Introduction
A minimal cardiac model has been developed which accurately captures the essential dynamics of the cardiovascular system to assist medical staff in diagnosis and treatment selection. Including time varying resistance around heart valves produces significantly different haemodynamic response. However the increased complexity has significant extra computational cost reducing the ability to easily identify model parameters.

Objective
To reformulate the model for rapid solution with minimal error and suitable for easy parameter identification.

Result
Speed increases up to 16.6 times were seen with errors less than 1%. Very fast simulation enables the time varying resistance to be readily included in the optimization required to match the model to patient data. This is important as it enables more physiological accuracy with minimal cost in increased computation, enabling greater clinical application of these models.

Model and Method
Equations (1)-(3) are solved by a finite element method where the radius r0 is equally spaced into N nodes and the N derivatives ur and urr are approximated by finite differences. After simulation of the model with a wide range of parameters it was found that the volume could be represented by parabolas and straight lines as shown in Figure 1. Most of the unknown parameters can be measured leaving at most four constant unknowns, one for each parabola. Note that if ultra-sonography is used then the volume could be calculated for each time point giving the whole volume profile. With this new definition of volume the differential equations become linear with an analytical solution and they only have to be simulated through one heartbeat since the volume is already in the steady state form.

New model (three nodes)
\[
\frac{du}{dt} = Au + E(t),
\]
\[
E(t) = \frac{1}{\rho} \left[ \frac{P_e - P_i}{\rho} \right] \left( \frac{1}{\rho} \right) u(0) + q,
\]

Conclusions
The new method does not make use of the analytical solution which would give greater computational savings. Speed increases up to 16.6 times were seen with errors less than 1%. Very fast simulation enables the time varying resistance to be readily included in the optimization required to match the model to patient data. This is important as it enables more physiological accuracy with minimal cost in increased computation, enabling greater clinical application of these models.