Identifying haemodynamic determinants of pulse pressure: An integrated numerical and physiological approach

Samuel Vennin\textsuperscript{1,2}, Ye Li\textsuperscript{1}, Marie Willemet\textsuperscript{2}, Jordi Alastruey\textsuperscript{2} and Phil Chowienczyk\textsuperscript{1}

\textsuperscript{1}Department of Clinical Pharmacology, King’s College London British Heart Foundation Centre, St Thomas’ Hospital, London
\textsuperscript{2}Division of Imaging Sciences and Biomedical Engineering, King’s College London, St Thomas’ Hospital, London

Background

- Hypertension, the single most important cause of morbidity and mortality worldwide, arises mainly as a result of an increase in pulse pressure (PP).
- Haemodynamic basis of this increase in PP is still disputed

Method

- Three-element Windkessel model

\[ P(t) = Z_c Q(t) + \frac{1}{C} \int_0^t e^{-\frac{t-t'}{C}} \left( DBP - P_{out} \right) dt + P_{out} \]

- \textit{In silico data}
Focusing on a similar approach to Willemet et al.\textsuperscript{1}, we created a virtual database of patients (n = 3,095) using a validated 1D model of the arterial network, with cardiac and arterial parameters varied within a physiological range.

- \textit{In vivo data}
Tonometric pressures and echo flows were acquired in normotensive healthy volunteers (n=13,10 men, age 49±8 yr, BP 110±16/69±10 mmHg, mean±SD) and in hypertensive subjects (n=156, 83 men, age 46±17 yr, BP 130±23/83±13 mmHg). Healthy volunteers took part in cross-over studies to investigate the changes in pulsatile haemodynamics during administration of drugs with different inotropic and vasopressor/vasodilator properties.

Results: Investigation

- Impact of variations of the model parameters on PP

- Specific influence of Volume at time of PP and Total Compliance on PP

- Sensitivity analysis on the parameters of the model

Results: Validation

Bland-Altman plots comparing the simulated/measured PP with the estimated PP

Implications

- The 3-element Windkessel model estimates accurately PP
- The main contributors to PP are the total arterial compliance (related to PWV) and the stroke volume
- Ventricular dynamics account for a relatively large proportion of the increased PP in hypertension (20.1 mmHg of the 39.0 mmHg difference in PP between upper and lower tertiles of the hypertensive subjects)\textsuperscript{2}
- This approach can provide a haemodynamically orientated stratified approach to hypertension


\textsuperscript{2}Vennin et al. (2017) “Identifying haemodynamic determinants of pulse pressure: an integrated numerical and physiological approach”, Hypertension, 70(6), 1176-1182.