Towards personalised treatment in septic shock via Bayesian inversion of a one-dimensional cardiovascular model

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Background and purpose

Patients with septic shock are heterogeneous, with varying degrees of hypovolaemia, myocardial depression, vasoplegia and endothelial dysfunction. These pathologies affect cardiac output and arterial wave behaviours, changing the arterial pressure waveform. We aim to enable personalised treatment in septic shock through a physiologically-grounded system for arterial pressure waveform analysis.

Methods

We specified a cardiovascular simulator, coupling a parsimonious heart model to a one-dimensional arterial tree model which accounts for wave behaviours. Hierarchical, patient-specific prior distributions were defined based on population studies. Offline, we trained an uncertainty-aware neural network to emulate the simulator, making Bayesian inference tractable. Measurement noise was modelled, including resonance and damping from the fluid-filled arterial catheter. We generated 192 different radial arterial pressure waveforms using known parameters, then ran inference on these waveforms to assess which cardiovascular parameters they could identify.

Findings/Results

Pressure waveforms were informative about cardiac output, and somewhat informative about aortic stiffness and splanchnic blood flow (see Figure 1), as well as vascular resistances in the extremities. Vascular bed compliances, small-artery stiffness and dimensions of the arterial tree were not identifiable.

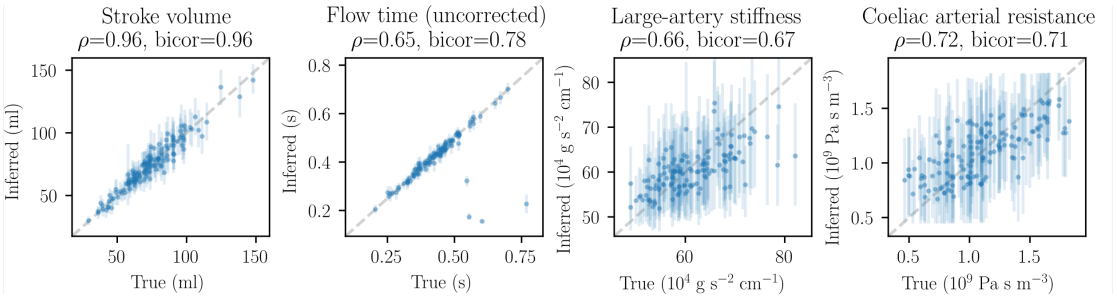

Figure 1 *'True' parameters used to simulate radial pressure waveforms, compared with posteriors inferred from those waveforms. Points=means, lines=94% credible intervals, ρ=Pearson correlation, bicor=biweight midcorrelation.*

Discussion/Conclusion

Our model identifies cardiovascular parameters relevant to septic shock using the radial pressure waveform, and thus has the potential to personalise treatment. By quantifying posterior uncertainty, we guard against poorly-identified parameters being used in clinical decisions.