Chapter 16

Doppler Velocimetry of the Uteroplacental Circulation

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Introduction

Since the last edition of this volume, interest has continued in uterine artery Doppler velocimetry (UADV) as a screening technique to predict adverse pregnancy outcomes such as preeclampsia, for pregnancy risk scoring, and as an entry criterion for randomized trials on medical therapies for the prevention of preeclampsia and intrauterine growth restriction. These areas have been updated and UADV for predicting pregnancy outcome in medical conditions other than preeclampsia has been added. The areas regarding non-Doppler assessment of uterine artery flow, physiology and development of uterine artery flow, and the development of uterine artery Doppler waveform remain essential and have been retained for historical purposes.

Non-Doppler Methods to Measure Uterine Artery Blood Flow

Methods developed to measure uteroplacental blood flow in humans, such as the nitrous oxide technique based on the Fick principle [1, 2], clearance of radioactive $^{24}$N [3–6], and the flow probe technique [7], are obviously not suitable for human application. They suffer from various limitations, such as questionable accuracy, invasiveness, requirement for radiation, and being unsuitable for longitudinal observations. Once it was realized that the placenta must utilize maternal dehydroisoandrosterone sulfate, testosterone, and androstenedione in the intervillous space for the synthesis of estradiol, a technique that measured the rate of estradiol synthesis was developed to assess intervillous space perfusion in human pregnancies [8, 9]. This technique was tedious, required sophisticated laboratory equipment (which made it expensive), made use of isotope-labeled prehormone, and proved to be of questionable accuracy. Its clinical applicability is limited. Nonetheless, when all these techniques were applied to human pregnancies they had surprisingly similar results. Normal uterine blood flow at term was estimated at 500–700 ml/min with a two- to threefold decrease in uteroplacental perfusion noted in the presence of preeclampsia.

Uterine artery Doppler velocimetry was first reported by Campbell and colleagues in 1983 [10]. They showed that, compared to pregnancies with normal uterine artery waveforms, pregnancies with abnormal uterine artery Doppler waveforms were associated with more proteinuric hypertension, required more antihypertensive therapy, and resulted in lower birth weights and younger gestational ages at birth. Thus the capability for this potentially safe, noninvasive, prospective means of analyzing uterine artery blood flow during pregnancy was realized and set off a wave of interest and research that has continued until today.

Anatomy of Uterine Circulation

The uterine artery originates from the internal iliac artery and meets the uterus just above the cervix. The main uterine artery branches into the arcuate arteries, which arch anteriorly and posteriorly and extend inward for about one-third of the thickness of the myometrium (Fig. 16.1). They are tortuous and vary in thickness and in the area they supply. The arcuate artery network anastomoses near the midline [11]. The radial arteries arise from this network, are directed toward the uterine cavity, and become spiral arteries when they enter the endometrium.

There are a variety of arterial anastomoses of the human uterine circulation that have been demonstrated by anatomic and radiographic studies and uterine perfusion experiments [11–14]. Ipsilateral connections between uterine and ovarian arteries have been demonstrated. Also identified are contralateral anastomoses between the right and left uterine arteries and their branches. The uterine circulation is also connected to the systemic circulation, for example the inferior mesenteric, middle sacral, and inferior or epigastric arteries. During pregnancy these anastomotic connections can increase in size and function after occlusion of major vessels.
Normal Growth and Development of Uteroplacental Circulation During Pregnancy

During the first 12 weeks of pregnancy cytotrophoblasts invade the spiral arterial walls in the decidua and replace the endothelium and muscular media with a matrix of cytotrophoblasts and fibrinoid and fibrous tissue [15, 16]. The fibrinoid material is a complex of maternal fibrin and other plasma constituents plus proteinaceous material derived from the trophoblastic cells. Beginning at about 12 weeks' gestation and continuing throughout the remainder of the second trimester, the endovascular trophoblasts move into the myometrial segments of the spiral arteries. Once again the trophoblasts replace the endothelium and establish themselves in the muscular media. The elastic and muscular tissue of the myometrial segments of the spiral arteries is gradually lost and replaced with fibrinoid material (Fig. 16.2). This condition, along with the increase in blood flow and the associated hemodynamic forces, converts the entire length of the spiral arteries from small muscular arteries to dilated, tortuous uteroplacental vessels (Fig. 16.3). At term these changes can be seen at the distal portions of the radial arteries. The mean external diameter of the myometrial segments of the spiral arteries is approximately 500 µm, an increase from 200–300 µm in the nonpregnant state. The small muscular arteries that branch off the radial and spiral arteries, the basal arteries, do not undergo these

Fig. 16.1. Anatomy of the arcuate, radial, and spiral arteries during pregnancy. (From [112] with permission)

Fig. 16.2. Normal pregnancy. Spiral artery at the myometrial junction shows extensive structural alterations (physiologic changes). (Reprinted from [15] with permission)