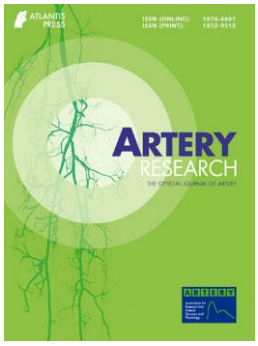

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P4.05: CHARACTERISTICS OF AORTIC STIFFNESS IN DIABETIC RATS TREATED WITH VITAMIN D

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Table: Peak cap stress in kPa (mean±st. dev.)

	Median Value	Peak cap stress in low group (kPa)	Peak cap stress in high group (kPa)	p-value
Min cap thickness	146 μm	170 ± 110	85 ± 40	<0.05
Max necrotic core th.	537 μm	172 ± 113	83 ± 30	<0.05
Necrotic core angle	58°	148 ± 103	109 ± 81	>0.05
Min intima thickness	196 μm	142 ± 130	116 ± 38	>0.05
Min media thickness	78 μm	138 ± 100	119 ± 90	>0.05
Min adventitia th.	47 μm	124 ± 82	134 ± 108	>0.05

P4.03

THE RESERVOIR-WAVE PARADIGM INTRODUCES ARTEFACT INTO WAVE INTENSITY ANALYSIS: A COMPUTER MODELLING AND IN VIVO STUDY

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Background: Wave intensity (WI) has traditionally been calculated from measured pressure and velocity waveforms. In the recently proposed reservoir-wave approach, wave intensity is calculated using excess pressure (WI_{RW}), i.e. the difference between measured and reservoir pressures. Although it has been suggested that WI_{RW} is more accurate than WI [1], this has not yet been validated in a system with known wave reflection properties.
Methods. This study assessed WI and WI_{RW} in two one-dimensional models, first, a simple network containing three bifurcations (two producing positive reflection and one producing negative reflection) and second, a full model of the systemic arterial tree. In both, a forward component of pressure was prescribed at the (non-reflecting) inlet, thus forward waves were known *a priori*. 3-element windkessels formed the model outlets. Modelling results were compared with measurements in the ascending aorta of five adult sheep.
Results. WI accurately predicted the three reflection sites in the simple network, whereas WI_{RW} did not detect the first or third (positive) sites and overestimated the second (negative) site. In both models, an artefactual mid-systolic forward expansion wave appeared in WI_{RW} but not WI. In the systemic arterial model, WI_{RW} predicted predominant negative reflection during systole, whereas WI correctly predicted positive reflection; in vivo results were qualitatively similar.
Conclusion: WI_{RW} introduces artefactual expansion waves and attenuates or eliminates compression waves. This may limit the utility of WI_{RW} in the assessment of both forward-running waves and wave reflection in arterial networks.
[1] Tyberg J. et al, Med Biol Eng Comput, 47(2):221-232, 2009

P4.04

CARDIOVASCULAR PARAMETERS OTHER THAN MEAN ARTERIAL PRESSURE ARE PREDICTIVE OF DYNAMIC CHANGES IN AORTIC STIFFNESS IN THE RAT

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It has been observed that phenylephrine induced mean arterial pressure (MAP) changes in rats cause different values of aortic stiffness, measured by pulse wave velocity (PWV), at the same MAP during increasing, compared to decreasing pressure. The reason for this hysteresis in the MAP-PWV relationship is not understood. This study evaluates the influence of a variety of cardiovascular factors on PWV. Five, 12 week old Wistar-Kyoto rats were anaesthetised and two pressure sensors introduced into the thoracic and abdominal aorta. Pressure was increased with intravascular phenylephrine infusion (30μg/kg/min), and allowed to return to baseline following cessation of infusion. This was repeated following intravascular hexamethonium bolus (20mg/kg), blocking autonomic activity to quantify the role of the sympathetic system. PWV, thoracic MAP, pulse pressure, form factor, maximum slope of pressure (dP/dt, surrogate measure of cardiac contractility), and R to R interval from the electrocardiogram were calculated for each individual pulse. These variables along with hexamethonium presence, and dynamic MAP direction were entered into a stepwise linear regression model (dependent variable: PWV). MAP, R to R interval, sympathetic activity, pulse pressure, dynamic MAP direction and dP/dt were significant predictors (Table). The results indicate that cardiovascular parameters other than MAP, especially pulse pressure, and notably sympathetic activity and R to R interval, are predictive of PWV. MAP direction remained in the model, indicating that other factors are at play, or that the aorta displays a short term viscoelastic memory. Further studies are required to isolate each of these factors and their effect on PWV.

	standardised coefficient	p	r^2 change
MAP	0.242	<0.001	0.476
R to R interval	0.275	<0.001	0.105
sympathetic activity	-0.193	<0.001	0.034
pulse pressure	0.453	<0.001	0.005
MAP direction	0.129	<0.001	0.014
maximum dP/dt	-0.168	<0.001	0.011

P4.05

CHARACTERISTICS OF AORTIC STIFFNESS IN DIABETIC RATS TREATED WITH VITAMIN D

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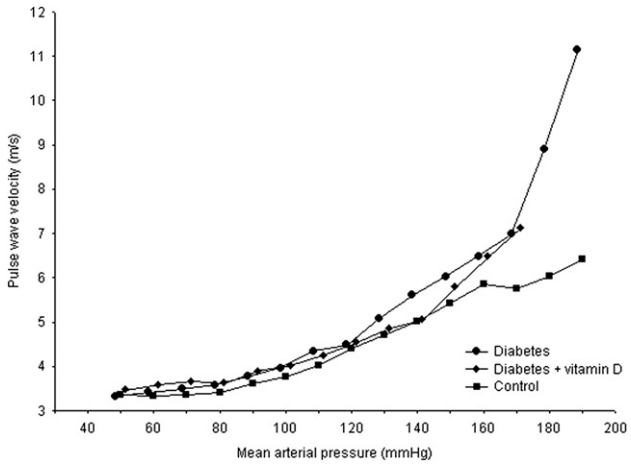
Background: Diabetes mellitus is associated with macrovascular complications characterized by increased aortic stiffness. Mechanisms of diabetes-induced vascular impairment include persistent activation of the inflammatory system that may be improved by the immunomodulatory effects of orally administrated vitamin D. This study aimed to examine the effects of diabetes on the elastic properties of the aorta and the protective effects of vitamin D treatment.
Methods: Diabetes was induced by injection of streptozotocin in male Wistar rats (age 4 months), followed by oral administration of cholecalciferol (500 IU/kg) for 10 weeks. Aortic pulse wave velocity (PWV) and other hemodynamic parameters were recorded over a mean arterial pressure (MAP) range of 50 to 200 mmHg using a dual pressure sensor catheter. Serum 25-hydroxyvitamin D (25[OH]D) level was measured using a radioimmune assay.
Results: In diabetic rats, PWV was significantly elevated across MAP range between 120 and 200 mmHg. PWV across lower MAP range did not reveal any significant differences between all groups. Administration of vitamin D did not improve aortic stiffness, despite high levels of serum 25(OH)D in the treatment group, compared to the placebo group (513±132 nmol/L *vs* 108±38 nmol/L, respectively). Other hemodynamic parameters (heart rate, systolic and diastolic blood pressure, and pulse pressure) were not different between all groups at any given level of MAP.
Conclusion: PWV profile determined under isobaric conditions demonstrated increased aortic stiffness in diabetic rats that was not improved by vitamin D supplementation.



P4.06
MECHANICAL PROPERTIES AND STRESSES IN CAROTID ARTERIES QUANTIFIED USING CLINICAL DATA FROM NORMOTENSIVE AND HYPERTENSIVE HUMANS

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Objectives: To model the in vivo nonlinear mechanical behavior of human common carotid arteries (CCAs), to compute wall stresses and to deduce changes in wall micro-constituents (elastin-dominated matrix, collagen fibers, vascular smooth muscle cells (VSMC)) in normotensive subjects (NT) and hypertensive patients (HT).
Methods: Clinical data were obtained non-invasively from CCAs in 16 NT (21-64 years old) and 25 treated HT (44-69 years old). Medial diameter, intimal-medial thickness and blood pressure (BP) were measured during several cardiac cycles by high-resolution echotracking (Art.Lab®) and applanation tonometry (SphygmoCor®) systems, respectively. For the theoretical mechanical modeling, the CCAs were assumed to be hyperelastic, anisotropic, active-passive, and residually- stressed. We semi-analytically solved the boundary value problem to compute the intraluminal pressure from carotid distension, while accounting for perivascular tissue. Best-fit values of model parameters were adjusted by minimizing the difference between computed and measured inner BP over the cardiac cycle.
Results: In NT, age was positively correlated ($p<0.05$) with residual stresses and fibrillar collagen (stiffness and orientation). Despite treatment, HT had increased VSMC tone ($p=0.003$, +17.3%), a stiffer elastin-dominated matrix ($p=0.01$, +20.5%), and higher levels of stresses.
Conclusions: We were able to estimate wall stress fields and to quantify changes in mechanical characteristics of wall micro-constituents with aging and hypertension from non-invasive clinical data, though mechanical modeling of the wall behavior. Our results are consistent with prior reports on effects of age and hypertension, but provide increased insight into evolving contributions of cell and matrix mechanics to arterial behavior in vivo.

P4.07
ON THE RELEVANCE OF A PPG BASED TWO PULSE SYNTHESIS MODEL FOR SCREENING AGAINST CORONARY ARTERY DISEASES

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Abstract: Arterial stiffness is an independent predictor for coronary artery diseases (CAD). Various methods to predict coronary artery involvement are known but most of them have limited applicability in large-scale population screening due to cost barrier [1].
Photoplethysmography (PPG) to capture digital volume pulse signal is a simple, low-cost and noninvasive method for rapid assessment of arterial health conditions. An important application of PPG signal analysis has been towards early detection of altered arterial stiffness leading to increased risk of CAD. A Two Pulse Synthesis (TPS) model has been suggested recently for measurement of vascular parameters based on PPG signal and the usefulness of the model has been established for hypertensive and diabetic subjects [2].
This communication reports the outcome of a study based on the use of TPS model on finger-tip PPG of 40 suspected CAD subjects. The TPS model-based parameters considered in the study are Rise Time, Reflection Index, Foot-to-Foot Delay, Differential-Pulse-Spread and the Spread-Delay Ratio. Angiography has been subsequently carried out on these subjects and the findings have been compiled to find out sensitivity, specificity, positive and negative predictive values.
The study shows that the Positive Predictive Value of the TPS model is respectable (69%) while the Negative Predictive Value (93%) is high. It appears that this mathematical model may be applied to predict or rule out CAD conditions fairly successfully. Gradual development of functional embarrassments even in the absence of clinical manifestations may be possible with PPG analysis through periodic application of TPS model.
References
1. Laurent S., Boutouyrie P., Asmar R., Gautier I., Laloux B., Guize L., Pierre Ducimetiere P., Benetos A., 'Aortic stiffness is an independent predictor of all-cause and cardiovascular mortality in hypertensive patients'; *Hypertension* 2001; **37**: 1236—1241.
2. Goswami D., Chaudhuri K., Mukherjee J., 'A New Two-Pulse Synthesis Model for Digital Volume Pulse Signal Analysis,' *J. of Cardiovascular Eng;* DOI 10.1007/s10558-010-9098-8.

P4.08
BIOMECHANICAL STUDY OF ANEURYSM RUPTURE

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The rupture of aortic aneurysms is a catastrophic event that represents a major public health issue. It has received a large interest from the scientific community. However, only limited research has provided quantitative values of mechanical stresses that may assess the risks of rupture of aneurysms [1].
In this study we have applied an imaging approach for measuring the deformations of the aneurysmal tissue tested in a biaxial inflation test [2]. The tissues have been taken from the thoracic ascending aorta of 6 diseased patients operated for aneurysm treatment by conventional surgery at the University Hospital of Saint-Etienne, France.
Quantitative values of ultimate stresses are reported in Tab. 1. Rupture is anisotropic, but primarily induced by axial stresses. Moreover, it is observed that rupture in aneurysms is preceded by a local weakening of the mechanical properties of the tissue, especially in the intima and media layers which are more fragile, and that these effects announcing a pending rupture can be detected by advanced imaging techniques. Our investigations continue in that sense for proposing novel diagnosis methodologies based on these observations.
Refs:
[1] Li ZY, Sadat U, U-King-Im J, Tang TY, Bowden DJ, Hayes PD and Gillard JH: Association between aneurysm shoulder stress and abdominal aortic aneurysm expansion - a longitudinal follow-up study. Circulation 2010, 122(18):1815-22.
[2] Kim J, Avril S, Badel P, Duprey A, Favre JP. Characterization of failure in human aortic tissue using digital image correlation. Computer Methods in Biomechanics and Biomedical Engineering, 2011, in press.

Tab. 1. Quantitative values of ultimate stress measured at rupture

Patient gender	M	M	M	M	M	M
Age	81	81	68	69	76	76
Type	adventitia	media	media	media	media	adventitia
Stress at rupture (MPa)	0.6257	0.3719	0.3686	0.4107	0.3483	1.0522