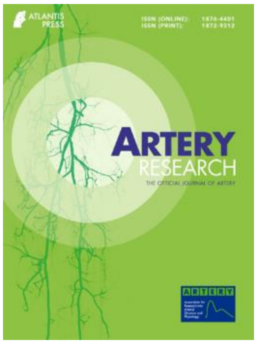

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P11.11: VENOUS VALVES DYNAMICS AND THE HEMODYNAMICS OF THE MUSCLE PUMP EFFECT: A MODELING APPROACH

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Conclusions: PWV^2 is superior to PWV for data analysis for its direct association with stiffness and linear dependence on DBP with age- and disease-dependent but pressure-independent coefficients β and α.

P11.10

CAN THE BEHAVIOR OF LIQUIDS UNDER HIGH PRESSURES HELP INTERPRETING STIFFNESS-RELATED MEASURES IN ARTERIES?

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One expression of the fact that real arteries, in the physiological range, are not simple elastic tubes is expressed by increase of its stiffness at greater pressures. Let stiffness G be defined as rate of change of arterial pressure P with size V, i.e. dP/dV, where V stands for volume or cross-section area or diameter, relatively to a reference value. It has been shown that $G(P) = \beta(P+\alpha)$, where β and α are pressure-independent constants and β ('stiffness index') measures the rate of stiffness increase per one unit of pressure change. Both parameters can be determined by measuring stiffness at different pressures. This equation is identical to the so-called Tait equation (Tait, 1888) that describes the 'equation of state' liquids (P-V relationship over thousands of atmospheres) with remarkable accuracy. Although at elevated pressures liquids are compressed while arteries are stretched, in both cases the constituting components change its packing under pressure. This suggests using the knowledge accumulated in high-pressure physics for interpreting stiffness-related measures in arteries. Following this approach it can be shown that arteries behave as elastic tubes only for size changes $\Delta V << 1/\beta$ -a condition that is violated frequently during the systole; the known increase of β with age and vascular pathology may reflect 'enhanced structuring' of the wall components; The parameter α may stand for 'internal pressure' contributed, in part, by the net attraction/repulsion of wall elements, independently of the applied pressure. In conclusion, stiffness-related measures may probe the physical state of the arterial wall microstructure.

P11.11

VENOUS VALVES DYNAMICS AND THE HEMODYNAMICS OF THE MUSCLE PUMP EFFECT: A MODELING APPROACH

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Orthostatic intolerance is observed in astronauts after spaceflight, in patients with spinal cord injury and in the elderly. Their inability to compensate for the gravity-induced blood volume shift towards the legs in upright position can result in critical events as syncope. Normally, the muscle pump effect plays a crucial role in proper regulation of the fluid distribution. Leg muscle contraction increases venous return by collapsing deep veins while distal valves close. During muscle relaxation venous refilling is fastened as perfusion pressure is increased due to pressure shielding by the proximal valves. Furthermore, the connected superficial veins, which are less affected by muscle contraction, serve as an extra reservoir during venous refilling. Unfortunately, this complex physiological mechanism, in particular the contribution of deep and superficial veins in blood volume shift, remains poorly understood.
Therefore, the objective of this study is to characterise the muscle pump effect using a 1D pulse wave propagation model of the venous system including venous collapsibility, hydrostatic pressure and venous valves. A four-second muscle contraction has been simulated in a configuration connecting a deep to a superficial vein via four perforating veins.
Muscle contraction resulted in increased venous return and distal valve closure. Furthermore, increased perfusion was observed during relaxation and the superficial veins contributed to venous refilling.
In summary, the model can qualitatively reproduce the local muscle pump effect. Future work will focus on extending the model with regulation mechanisms and a closed loop circulation, which can ultimately result in increased insight in orthostatic intolerance.

P11.12

SIMPLIFICATION OF A NON-LINEAR MECHANICAL MODEL OF HUMAN COMMON CAROTID ARTERY WITH SENSITIVITY ANALYSIS

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Background: We described a model allowing in vivo non-linear mechanical characterization of human common carotid arteries (CCAs) (Masson 2011). It relied on 14 different parameters corresponding to geometric properties (number 1 to 3), fibrillar constituents (n. 4 to 9), perivascular parameters (n. 10 and 11) and contractile properties (n. 12 to 14). Because of the non-linearity and the high number of parameters of the objective function, convergence towards an optimal solution is difficult. We propose here to quantify the contribution of each parameter for optimizing the model.
Methods: We studied 58 subjects. The 14 parameters were first determined using Masson's method, then each parameter was independently changed by +/- 1, 5 and 15%. Changes in objective function were computed and compared. Parameters were ranked.
Results: Geometric parameters contributed the most (rank 1, 2 and 3), followed by contractile components. The elastic component parameters contributed the least to the energy function. The ranking depended on the amplitude of imposed variation, especially for geometrical parameters. Some fibrillar parameters (7 and 9) had marked contribution for negative imposed change (rank 2 and 4) but not for positive one (rank 13 and 14). Convergence of modelling was more reliably obtained when using stepwise procedures based on the ranking than with standard least-square procedures.
Conclusion: The contribution of parameters in large artery energy function is unequal and stepwise introduction of parameters improves the optimization procedure. Reduction in the number of parameters might be made possible by a smart selection of the parameters.