranging in trials from 81 mg to 120 mg daily), may be effective in reducing the incidence of hypertension and preeclampsia.

Although larger trials are underway, they have not yet substantiated the benefits of low-dose aspirin that were seen in the small, original trials; nevertheless, at this point the potential of reducing the incidence and severity of hypertensive complications makes Doppler screening a worthwhile consideration.

Ultimately, I believe, trials will prove that uterine artery Doppler by itself is not the only answer for the detection of hypertensive complications, but is a valuable tool to

Figure 2



Umbilical artery Doppler in the first trimester (left) also shows high resistance with low velocity in the last portion of the cardiac cycle (low end-diastolic flow). As the placenta develops, the larger area for umbilical outflow means low resistance and much more flow in the end-diastolic phase (right).

PHOTOS COURTESY DR. CHRISTOPHER HARMAN

be used in the context of other forms of evaluation—a conclusion that reflects a broader axiom of Doppler technology.

This principle may be even better illustrated when we consider umbilical artery Doppler screening. We might think that the inability of the fetus to properly develop umbilical arterial perfusion of the placenta would be virtually guaranteed to predict poor placental development and subsequent IUGR. Although that is largely true, studies have shown that it can be up to 24-28 weeks before Doppler predicts with optimal precision the likelihood of severe IUGR.

At this point in time, other factors—such as lack of fetal growth and changes in amniotic fluid volume—are also usually apparent, leaving umbilical artery Doppler without singular, populationwide benefit.

On the other hand, when umbilical artery Doppler, uterine artery Doppler, maternal blood pressure, and biochemical markers are combined, we have the ability to more precisely predict the maternal and fetal ramifications of placental insufficiency. In other words, Doppler by itself is not sufficient, but it will likely be a key component in a multifactorial assessment.

#### Doppler in 2007

We are on the verge, I believe, of accepting first- and early-second-trimester Doppler—DV Doppler in the context of NT screening, uterine and umbilical artery Doppler screening for placental disease—and putting them into practice.

Every ultrasound machine capable of doing fetal measurements and assessing fetal anatomy comes with Doppler capabilities, so access to technology is no longer a pertinent issue. The last 5 years have brought dramatic change in the application of Doppler ultrasound within ob.gyn. residencies as well.

Methodologies need to be standardized, and the issues

of advanced training, certification, and quality control will be an ongoing focus of discussion and debate. Within the next 10 years, however, Doppler assessment will be not only an established tool but also a routine part of the first-trimester evaluation, even in low-risk populations.

Right now, it is no longer acceptable to use fetal heart rate testing alone, or fetal heart rate testing with biophysical profile scores, in managing the IUGR fetus. Current management should include detailed Doppler evaluation of multiple vessels in the fetal circulation.

Corresponding intrauterine treatment for placental insufficiency is less than optimal, but its development is positive. Work is underway, for example, on ways to alter maternal blood flow, address nutritional aspects, and deliver oxygen, and all these approaches are showing promise in assisting placental development once problems are detected. If these measures prove effective, the role of Doppler will continue to expand. ■

## CSE Tied to Brief Drop In Uterine Blood Flow

BANFF, ALTA. — Combined spinal epidural produces a transient decrease in uterine but not umbilical artery blood flow that does not impact the fetal circulation, fetal heart rate pattern, or immediate neonatal outcome, according to the results of a small study.

“In normal pregnancies, we were able to find a statistically but not clinically significant decrease in the uterine blood flow after CSE [combined spinal epidural],” Dr. Cristian Arzola said at the annual meeting of the Society for Obstetric Anesthesia and Perinatology.

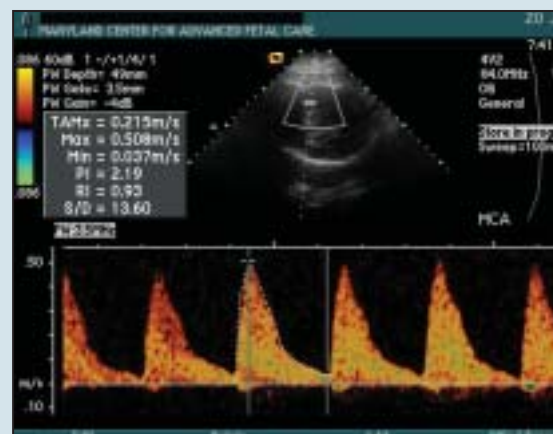
The prospective study included 30 healthy patients in active labor with singleton, uncomplicated pregnancies at term. Pain, maternal blood pressure, fetal and maternal heart rate, blood-flow velocity waveforms, and pulsatility indices (PI) of the uterine and fetal umbilical arteries were measured before and at 5, 10, 15, and 30 minutes following administration of CSE (bupivacaine and fentanyl).

Dr. Arzola observed a drop in maternal systolic arterial blood pressure of 20% from baseline that was significant only at 10 and 15 minutes after CSE. Maternal heart rate dropped significantly at all time points, but remained within normal range. Pulsatility indices for the uterine artery were increased significantly at 10 minutes, indicating reduced blood flow; however, the PI for the umbilical artery remained stable, reported Dr. Arzola of the University of Chile, Santiago.

As expected, pain scores dropped dramatically, and with them adrenaline levels, which decreased more than 50% from baseline. Fetal heart rate did not change significantly, and tracings did not show altered patterns. Apgar scores and cord blood gases were all within normal range, and there were no signs of fetal distress, he said.

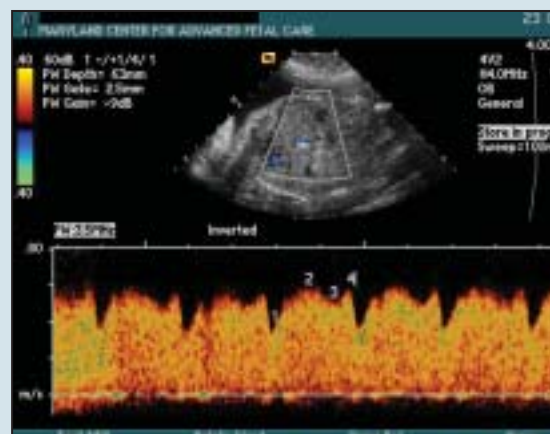
—Kate Johnson

Figure 3



In the middle cerebral artery, high resistance is normal, with low flow in diastole: a normal third-trimester pattern in a nonanemic fetus.

Figure 4



This is a normal ductus venosus waveform, with only a slight reduction in the amount of forward flow during the a-wave.

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