STATISTICAL MODELLING OF THE PLACENTAL VASCULATURE

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Introduction

Pregnancy is a beautiful but complex experience that affects both the mother and the developing fetus. Unfortunately, around 10% of all expectant mothers face pregnancy-induced hypertension, with 3% being diagnosed with the severe condition of pre-eclampsia [1]. The cause of these complications often stems from abnormal placentation, leading to a malfunction in the crucial role the placenta plays in nourishing and sustaining the growing fetus [2].

Clearly, a closer examination of the placenta's vasculature, hemodynamics, and function is necessary. An accurate hemodynamic model of the placenta's vasculature has the potential to unlock new physiological knowledge that can aid in the early detection and prediction of pre-eclampsia and other pregnancy complications. However, a detailed vascular model of the feto-placental placenta is difficult to obtain in practice. In this study, we aim to create an anatomical model of the feto-placental vasculature that ultimately will be used as a basis for a hemodynamics model.

Methods

For the model of the feto-placental vasculature, the placental geometry is defined on which a space-filling algorithm is applied [3,4]. This method allows the arterial system to grow within the placental boundaries and its functional units (cotyledons) according to rules that capture statistics of real vascular trees.

For cardiovascular hemodynamical simulations, a combination of a 1D pulse wave propagation model – representing the feto-placental arterial system, and 0D windkessel models for the venous system will be applied to the simulated vasculature.

Results

The modelled term placenta (see Fig. 1) realistically mimics the placental vasculature: The central cord insertion leads to a somewhat symmetric vasculature with max 8 branches on the chorionic plate, space between villus trees is present to allow maternal blood to travel past the capillary's membrane, the umbilical arteries have a diameter of 2 mm, and the smallest vessels are at capillary level (10 microns in diameter) and the number of cotyledons are all within the physiological ranges [5]. Also, the number of vessel segments within a diameter range shows good agreement with real placental vasculature data [6].

A simulated marginal cord insertion shows a monopodial structure on the chorionic plate, as is seen

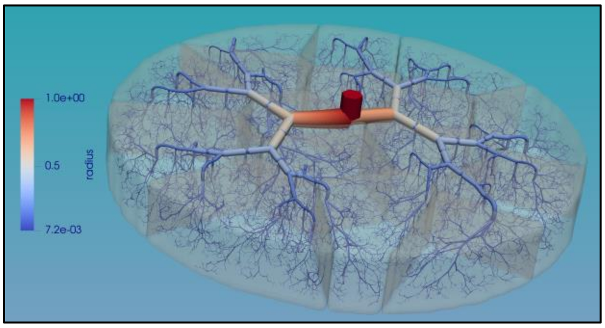

Figure 1: Simulated feto-placental arterial vasculature with a central cord insertion. The color gradient shows the radius in millimeters throughout the modelled vasculature.

for real placentae. Also, abnormalities, such as velamentous cord insertions are modelled realistically. These umbilical arteries start bifurcating before they reach the placental chorion.

Discussion

The resulting arterial vasculature has shown to be realistic. The results are verified with literature and the missing information will be validated and tuned via a clinical study at the Máxima Medical Centre, Veldhoven, the Netherlands.

The model shows great potential for clinical decision support regarding the treatment and prediction of pregnancy complications. Therefore, in the nearby future, this model will be used to simulate the hemodynamics through the vasculature and allows physicians to gain insight in the problematics of several pregnancy complications.

References

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