State-Space Detection of the Impulse Response Gain and Delay from Intra-Partum Cardiotocography

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Objectives: We model the signals acquired from intrapartum cardiotocography (CTG), uterine pressure (UP) and fetal heart rate (FHR), as an input-output system to estimate its dynamics in terms of an impulse response function (IRF). In previous work, we have demonstrated discrimination of the IRF gain with the state-space subspace approach, which incorporates noise-suppression and permits the use of non-contiguous data. This is important because CTG data is very noisy and missing data are common. In this study we aimed to improve the estimation of the IRF delay.
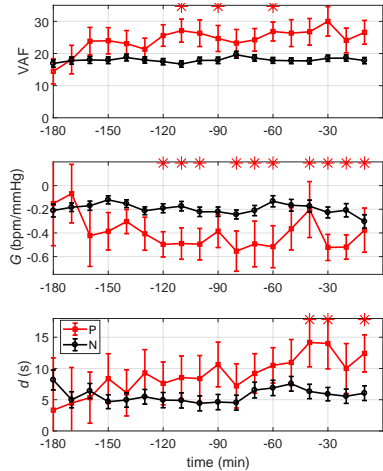
Methods: Recordings of 449 normal (N) and 85 severely pathological (P) fetuses were detrended and analyzed with 20-min processing epochs. The LTI-Toolbox was used for state-space estimates.

Results: The figure shows IRF parameter time progression over the final 3 hrs of labour and delivery. Gain was most discriminating (10 of 18 epochs) starting 120 min before delivery, while VAF and delay were discriminating in 3 of 18 epochs, starting at 110 min and 40 min before delivery, respectively. Models were found in 281 of the N fetuses (62.6%) and 38 P fetuses (44.7%).

Conclusions:

The models were discriminating for all the IRF parameters and early enough to allow clinical intervention.

VAF, gain and delay in last 3 hrs before delivery. *epochs with distributions having significant differences (KS-test, $p<0.05$).

These parameters indicating the degree of the UP-FHR coupling (VAF), the strength of the fetal response (gain) and the response delay, have sensible associations to known clinical notions of the degree and timing of fetal insult. In future work we intend to improve the success rate of the identification.