Using Dynamic Contrast Enhanced MRI to Quantitatively Characterize Maternal Vascular Organization in the Primate Placenta

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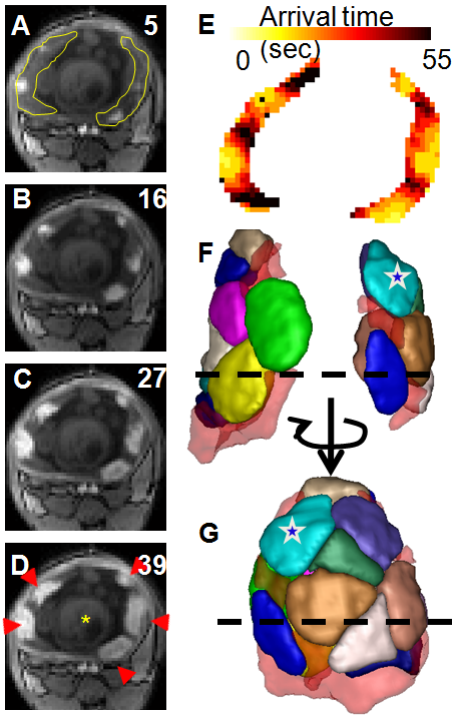
Figure 1.



Introduction Abnormalities of the placenta, the organ that facilitates nutrient exchange between maternal and fetal vasculature during pregnancy, are linked to virtually every obstetric complication, including pregnancy loss, fetal growth abnormalities, preterm labor, and preeclampsia. Although ultrasound can be used to characterize vascular dynamics within major blood vessels involving the placenta, measurement of perfusion within the intervillous space would potentially be of greater value because it is more directly linked to placental function.

A unique feature of the primate placenta is its organization into vascular units, or cotyledons, each supplied with maternal blood through spiral arteries. Here we describe a procedure to use dynamic contrast enhanced MRI (DCE-MRI) to identify individual cotyledons in the nonhuman primate placenta, and to provide quantitative characterization of maternal vascular perfusion within each cotyledon.

Methods Two pregnant rhesus macaque monkeys were examined on gestational days (G)114, G129, and G160 (monkey 1) and G85, G110, and G135 (monkey 2). Term gestation is ~168 days. For MRI procedures, monkeys were sedated with 1% isoflurane, positioned within a 15-channel extremity transmit/receive RF coil in a whole-body 3T T MRI system (Siemens, Erlangen, Germany), and intravenously administered 1 mmol/kg of the contrast reagent (CR) Prohance. Throughout the perfusions, T_1-weighted gradient-recalled echo images with (2 mm)^3 isotropic resolution (TR=86 ms, TE=1.5 ms, flip angle=8˚) were acquired throughout the infusion at 5.5 sec time intervals. T_1-weighted voxel intensities were converted to arrival time maps via nonlinear regression using a modified DCATH model [1,2].

Results and Discussion Panels A-D of Fig. 1 show axial T_1-weighted images acquired 5-39 sec following CR injection for monkey 1 on G114. As is characteristic of rhesus monkeys [3], two placental lobes can be observed (Fig. 1A, outline). Signal enhancement spreads progressively from spiral arteries (red arrowheads, Fig. 1D, fetus indicated with yellow asterisk). Segmentation of the arrival time parameter map (Fig. 1E) using a watershed algorithm reveals the cotyledon vascular organization of the placenta. Two views of the segmented placenta surface for monkey 1 are shown in Figs. 1F and G. Semi-transparent red regions are placental tissue not assigned to specific cotyledons due to constraints to the watershed algorithm that cotyledons be greater than 1.75 mL, and contained within a 20 mm radius of the spiral artery.

Immediately following the G135 MRI, monkey 2 underwent cesarean section delivery. Inspection of the maternal face of both placental lobes enabled each cotyledon to be labeled, and the correspondence between segmentation results and anatomical structure to be confirmed (Fig. 2).

Within each cotyledon, placental function may be characterized by quantifying the maternal perfusion flow rate. Fig. 3A provides an example for a single cotyledon in monkey 1 (star, Figs. 1F and G). For each image voxel within the cotyledon, arrival time is determined, and plotted as a function of distance from the voxel within the same cotyledon that has the shortest arrival time (e.g. the location of the spiral artery). The rate of increase in arrival time with distance from the spiral artery is approximated by the linear fit in Fig. 3A. Flow rates for all cotyledons at each age are shown for both monkeys in Fig. 3B (black data values). Interestingly, the mean flow rates are substantially higher for monkey 1 (red data points) than monkey 2 (blue data points) across age. The observed variation in flow rate throughout the placenta at a given age, and systematic differences between monkeys across ages, are suggestive that cotyledon flow rates may provide valuable data on maternal perfusion related to placental function.

Figure 2.

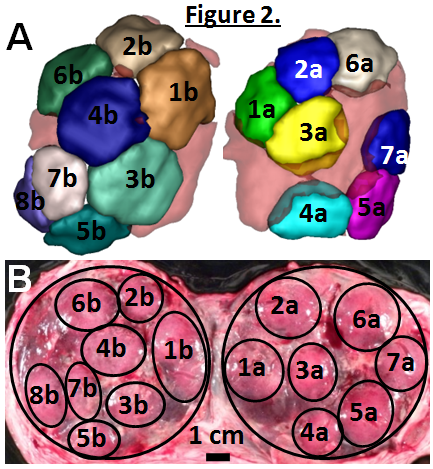
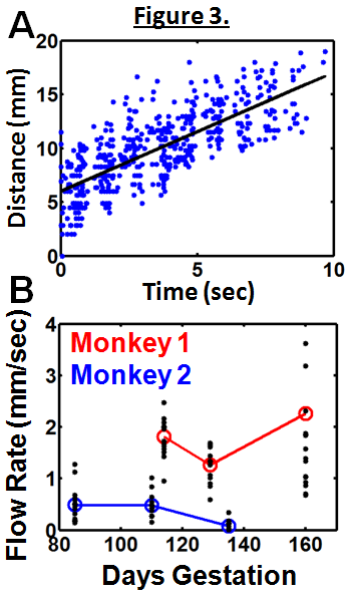


Figure 3.



References [1] TS Koh *et al., Phys. Med. Biol.* 2001 **46** 1519-1538. [2] MC Schabel Abstract #2192. [3] MJ Novy *et al., Am. J. Obstet. Gynecol*. 1981 **140** 552-562.