



## Artery Research

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### **P2.25: MATHEMATICAL MODELLING OF THE SYSTEMIC CIRCULATION: INVESTIGATING PRESSURE AND FLOW THROUGHOUT THE MICROCIRCULATION**

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from the brachial artery would be an acceptable substitute for the AO in the VaMoS computations.

Pulsatile diameter change in the AO was registered with aid of a wall track system, and pressure curves measured simultaneously in the AO and the brachial artery with aid of Millar catheters in healthy volunteers (n= 29, 23-72 years).

There were significant differences in 4 out of 6 aortic wall parameters when pressure curves from brachial artery was compared with AO, emphasizing that the VaMoS computation is sensitive to the pulse wave form and that pressure curves in the brachial artery is not an acceptable substitute for the AO when using VaMoS. A transfer function between the brachial and AO pressure curve form might lead to more accurate results.

<sup>1</sup> Stålhand J. 2008; DOI 10.1007/s10237-008-0124-3

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## P2.23

### THE RESERVOIR PRESSURE CONCEPT: THE 3-ELEMENT WINDKESSEL MODEL REVISITED? APPLICATION TO THE ASKLEPIOS POPULATION STUDY

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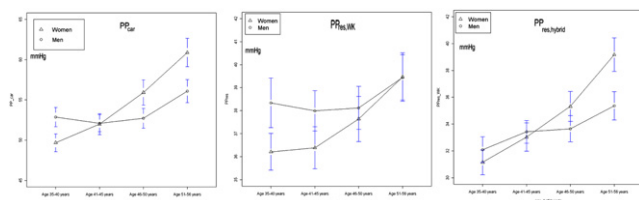
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**Background:** Traditionally the arterial system is either modelled as a lumped-parameter windkessel model, or as a wave system. Recently, a hybrid model has been proposed in which the arterial system is considered to be a reservoir while still allowing for superimposed wave phenomena. We applied this novel approach to non-invasively obtained carotid pressure waveforms from 2024 subjects from the Asklepios population to investigate the contribution of reservoir pressure to pulse pressure with age and gender and compared it to the windkessel pressure obtained from a more traditional 3 element windkessel model approach.

**Methods:**  $PP_{res,WK}$  and  $PP_{res,hybrid}$  were determined by applying a 3-element windkessel model and the hybrid reservoir pressure concept to scaled carotid artery tonometry readings, respectively. The evolution of  $PP_{car}$ ,  $PP_{res,WK}$  and  $PP_{res,hybrid}$  was separately examined for men and women after stratification of the population into age quartiles.

#### Results:



**Discussion:**  $PP_{car}$  increased with age regardless of sex, but was more pronounced in women. This increase is largely due to reservoir pressure, regardless of the model used. Hybrid model results closely resemble those obtained by a 3 element windkessel model, with a strong correlation ( $r=**$ ,  $P<0.001$ ) between  $PP_{res,WK}$  and  $PP_{res,hybrid}$ .

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## P2.24

### ESTIMATION OF ARTERIAL MECHANICAL PROPERTIES BASED ON A PATIENT SPECIFIC WAVE PROPAGATION MODEL

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**Background:** Arterial stiffness can be assessed using pulse wave velocity (PWV). However, distance measurement introduces an error and an average PWV is considered although arterial stiffness increases distally. A patient specific one-dimensional wave propagation model may reveal details of pressure wave propagation phenomena and mechanical properties of arteries.

**Methods:** For 6 healthy volunteers, ultrasound wall distension (WD), blood pressure (BP) waveform and blood velocity were assessed at 5 positions along the leg. Blood volume flow (BVF) for each position was estimated assuming Womersley profile. The Young's moduli and diameters of the arteries were derived from the BP and WD. The BVF at the iliac artery (IA) is used as input for the simulations. The in-vivo results were compared with simulated BVF and BP curves to adapt the model parameters iteratively.

**Results:** The group average diameter equals  $7.4\pm 0.6$  for the IA,  $1.9\pm 0.8$  for the posterior tibial (PTA) and  $1.7\pm 0.5$ mm for the pedal (PDA) artery. The ratio  $IMT/diameter$  increases along the arterial tree, from 7.5% to 21.1% and 27.5% in the IA, PDA and PTA, respectively. The distensibility equals  $0.39\pm 0.07$  and  $0.36\pm 0.09$ MPa<sup>-1</sup> at the IA and PDA; the PWV over IA to PDA segment is  $7.4\pm 1.0$ m/s. The distensibility resulting from the iterative method is 20% smaller than the first estimate based on the measurements while the PWV was the same.

**Conclusion:** The results show that the shape of simulated BVF is comparable with in-vivo estimations and that the wave propagation model can be used to estimate more accurately arterial mechanical properties.

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## P2.25

### MATHEMATICAL MODELLING OF THE SYSTEMIC CIRCULATION: INVESTIGATING PRESSURE AND FLOW THROUGHOUT THE MICROCIRCULATION

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An early pathological process common to many vascular diseases is dysfunction of the small arteries. A variety of mechanisms are implicated including endothelial dysfunction. The final common pathway linking these functional pathologies to clinically significant disease is alteration of haemodynamic characteristics of the microcirculation, including the generation of small arteries at which the majority of the pre-capillary pressure drop occurs (resistance arteries).

We have extended a model of the systemic arterial system into the microcirculation. The model is divided into two parts: one comprising the larger arteries and one comprising the smaller arteries, coupled together through an outflow boundary condition at the terminals of the larger arteries. Blood flow and pressure in the larger arteries are predicted from a nonlinear 1D cross-sectional area-averaged model based on the Navier–Stokes equation. Inflow is ascending aortic flow measured using MRI. Small arteries in vascular beds are modelled as an asymmetric structured tree. Impedance is calculated throughout the asymmetric tree, allowing pressure and flow to be calculated at each vessel generation. Physical properties (dimensions, compliance etc) can be altered independently at each vascular generation of the microvasculature.

Using this model, we are able to simulate resistance artery pathologies identified as potential precursors of systemic disease. A detailed theoretical understanding of the haemodynamic impact of such resistance artery pathology on systemic blood flow and pressure has multiple potential uses. Current hypotheses concerning the pathophysiology of very early vascular disease eg 'essential' hypertension may be tested in silico and new hypotheses could potentially be generated.

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## P2.26

### DYNAMIC ASSESSMENT OF VASCULAR RESISTANCES IN DIABETIC MICE USING A NON-INVASIVE NMR IMAGING APPROACH

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The dynamic determination of peripheral vascular resistances requires simultaneous determination of organ perfusion and systemic arterial blood pressure (BP). We developed an integrated Nuclear Magnetic Resonance (NMR) approach combining measurements of systolic and diastolic BP with tissue perfusion by NMR-Imaging using Arterial Spin Labeling technique (NMRI-ASL) in small animals. This allowed non-invasive determination of local peripheral resistances *in vivo*. As a first example of application, we assessed the vascular conductance in skeletal muscle of type-2 diabetic mice.