FSI simulation of the velocity profile in the human fetal ductus venosus.

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The veins distributing oxygenated blood from the placenta to the fetal body have been given much attention in Doppler velocimetry studies. In particular, the ductus venosus (DV), which bypasses the hepatic veins and delivers oxygen rich blood directly to the inferior vena cava, has been the subject of numerous studies. In early pregnancy DV velocimetry can give indications on chromosomal defects, specifically in the presence of abnormal and reversed flow during arterial contraction. The degree of DV shunting has been investigated in several studies in the later stages of human fetal gestation. However, the interpretation of Doppler signals from the DV at an early gestational age poses some challenges. The DV flow velocities are low and fluctuate about 0 cm/s, and the DV diameter is small.

In current work we have developed a mathematical model for the DV as a tool to assist the clinical assessment of the velocity profiles in the DV. In the mathematical approach we have employed a 3D fluid-structure-interaction (FSI) model for the intra abdominal umbilical vein (UV), DV and the left portal vein (LPV). The placenta and the veins entering the right liver lobe were incorporated as lumped model boundary conditions for the FSI model. A physiological time-varying pressure was imposed at the DV outlet. Additionally, a neo-Hookean, hyperelastic material model was employed for the structural model of the vessel walls, based on recently available experimental data for human UVs. The model geometry was based on typical, physiological geometries of the UV/DV bifurcation. From initial simulations we have found that velocity profiles in the DV close to the DV isthmus are skewed towards the LPV at maximum flow and flow velocity, additionally giving a blunt velocity profile. Further, we have also found significant pulsation in the isthmus DV diameter. In conclusion, the mathematical model we have presented have proved to be a promising tool for assessment of DV Doppler velocimetry. Further, investigations on the impact of model input parameters, such as the UV/DV geometry, material parameters, and other boundary conditions are needed.