Student: Will Moot

Title: Monitoring the Transient Hemodynamic Impact of Mechanical Ventilation

Supervisors: Professor GM Shaw, Dr CG Pretty, Dr JL Dickson and Distinguished Professor J Geoffrey Chase

Sponsor: The New Zealand Heart Foundation

Introduction:

In 2016, Kamoi et al. proposed a method for calculating stroke volume based on work they had performed on pigs. Kamoi postulated that pulse transit time could be obtained through measurement of arterial waveforms at the abdominal aortic and femoral arteries, and time between corresponding peaks would be used. This pulse transit time was an excellent indicator of stroke volume, and furthermore could be used to help gain an accurate measure of stroke volume through dissection of the femoral arterial waveform. [1]

The work done by Kamoi et al. provided a platform for calculation of stroke volume in humans. This would greatly enhance ICU treatment, giving clinicians a better working knowledge of patient hemodynamic status, and rapid response to changes.

The method used by Kamoi et al. in pigs could not be completely transposed into a clinical setting, as an abdominal aortic catheter was inappropriate for patient use. As an alternative, ECG waveforms were proposed, as ECG is the electrical activity governing the heart and should be relatively uniform in providing the same time difference between pulse pressure stimulation on every beat.

Aim:

To determine the validity of pulse transit time as an indicator of stroke volume, and whether this could be used in the ICU setting to determine patient fluid status.

Impact: The ability to figure out whether a patient's blood volume was deteriorating, in a quicker and more precise manner. This would give nurses and doctors alike the ability to undertake a more rapid response to changes in patient status.

Method:

Study patients were identified as patients in the ICU, who were undergoing mechanical ventilation. Patients required a femoral arterial catheter, ECG leads, and a Pulse index Continuous Cardiac Output (PICCO) line in order to be eligible. Patient's data was then retrieved retrospectively, through provided 24 hour sheets, which indicated patient eligibility. PICCO estimates of cardiac output were taken manually from these sheets, and corresponding ECG and femoral arterial waveform data was obtained for 30 second intervals from the BedMaster™ programme, which stores real-time wavefoms of all ICU patients.

Using a programme developed in Python software, ECG R-wave and femoral arterial waveform peaks were identified, and corresponding peaks were distinguished to calculate pulse transit time.

Estimated patient arterial length was then obtained based on patient height, and pulse wave velocity was obtained. The program developed however, was not completed and as such stroke volume could not be fully calculated. It was decided that pulse transit time would also provide a surrogate metric inversely related to stroke volume and could be used in lieu. Stroke volumes were estimated from the PICCO cardiac output measurements, divided the heart rate.

Results:

We managed to obtain data from three patients who fitted the specified criteria. After data processing, we were able to obtain at least ten data points over each patients stay, of which we could accurately calculate pulse transit time and stroke volume.

The findings showed a strong agreement between the inverse of pulse transit time and stroke volume changes as estimated by the PiCCO monitor in each of the 3 patients within 20% accuracy, which was expected due to measurement errors in the PiCCO and patient variability. We were unable to account for other factors such as hematocrit levels and aortic cross sectional area which may influence pulse transit times

Conclusion:

Changes in stroke volume are of great importance in the management of ICU patients, particularly those where cardiac and fluid status are likely to be variable. Current measures of stroke volume are time consuming and not continuous. The use of pulse transit time as a surrogate, has successfully tracked changes in cardiac output as estimated by the PiCCO device.

From the limited patient data, the use of this method to estimate continuous stoke volume in real time looks promising. This project has provided added support to a program of cardiovascular research currently being conducted in Christchurch and Belgium investigating real-time estimates of stroke volume in critically ill patients.