Quantitative flow imaging in the human umbilical vessels in-utero using non-triggered phase contrast MRI

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Introduction: The human fetus receives nourishment and oxygen through the umbilical vessels. In vivo quantification of fetal hemodynamics has been shown to be of clinical importance in management of fetal distress, fetal growth restriction (IUGR), fetal anemia and fetal cardiac related anomalies [1]. While most of the fetal diagnostic imaging has been limited to ultrasound (US), Magnetic resonance Imaging (MRI) is gaining acceptance in fetal evaluation and clinical management. In recent years, phase contrast MRI has been widely accepted as a clinical tool for assessment of flow dynamics (time resolved) in most blood vessels including those having small cross section and/or slow flow. While velocity encoded phase contrast MRI has been routinely used in measuring the velocity and blood flow profiles in adults, children and even in neonatal population, their application in fetal imaging has been limited primarily due to motion and lack of triggering signal. In this study we employ phase contrast imaging, without external triggering, to evaluate average umbilical flow (arteries and vein) in second and third trimester fetuses.

Purpose: We describe an adaptation of time resolved PC-MRI technique which is used for in-utero measurement of the average blood flow in human umbilical vessels.

Sequence: In conventional time resolved phase contrast imaging, k-space data for each time frame is acquired in a particular time point along the cardiac cycle, over multiple heart beats, which is monitored using the pulse-oxymeter or MR safe ECG leads. Unfortunately, an MRI safe fetal ECG/heart beat monitoring system isn't yet available commercially. To obviate the necessity of a triggering signal, in this work we modified the conventional phase contrast imaging sequence to collect data continuously across multiple fetal heartbeats to provide two images which are flow encoded with bipolar gradients of opposite polarity. Complex dividing these two phase images from one another removes the influence of background field in homogeneities and provides an image whose phase values are proportional to the velocity.

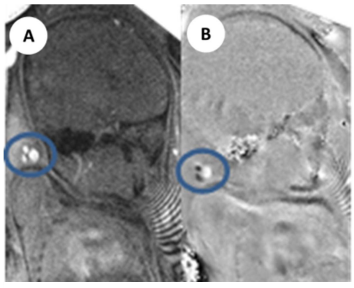

Figure 1: Magnitude (A) and the phase image (B) obtained from the phase contrast MRI. Note the different phase in the artery (dark in B) and the vein (bright in B).

Methods: Pregnant women who were receiving care at Hutzel Women's Hospital in Detroit, MI, USA, were recruited in this study. The imaging study was approved by the local institutional review board and was compliant with HIPAA regulations. Fetal MRI scans were performed using a 3.0T Siemens Verio system (Erlangen, Germany) with 4 channel body flex array coil along with the spine coil. An additional 2 channel flex extremity receive coil was used in some patients with larger girth. Following scout/localizer scans, anatomical data was time of flight (TOF) imaging sequences to localize the umbilical cord. Once the umbilical cord was localized, phase contrast images using a modified sequence were acquired using the following parameter. Flow data was first reviewed for general quality and artifacts. Quantifiable data could not be obtained from all the datasets due to fetal motion, lack of proper coverage, oblique/ in plane orientation of the umbilical vessels relative to the slice acquired, severe partial voluming and/or very small vessel size.

Results: A total of 49 fetuses were imaged to measure the flow from the umbilical vessels of which quantitative analysis could be performed only in 19 cases owing to one or a combination of the factors mentioned previously. The median gestational age of the fetuses included in this study was 30 2/7 weeks and had an interquartile range of 4 weeks.

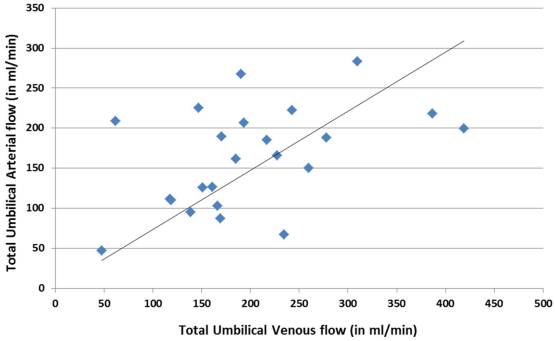

Figure 2: Plot of the umbilical arterial flow across the corresponding umbilical venous flow

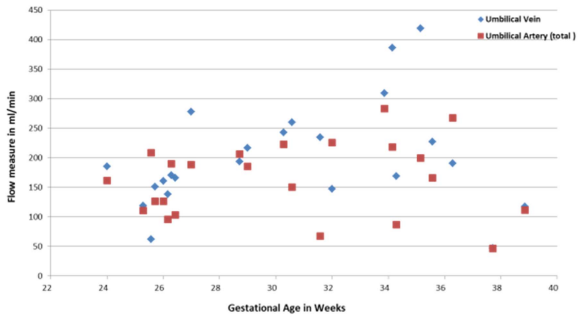

Figure 3: Plot of the umbilical flow (arteries – red; vein – blue) shown across different gestational age.

Discussion and conclusion: This work shows the feasibility of performing quantitative average blood flow measurements in the fetal vessels using phase contrast MR imaging without the necessity of a triggering signal. However fetal motion remains an issue which precluded us from being able to perform this in every single fetus. Although this technique is limited to measuring the average flow, advancements in compressed sensing and ability to perform fetal ECG triggered acquisitions [2] opens the door for time resolved velocity measure. In conclusion, we show one of the first applications of quantitative phase contrast imaging in human fetal imaging for measuring flow in the umbilical vessels.

References: [1] Ferrazzi E., et al., *UOG (2002);* [2] Paley, Martyn NJ, et al. *Sensors* (2013).