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DOPPLER EVALUATION OF HEMODYNAMIC CHANGES IN UTERINE BLOOD FLOW

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INTRODUCTION

The main uterine artery and its branches are derivatives of the hypogastric artery. At the level of the internal cervical os, the uterine artery bifurcates into the cervical and corporal branches. At the uterotubal junction, the corporal branch turns laterally and upward toward the ovary where it establish anastomoses with the ovarian artery, forming an arterial arcade that provides perfusion to the upper aspect of the uterine corpus. The blood flow takes a linear course in the hypogastric artery, then turns into a serpentine course in the uterine artery, and finally regains a linear course throughout the gestation, as the uterus gradually increases in size.

Approximately eight to ten arcuate arteries originate from each uterine branch and envelope both the anterior and the posterior walls of the uterus for about one-third of the thickness of the myometrium[1]. These arteries take a tortuous course and establish anastomoses with the corresponding arteries from the contralateral side in the midline of uterine myometrium.

The radial arteries arise from the arcuate arteries and are directed inward toward the uterine mucosa. The total number is undefined and most likely is dependent on parity and human biodiversity.

In the past, conventional Doppler techniques have been used unsuccessfully to study uterine hemodynamic patterns in an attempt to provide diagnostic clues for the management of postpartum hemorrhage. Recently, however, advances in signal acquisition and processing have allowed precise and reproducible analysis of velocity profile patterns and other variables such as wall distension and shear rate at specific sites of the uterine circulation.

Several studies have demonstrated a progressive drop in impedance in all the compartments of the uterine circulation, from the main arteries to the spiral arteries, as pregnancy advances[2–4]. The impedance of the spiral arteries decreases and blood flow velocities increase between the 5th and 7th weeks of gestation. During that period, the hemodynamic status of the uterine and arcuate arteries remains unchanged; it is only after the 8th week of gestation that a decrease in impedance and an increase in absolute flow velocities are detectable. This delay between the changes in the spiral and uterine arteries may represent the magnitude of the increase of placental volume and spiral arterial involvement, which is needed to effect appropriate and supportive uterine hemodynamics[5].

INTRAPARTUM DOPPLER VELOCIMETRY

Fleischer and colleagues[6] assessed 12 normal parturients throughout labor with a continuous wave Doppler unit to assess intrapartum changes in uterine and umbilical artery waveforms during labor. Each patient served as her own control. In the latent-phase of labor and with intact membranes, as well as in the active phase after rupture of membranes or during oxytocin stimulation, no significant changes were noted in umbilical artery systolic/diastolic (S/D) ratios before, during or after a uterine contraction. The uterine artery end-diastolic flow velocity fell progressively during uterine contractions, reaching 0 when the uterine pressure exceeded 35 mmHg. Despite intrauterine pressure of > 60 mmHg, the diastolic notch did not appear. This study demonstrated that, at term, umbilical artery velocity waveforms do not change over a wide range of uterine pressures. Changes seen in uterine artery waveforms suggested that the end-diastolic component is primarily determined by changes in the arcuate and spiral arteries, both of which are affected during uterine contractions.

MULTIGATE SPECTRAL DOPPLER ANALYSIS

In our studies, we used a new ultrasound method to investigate blood flow, called multigate spectral Doppler analysis (MSDA), a technology that overcomes the limitations related to the use of a single sample volume[7]. With this method, 256 small sample volumes are aligned along an ultrasound scan line that intercepts the blood vessel, and the Doppler data from each sample volume are independently analyzed to produce a high-resolution flow profile. This non-standard method has been implemented in a system based on a proprietary electronic board connected to a commercial ultrasound machine (Aloka SSD1400) and a personal computer. The board, which is installed on a PCI slot of a host PC, samples the I/Q signals and processes the data in an on-board DSP to carry out the velocity profile. The profile is finally transferred in real-time to the PC to be displayed on the monitor. The hypogastric, uterine and arcuate arteries were investigated in women in labor before epidural anesthesia, after at least 1 h postpartum, and in women before pregnancy. To our knowledge, no group of investigators had previously considered flow rates in terms of the capacity to sustain a life-threatening postpartum hemorrhage.

This Doppler evaluation shows essentially how we define bidimensional Doppler or '2-DD'. Multi-sample volumes from multigate along the scan line depict a bidimensional dynamic representation of the blood flow, where the horizontal axis is the depth and the longitudinal axis is the velocity. Actually, this is the best estimation in real time of the blood flow throughout the vessels, showing an areal flow (cm^2/s) from depth (cm) × velocity (cm/s). Our experience shows that, during menses, areal flow through the arcuate artery is one-eighth (or perhaps one-tenth, depending on the anatomic variants) of the flow in the uterine artery, which is three-quarters of the flow in the hypogastric artery at the start of the menstrual cycle. This flow increases by one-third until ovulation (Figure 1) and remains constant until menstruation. By way of comparison, after conception and in early gestation, this flow increases until the end of the second trimester, after which it remains stable throughout labor, at which time the arcuate artery flow is one-fifth of the uterine, or almost double the flow before pregnancy. In the first and second stages of labor, this flow is markedly reduced, if not totally discontinued, by compressive action of the uterine contractions. During uterine contractions, the myometrial fibers also obliterate the flow in the radial arteries, reflecting the fact that they are tributaries of the arcuate arteries (see above), wherein flow stops until the end of contraction and then rises to reach a steady-state flow until the next contraction ensues. During each contraction, the placental lacunar space is compressed, thus pumping the blood to the fetal circulation throughout the umbilical vein. The compression of the radial arteries during each contraction acts as a valvular mechanism, avoiding reverse flow in the uterine circulation while directing the flow to the fetus. After delivery of the placenta, the resistance in the radial and spiral arteries decreases abruptly, being close to '0'. As a consequence, there is an open flow of blood in the uterine cavity, which is contained by the compression caused by the prolonged uterine contractions. At this stage, the arcuate and radial flow is almost absent. The absence of flow through the radial and spiral arteries facilitates the clotting mechanism in the endometrial bed.

Inefficiency of uterine contractions for whatever reason is a high-risk factor for postpartum hemorrhage. Likewise, an increase in the areal flow of the arcuate arteries, i.e. higher than one-fifth of the flow in the uterine arteries, is also a potential risk for postpartum hemorrhage. The differences of areal flow between the hypogastric, uterine and arcuate arteries, in various physiologic conditions, including postpartum, are shown in Figure 1.

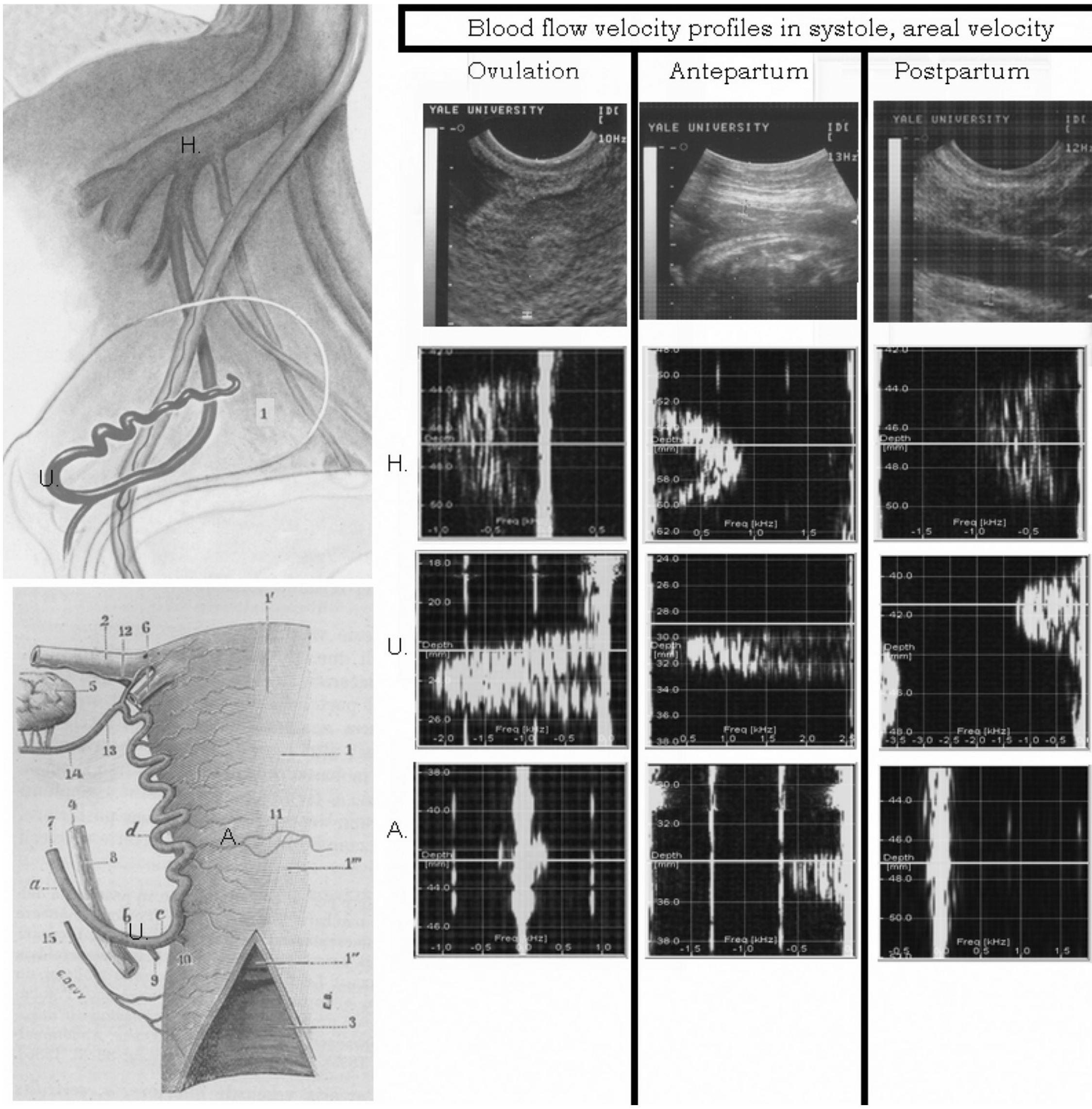

Figure 1 Multigate spectral Doppler analysis using GASP software for areal velocity in women at the ovulation phase of the normal menstrual cycle, in the antepartum phase of labor and at 1 h postpartum. In each column, the first image is the conventional bidimensional image of the area of interest during multigate acquisition, the following from top to bottom are hypogastric (H) artery velocity profile (areal flow), uterine (U) artery velocity profile (areal flow), and arcuate (A) artery velocity profile (areal flow). All images are frozen in systolic peak

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