Electrophysiological Simulation Of Maternal-Fetal ECG on a 3D Maternal Torso Model

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Background Congenital heart disease (CHD) is a leading cause of infant death. ECG recorded on the maternal abdomen (aECG) can non-invasively diagnose CHD. However, extracting the fetal cardiac signal from the maternal abdominal ECG signal is challenging mainly due to low signal-to-noise ratio and limited access to reference data of the direct fetal signal.

Objective The objective of this study is to generate biophysically realistic synthetic maternal abdominal ECG and direct fetal cardiac signals through physiological modelling.

Methods A maternal and fetal biventricular cardiac model were incorporated into a pregnant torso model at 24 weeks gestation. Tissue regions of the uterus, maternal bones and lungs were assigned conductivities to replicate realistic electrophysiological propagation. Ionic current properties of the maternal heart were represented using the Ten Tusscher human ventricular cardiomyocyte model, while a modified version adapted to match experimental aECG was used for the fetal heart. Pseudo-bidomain simulations for ventricular excitation using a baseline cycle of 500 ms and 450 ms for mother and fetus, stimulated at the endocardium with a transmembrane current, were conducted to obtain isolated measures of fetal and maternal signal contributions.

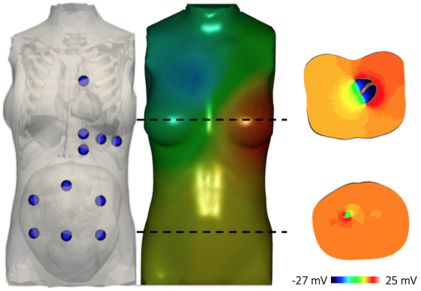

Figure 1: Extracellular potential at t=11 ms.

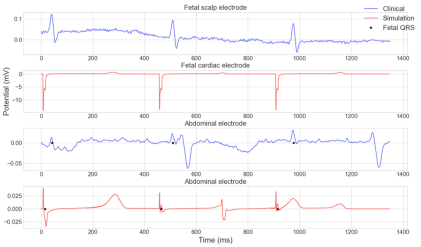

Figure 2

Results The electrode sites used for the aECG, as well as the extracellular potential on the torso surface and at two cross sections through the maternal and fetal heart can be seen in figure 1. Figure 2 shows simulated and clinical ECG [1]measured on a direct fetal electrode and abdominal site. The QT and corrected QT interval calculated at 283±11.19ms and 422.62±16.68ms, are consistent with clinical observations [2]. The R-peak amplitude is larger at the direct fetal site than at the abdominal electrode similar to the clinical signal.

Conclusion Presented is an electrophysiological model based on ionic current properties for generating synthetic fetal and maternal ECG signals.

[1]Jezewski et al. (2012) *Biomedizinische Technik. Biomedical engineering*, 57(5)
[2]Strand et al. (2019) *Physiological measurement*, 40(3)