Vessel geometry impact on the velocity profile in the human fetal ductus venosus umbilical vein bifurcation
Paul Roger Leinan, Torvid Kiserud, Joris Degroote, Leif Rune Hellevik

The ductus venosus (DV), which bypasses the right liver lobe and delivers oxygen rich blood directly to the inferior vena cava (IVC), is vital in human fetal blood circulation. Clinical quantification of the blood flow through the DV and the umbilical vein (UV) is valuable to understand fetal physiopathology. The velocity profile shape coefficient (Vmean/Vmax) is important for ultrasound (US) flow estimation.

Our aim was to investigate the impact of geometrical changes on the DV velocity profile shape factor (HF). For DV flow quantification, we developed a 3D fluid-structure-interaction model of the UV/DV bifurcation. The vessel walls in the US based geometry, were rendered hyperelastic, with material parameters from experiments. A physiological time-varying pressure was imposed at the IVC close to the right atrium. In particular, the impact of changes in the UV/DV angle, the ratio DVo/DVi of the DV-outlet diameter (DVo) and DV-inlet diameter (DVi), the ratio DVi/UV, and the smoothness of UV/DV junction, has been investigated.

Blunt and skewed velocity profiles were found at the DVi, parabolic velocity profiles were found in the UV, whereas the profiles were partially blunt in the left portal vein. The corresponding HFs at the DVi and DVo were in accordance with values in the literature. The HFs at the DVi, were not found to be very sensitive to changes in geometries and flow conditions. Thus, our findings indicate that the flow split in the UV/DV bifurcation may be estimated clinically, based on assumptions on geometry/hemodynamics.