Fetal PCG extraction from raw abdominal recordings using deep U-Net neural networks

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Introduction: Assessment of fetal health during pregnancy is essential to ensure the delivery of a healthy offspring. However, conventional clinical tools including echocardiography are still heavily dependent on expert interpretation which makes it a difficult task in lengthy and frequent sessions. **Methods:** Here, we propose for the first time the use of a deep learning-based approach using U-Net neural networks for the extraction of fetal phonocardiograms (PCG) and interpretation of fetal heart rates as a reflection of fetal well-being. A total of 20 healthy pregnant women were included in the study and asked to record 4-channel PCG for 10 minutes. Data preparation included only the identification of less-noisy channels and the removal of low-frequency breathing sound waves. The U-Net model was then trained using 1-second PCG segments and validated through a leave-one-subject-out (LOSO) cross-validation scheme to predict patient-wise fetal heart activity. The performance was evaluated relative to ground-truth fetal PCG identified through fetal electrocardiography (ECG) masks. **Results:** The model successfully extracted fetal PCG with a median root mean square error (RMSE) of 0.702 [IQR: 0.695-0.706] compared to the ground-truth. Moreover, the estimation of fetal heart rates using the U-Net-based fetal PCG had a correlation with the ground-truth of 0.642 (p-value = 0.002) and a median error of 18.508 [IQR: 11.996-23.215]. The Bland-altman analysis revealed a slight decrease in mean heart rates using the U-Net approach of 5.18±24.97. **Conclusion:** This study suggests deep learning as an automated approach to extract fetal heart sounds and accurately diagnose fetal well-being. It could act as a clinical AI-assisted tool to clinicians to reduce the dependency on medical experts when continuous and frequent assessment sessions are required.

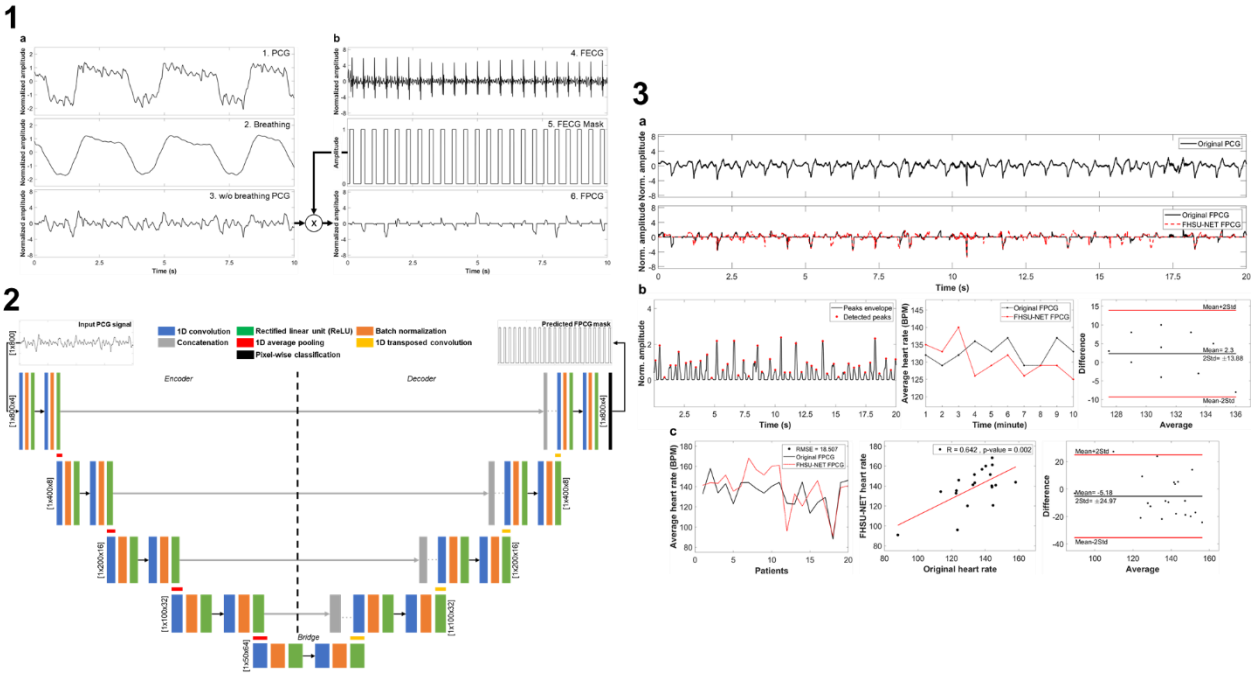

Figure 1. The complete approach followed to extract fetal phonocardiogram (PCG) using deep learning-based U-Net neural networks. 1) Preparation of fetal input data and ground-truth signals. 2) Deep U-Net neural network architecture. 3) Performance evaluation in extracting fetal PCG and estimating heart rates.