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Placental MRI

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Summary Placental function is of fundamental importance for normal fetal growth and development. The movement of blood within the placenta ensures adequate transfer of nutrients and waste products across the feto-maternal barrier. The placenta is a relatively easy organ to study with magnetic resonance imaging (MRI) as it has a very high blood volume. MRI can be used to assess both the growth and function of the normal placenta and can distinguish differences from normal in placentas from pregnancies compromised by fetal growth restriction and pre-eclampsia.

Introduction

The function of the utero-placental unit is crucial to ensure normal fetal development. The placenta is a fetal organ, and the fetal tissue forms villi in which the fetal blood flows, separated by only a thin layer of tissue from the maternal blood flowing in the intervillous spaces. The process of implantation causes the maternal spiral arteries in the uterine wall to be remodelled and changes their compliance so that there is a low resistance to maternal blood flow through the utero-placental unit. The villi grow and develop throughout pregnancy in a pattern that is thought to be influenced by the local physiological environment.

The patterns of blood flow in the maternal and fetal circulations within the placenta allow the transfer of oxygen and nutrients to the fetus and the removal of waste products (including heat, as the fetus has a higher metabolic rate than the mother) from the fetus. The rates of transfer across the placenta will depend on transport mechanisms across the placenta, but also on the detailed structure of the villi, fetal blood flow and blood volume, and the delivery of maternal blood to the placenta. This in turn depends on the resistance of the spiral arteries, the resistance of the placenta vascular bed, the resistance of the venous drainage system, and the pattern of maternal blood movements within the intervillous spaces. Pathological development of the utero-placental unit can lead to pre-eclampsia and fetal growth restriction (FGR). However, there are

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multiple aetiologies for FGR, including intrinsic fetal pathologies as well as failure of implantation, remodelling of the spiral arteries, and abnormal villous development.

The placenta is easy to image with a wide range of magnetic resonance imaging (MRI) pulse sequences, including quantitative imaging sequences. This is because the placenta is relatively immobile, and its blood volume is very large: approximately 50% of the whole placental volume. The magnetic susceptibility of all fetal tissues and the surrounding maternal tissues is similar, minimizing image artefacts resulting from differences in magnetic susceptibility between air and tissue found in other parts of the body. Furthermore, the rate of perfusion through the placenta is large, making it feasible to monitor this sensitively with MRI. However, it is likely that in some parts of the placenta the blood flow is pulsatile, reflecting the maternal cardiac cycle. The potential effects of this on imaging and perfusion measurements could be investigated by gating data acquisitions. Most of the research into MRI of the placenta has been carried out at low field (0.5 T), using a home-built scanner, and using echo-planar imaging (EPI), generally with a resolution of $2.5 \times 3.5 \times 7\ mm^3$. EPI is an ultrafast MRI technique, which freezes fetal motion. It creates relatively high acoustic noise but relatively low radio frequency (RF) heat deposition. It is particularly useful for quantitative imaging since multiple images can be acquired rapidly and since it applies only one RF pulse per image. There are only a few reports of placental pathology being studied with clinical MRI, although at present MRI is indicated for the diagnosis of placenta accreta with some advantages over ultrasound.[1,2]

Alternative methods of imaging the placenta

Clearly ultrasound is the method choice for imaging the position of the placenta and for studying conditions such as placenta accreta. Doppler ultrasound can be used to examine placental blood-flow velocity, and uterine artery Doppler measurements allow indirectly studies of the resistance of the utero-placental unit to maternal blood flow. Intervillous blood flow has also been studied qualitatively using ultrasound microbubble contrast agents,[3] although apparently no quantitative assessment of blood flow has been made from dynamic studies.

Beyond this there have been few reports of placental blood flow in the past, although a single study used nuclear medicine techniques to visualize placental blood flow.[4]

Structural imaging of the placenta with MRI

On an MRI scan the normal placenta is a fairly homogeneous organ, with relatively low signal intensity on T1-weighted images and relatively high signal intensity on T2-weighted images (Fig. 1). Heterogeneities are sometimes observed at later gestation and in complicated pregnancies. It is assumed that these regions of altered signal intensity correspond to regions of infarction, necrosis and fibrosis. The volume of the placenta can be measured easily from a multislice set of images. The boundary between the placenta and the amniotic fluid is extremely clear; the boundary with the uterine wall is reasonably clear or can easily be surmised from the angle between the placenta and uterine wall at all gestational ages.

There have been several MRI studies of the relative growth curves of the placenta, fetus and various fetal organs. The postnatal weight of the placenta relative to the size of the baby at birth has been shown to predict babies at risk of later cardiovascular disease.[5] However, the size of the placenta measured antenatally from MRI — whilst generally low in pregnancies complicated by FGR — does not fall outside the confidence limits set up for the normal population.[6,7] The volume of the placenta relative to the volume of the fetal brain or other organs may provide information about the different aetiologies of FGR. It should be noted that the delivered placenta is very different to the placenta in utero in that not only will it be dead, it will also no longer be inflated by maternal arterial blood, and the blood remaining within it will have started to undergo thrombosis.

Histology has shown that the placenta matures and alters in structure during gestation. The placental blood volume remains relatively stable,[8] but the surface area of the villi increases.[9] Quantitative MRI detects changes over time that must relate to this aspect of placental growth, although it is important to ensure that the pulse sequence used in such studies is not flow sensitive. Both the longitudinal (T1) and the transverse (T2) relaxation times of the placenta fall through gestation. At 0.5 T the T1 of the placenta was observed to drop from 1350 ms at 20 weeks to about 1200 ms at term, and the T2 was observed to drop from about 250 ms at 20 weeks to about 175 ms at term.[10] These values are shorter than the corresponding values for blood at the same