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IMAGING

Shunting the intervillous space: New concepts in human uteroplacental vascularization

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Objective: It is supposed that the intervillous space is not perfused by maternal blood during the first trimester, suggesting vascular shunts in the myometrium. We therefore attempted to provide arguments for a functional vascular anastomotic network located in the placental bed during human pregnancy.

Study design: Three-dimensional (3D) sonography, laboratory analyses, and anatomic studies (hysterectomy specimens, uteroplacental vascular cast) were performed.

Results: Color Doppler showed a vascular network with anastomotic aspect located in the placental bed. A vascular cast of a uterus, obtained after postpartum hemorrhage, demonstrated a vascular anastomotic network in the myometrium. Higher Po_2 levels in the uterine vein compared with the intervillous space confirmed the functional nature of this shunt. Low resistances in the uterine arteries during the first week after delivery suggested that this vascular network remains functional after placental expulsion.

Conclusion: Our studies have yielded functional and anatomic evidence of an arteriovenous shunt located in the subplacental myometrium.

Until the 18th century it was thought that the maternal and fetal circulations were in continuity. However, in 1754 John Hunter demonstrated that wax injected via the uterine arteries found its way into the intervillous space but not into the fetal circulation.[1,2] Major advances in the physiology of uteroplacental vascularization were made in the 20th century, notably by Ramsey et al.[2-8] The current model resembles a "series" system in which maternal blood enters the uterus via arcuate, radial, and spiral uterine arteries

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before "spouting" into the intervillous space. After circulating around the villi, the maternal blood is drained by the uterine veins and re-enters the maternal circulation. In this model the intervillous space behaves as an arteriovenous shunt.

Some authors have described intramyometrial arteriovenous anastomoses but have been unable to integrate them into the current model of uteroplacental vascularization.[9] Advances in ultrasonographic techniques now make it possible to study the human uteroplacental circulation in vivo. Three-dimensional (3D) reconstruction based on color Doppler images of the placental insertion site revealed a rich, apparently anastomotic intramyometrial vascular network. The aim of this study was to integrate this subplacental anastomotic network into a new physiologic model of uteroplacental vascularization.

Material and methods

Patients

This is a cross-sectional study. Each patient was included in 1 experimental part of the study. All the patients included in this study had uncomplicated singleton pregnancies and gave birth to healthy infants. The protocol was approved by the Ethics Committee of our university (Universite de Liege, Liege, Belgium), and informed consent was obtained from the patients before inclusion to the study.

Ultrasound examinations

Ultrasound examinations were performed with an HDI 5000 device (ATL Advanced Technology Laboratories, Bothell, Wash) and a 12.5-MHz linear-array transducer. Harmonic imaging was used for conventional 2-dimensional (2D) examination. High-sensitivity color Doppler imaging (PRF 700 Hz) was activated to analyze uteroplacental vascularization. Three-dimensional reconstruction was performed by manual scanning on an Advanced 3DI workstation (SGI O2 Silicon Graphics Model 1000, ATL Advanced Technology Laboratories). Pulsed Doppler was used to calculate the uterine artery resistance index.

Thirty pregnant patients were prospectively enrolled in this study, 10 between 8 and 14 weeks of gestation, 10 between 20 and 24 weeks, and 10 between 38 and 40 weeks. Examinations and 3D reconstructions focused on the center of the implantation site and on myometrium not involved in placentation.

After delivery, 22 patients were prospectively enrolled for postpartum ultrasound studies. The myometrium was analyzed by using tissue harmonic imaging. Color Doppler was used to study myometrial vascularization at 2 sites, namely, the implantation site and a site not involved in placentation. Uterine artery resistance was determined by calculating the resistance index (RI) by pulsed Doppler by using the formula $RI = S - D/S$, where D is the end-diastolic velocity and S is the peak systolic velocity.

Oxygen and hemoglobin measurements

This part of the study involved 9 pregnant women delivered by elective cesarean section between 37 and 40 weeks of gestation. The indications for cesarean section were breech presentation or at least 2 previous cesarean deliveries. The placental location and uteroplacental vascularization were determined by ultrasound examination the day before delivery. All the women, breathing room air, were delivered under neuraxial anesthesia. Uterine blood was collected during cesarean section, just before opening the inferior segment. The uterine vein was sampled on the side of placentation, or on either side if the placenta was located in the mid-portion of the uterus. Blood was collected from the intervillous space immediately after the infant was born, before the placenta was expelled. Intervillous blood was sampled in situ with a 21-gauge needle inserted through the chorial plate. Blood was also collected from the umbilical vein just after the placenta was expelled. Blood pH, Po_2, Pco_2, and hemoglobin levels were measured within 5 minutes on a blood gas analyzer (Omni9 Modular System, AVL Scientific Corp, Ga).

Hysterectomy

The pathology department of our institution provided 4 uteruses from women who had undergone early postpartum hysterectomy (3 for postpartum hemorrhage and 1 for uterine rupture). After hysterectomy, the uteri were immersed in 4% formalin solution during 24 hours and sent to the pathology department. Anatomic examination was then performed. Photographs were taken before dissection. The uterus was measured and weighted. First, an anatomic description was performed. Then, the uterus was opened from the left side and an anatomic description of the cervix, the uterine cavity, and the placental insertion was performed. Sections of the uterus were also taken for anatomic examination. Photographs of these sections were taken. Samples from the cervix, the uterine wall, and the implantation site were taken for histologic examination.

All hysterectomies were performed within 24 hours after delivery, and at gestational ages between 38 and 40 weeks. One of these cases was used for vascular casting.

Vascular casting

The uterus obtained after postpartum hysterectomy because of severe hemorrhage as a result of uterine rupture was perfused with 500 mL of heparin saline solution (500