Study of Human Placenta Function using MR Based Blood Oxygen Level Dependent (BOLD) Imaging

Y Zhou[1]*, Y Le[1],R Kedar[2],A Odibo[3]

(1) Department of Radiology, Mayo Clinic Arizona, Phoenix, AZ (2)Department of Radiology, University of South Florida, Tampa FL (3) College of Medicine Obstetrics & Gynecology, University of South Florida, Tampa FL

JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Growth and function of the placenta play a vital role in fetal development and growth. Abnormal vasculogenesis/angiogenesis and vascular maturation are the key factors leading to fetal growth restriction (FGR). FGR is a major contributor to perinatal mortality and morbidity worldwide. Affecting about a half million pregnancies delivered each year in the USA alone, FGR has negative effects on immediate health of neonates as exemplified by metabolic acidosis and hypoglycemia. Moreover, newborns diagnosed with FGR exhibit up to an 8-fold increased risk for developing hypertension, cardiovascular disease, diabetes mellitus and/or renal disease as adults. Despite improved understanding of the pathophysiology of, and subsequent complications associated with FGR, identification of pregnant women at high risk for this complication is poor. BOLD MR imaging has been used widely in the human brain functional studies and recently it has been applied in human pregnancies. Here we will apply the BOLD techniques to study the placental microstructure and function, which will significantly enhance understanding of both normal microvascular development and its dysfunction.

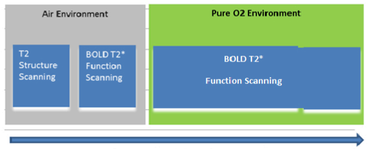
AIM

The goal of our study is to establish the feasibility of measurement of human placental blood oxygenation using blood oxygen level dependent (BOLD) MR imaging technology.

METHOD

1. MR BOLD images were acquired on a GE3.0 Tesla system (GE Healthcare, Milwaukee, USA). An 8-channel body array coil was used for signal reception. All the subjects were scanned while breathing air followed by medical oxygen (100% O2) (In the following Fig.) at a flow rate of 15 L/min with a face-mask.
2. T2-weighted structural images were acquired using a Single-Shot FSE in Sag and Ax planes.
3. A multi-echo GRE T2* sequence with 16 echoes was used to acquire BOLD images in 16 singleton pregnancies. T2* maps were reconstructed by the exponential curve fitting with the multi-echo data on a pixel-by-pixel basis. Regions of interest (ROIs) were drawn covering the entire placenta on one slice where there is no abnormal structure observed.

MRI IMAGING SEQUENCE



Sequence	TR (ms)	TE (ms)	Flip Angle	FOV (mmxmm)	Matrix Size	Voxel Size(mmxmmxmm)	Slice thickness (mm)	Distance factor (%)	Number of Slice	NSA	Acquisition Time (s)
Multiple echoes T2*-weighted gradient-echo BOLD sequence	~100	TE1 Minimum TE Maximum >70ms	20~40	400x400	128x128	3.1x3.1x10	10	10%	1	1	<20

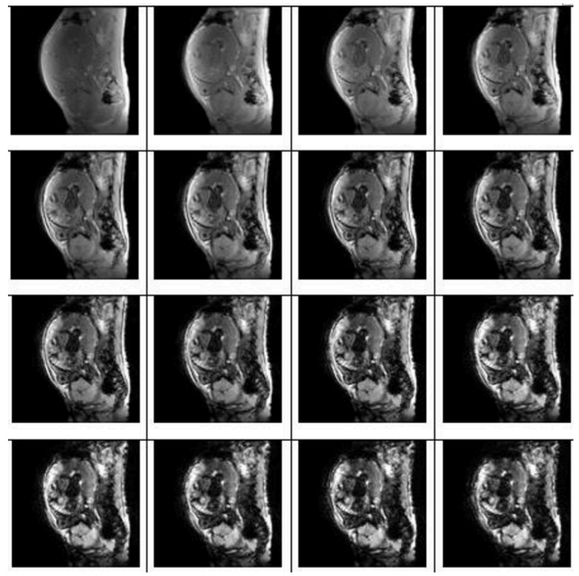
Table 1. BOLD T2* MRI Protocols for placental function

Sequence	TR (ms)	TE (ms)	Flip Angle	FOV (mmxmm)	Matrix Size	Voxel Size(mmxmmxmm)	Slice thickness (mm)	Distance factor (%)	Number of Slice	NSA	Acquisition Time (s)
localizer	5.11	2.56	59	450x450	256x256	1.8x1.8x10	10	100%	3	1	~20
2D T2 AXIAL HASTE/SSFSE/SSTSE	1200	100	180	400x400	256x256	1.6x1.6x4	4	10%	15	1	<20
2D T2 SAG HASTE/SSFSE/SSTSE	1200	100	180	400x400	256x256	1.6x1.6x4	4	10%	15	1	<20

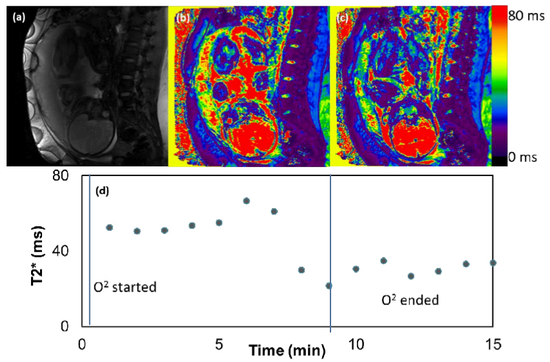
Table 2. MRI Protocols for placental structure

RESULTS

- Non-invasive imaging assessment of placental blood oxygenation, microstructure and function was performed for understanding of both normal microvascular development, oxygen utilization and its dysfunction.
- Heterogeneity has been observed in the T2* quantitative map.
- The T2* averaged over all 16 subjects was found to have values of 41.3 ± 10.5ms, and 52.7± 17.0 ms between normoxia and hyperoxia, respectively.
- The T2* values ranged from 23.1ms to 59.1ms, and 29.9ms to 99.0ms in these 16 placentas between normoxia and hyperoxia, respectively.



Typical T2* BOLD 16 Echoes Images



Representative T2 weighted image (a), T2* maps in normoxia (b) and hyperoxia (c), T2* plots against time (d) during breathing Air and Medical oxygen for the human placenta.

CONCLUSIONS

This study has demonstrated that BOLD MRI is a technology that can detect local variations in oxygenation for human placenta. Significant different T2* values have been found in the human placenta between breathing Air and Medical Oxygen. Quantitative T2* maps have been established using BOLD MR imaging technique. These quantitative values of human placenta will significantly enhance understanding of both normal microvascular development and its dysfunction leading to fetal growth restriction (FGR).

ACKNOWLEDGMENT

This project is supported by NIH through grant 1U01HD087213-01.

REFERENCES

1. McIntire DD, Bloom SL, Casey BM, Leveno KJ: Birth weight in relation to morbidity and mortality among newborn infants. N Engl J Med 1999, 340:1234-8.
2. Chalouhi GE, Salomon LJ: BOLD-MRI to explore the oxygenation of fetal organs and of the placenta. BJOG 2014, 121:1595.
3. Siauve N, Hayot PH, Deloison B, Chalouhi GE, Alison M, Balvay D, Bussières L, Clément O, Salomon LJ. , Assessment of human placental perfusion by intravoxel incoherent motion MR imaging, J Matern Fetal Neonatal Med. 2019 Jan;32(2):293-300.
4. Anblagan D, et.al., IVIM Assessment of the Placenta, Basal Plate and Chorionic Plate in Diabetic Pregnancies, Proc. Intl. Soc. Mag. Reson. Med. 20 (2012).
5. Sorensen A, Peters D, Frund E, Lingman G, Christiansen O, Uldbjerg N: Changes in human placental oxygenation during maternal hyperoxia estimated by blood oxygen level-dependent magnetic resonance imaging (BOLD MRI). Ultrasound Obstet Gynecol 2013, 42:310-4.
6. Huen I, Morris DM, Wright C, Sibley CP, Naish JH, Johnstone ED: Absence of PO2 change in fetal brain despite PO2 increase in placenta in response to maternal oxygen challenge. BJOG 2014, 121:1588-94.
7. Chalouhi GE, Salomon LJ: BOLD-MRI to explore the oxygenation of fetal organs and of the placenta. BJOG 2014, 121:1595.

CONTACT INFORMATION

Yuxiang Zhou, PHD, DABR
Department of RADIOLOGY, Mayo Clinic College of Medicine
Tel: 480-342-6485; (FAX) 480-342-6920