

Computer-Based Cardiovascular Monitoring

Tracking the effects of large pore hemofiltration in a porcine model of septic shock

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Introduction

Septic shock still remains the main cause of mortality in the intensive care unit (ICU) due to its global effect on the body and high prevalence in critical care. This research proposes using personalised computer models of the cardiovascular system (CVS) to track important hemodynamic changes in porcine study of septic shock. Such models, utilising only measurements available in the ICU, could be used to monitor the effectiveness of treatment and help diagnose complicated conditions.



Methods

An identification method is used to personalise a computer model of the CVS to each subject. The following processes outline this method:

- 1) Record required porcine measurements
- 2) Separately identify parts (ie the systemic and pulmonary sides) of the model using the measured data
- 3) Join identified parts together to create a mathematical representation of the whole CVS
- 4) Repeat process with new measurements to track changes

Porcine Measurements

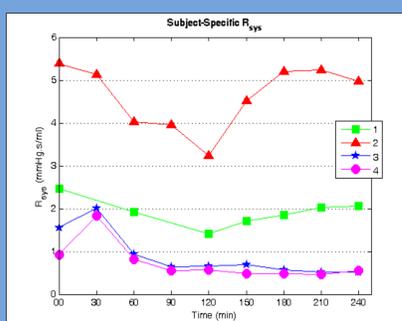
Computer models of the CVS are personalised using measurements obtained from a porcine study (N=4). The animals received an endotoxin infusion over the first 30 minutes and underwent continuous zero-balance veno-venous filtration with a large pore substrate from 60 minutes onwards. An extensive set of hemodynamic measurements were recorded every 30 minutes for four hours. From this extensive set only measurements available in the ICU were used to identify the CVS model including:

- Aortic and pulmonary artery pressure waveforms
- Stroke volume and heart rate
- Mitral and tricuspid valve closure times
- Global end diastolic volume



Results

- End diastolic ventricular volumes and maximum ventricular pressures were estimated to medium absolute errors of 7.1% and 6.7%.
- The model parameters of right ventricular end systolic elastance and pulmonary vascular resistance compared well to experimentally derived metrics (R=0.68 and R=0.72).
- Systemic vascular resistance (SVR) decreased on average by 26% over the duration of the pigs trials.
- Hyperdynamic states were observed in two swine (3 and 4) as SVR and mean aortic pressure (MAP) decrease.
- In contrast, SVR increases in pigs 1 and 2 after hemofiltration, maintaining MAP.



Systemic vascular resistance

Model Identification Method

Identification of the computer model was achieved using an iterative approach where outputs of the model were compared to the measured data to find better approximations for model parameters. This process utilises proportional gain control, where several subsets of parameters are identified separately and joint to together once converged to create a closed loop lumped parameter model of the CVS.

Conclusions

Personalised computer models of the CVS are capable of tracking disease dependent hemodynamic changes and monitoring the effectiveness of treatment in a porcine model of septic shock with large pore hemofiltration. Furthermore, the method...

- Has the potential to run in real time for continuous monitoring
- Is cheap and easy to implement as it only utilises equipment and measurements already available in the ICU
- Accurately estimates important CVS metrics of:
 - ✓ preload (LVEDV, RVEDV)
 - ✓ afterload (Systemic and pulmonary resistance and stiffness)
 - ✓ inotropy (Left and right ventricular end systolic elastances)

These results suggest their may potential benefits in using computer models of the CVS to assist medical staff with diagnostic and therapeutical decisions.