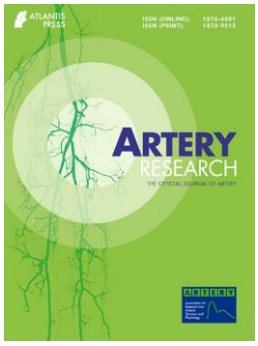

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# P10.11: THE EFFECT OF WALL MOTION ON THE HAEMODYNAMICS OF MIDDLE CEREBRAL ARTERY (MCA) ANEURYSM

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**Table 1** Comparison of the WSS and pressure magnitudes of the characteristic points between Newtonian and non-Newtonian simulations

| Point Number | Newtonian | | Non-Newtonian | | % Difference | |
|---|---|---|---|---|---|---|
| | WSS [Pa] | Pressure [Pa] | WSS [Pa] | Pressure [Pa] | WSS | Pressure |
| 1 | 0.688 | 15831.600 | 0.852 | 15832.500 | 19.284 | 0.006 |
| 2 | 2.980 | 15783.900 | 3.236 | 15784.600 | 7.911 | 0.004 |
| 3 | 5.670 | 15616.300 | 5.989 | 15616.600 | 5.325 | 0.002 |
| 5 | 4.403 | 15851.600 | 4.717 | 15852.500 | 6.639 | 0.006 |

**P10.08**

**COMPARATIVE INVESTIGATION OF MECHANICAL CHARACTERISTICS OF STABLE AND UNSTABLE CAROTID ATHEROSCLEROTIC PLAQUES**

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The prognosis of patients with carotid atherosclerosis is determined by the factor of unstable atherosclerotic plaque. Change of longitudinal strain in junction place of healthy artery wall to plaque determined by local artery elasticity and leads to instability.
**Aim of the study:** Comparative investigation of mechanical characteristics of the stable and unstable plaques in a carotid artery.
**Methods:** In the main group (MGr) were studied 16 plaques with stenosis 70-90%, and control group (CGr) 33 plaques with stenosis 25-45%. Carotid ultrasound examinations (PHILIPS iU22) were performed for estimated structure and stenosis of plaques. The "healthy" wall stiffness (free from plaques -βhw) and plaques zone stiffness (in adventitia -βadv and in plaques surface -βpl) were estimated using echo-tracking method by ALOKAα7 in B/M mode ultrasound imaging.
**Results:** In the MGr majority of plaques had structure with hypoechogenic area (>50%) and calcification, third plaques had rough or ulcerated surface. In CGr dominated heterogeneous plaques with smooth surface. In both groups βhw was significantly lower, than βadv (MGr: 8,95±3,14 vs 22,73±10,43, CGr: 9,43±2,64 vs 14,45±6,7, $p<0,001$), βadv was significantly higher than βpl (MGr: 22,73±10,43 vs 7,7±5,04; CGr: 14,45±6,7 vs 11,69±6,84, $p<0,001$). Relative changes of plaques zone stiffness (100-βpl×100/βadv) was significantly higher in the MGr (51,28±24,17% vs 26,93±21,45%, $p=0,036$).
**Conclusions**: Our results confirm presence the significant gradient of stiffness in junction place of healthy artery wall to plaque. In group with unstable plaques this gradient was significantly higher, that allows considering the possibility of the unstable plaques criteria developing by echo-tracking method.

**P10.09**

**ANALYZE OF A STOCHASTIC ANISOTROPIC FIBROUS CONSTITUTIVE LAW EFFECT ON THE HUMAN ARTERIAL PRESSURE**

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This research work deals with a stochastic approach using the entropy maximum principle to investigate the effect of parameters uncertainties on the arterial pressure. Motivated by a composite constitutive law with collagen fiber families [1], a set of uncertain parameters describing the mechanical behavior of the artery wall was considered. On the light of the available information, probability density functions were considered for the random variables governing the constitutive law in order to describe the dispersion of mechanical model response. Numerous realizations were performed according to the probability distributions and the corresponding arterial pressure results were compared to human non invasive clinical data recorded over a mean cardiac cycle. To prove the convergence of the probabilistic model, simulations of Monte Carlo were performed [2]. The different realizations were useful to define a reliable confidence region in which the probability to have a realization is equal to 95%. The obtained results demonstrate that the error in the estimation of the arterial pressure can reach 35% when the estimation of model parameters is subjected to an uncertainty ratio of 5%. Eventually, a sensitivity analysis was performed to discuss the influence of every uncertain parameter on the arterial pressure to identify the main parameters which contribute significantly in the constitutive law for a better understanding and characterization of the arterial wall mechanical behavior.
[1] I. Masson, P. Boutouyrie, S. Laurent, J.D. Humphrey, M. Zidi, *Characterization of arterial wall mechanical behavior and stresses from human clinical data*, Journal of Biomechanics 41, 2618-2627, 2008.
[2] A. Eddhahak-Ouni, I. Masson, E. Allaire, M. Zidi, *Stochastic approach to estimate the arterial pressure*, European Journal of Mechanics - A/Solids 28, 712-719, 2009.

**P10.10**

**THE INFLUENCE OF ANTIHYPERTENSIVE TREATMENT ON ARTERIAL STIFFNESS AND SELECTED MATRIX METALLOPROTEINASES PLASMA ACTIVITY**

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The aim of the study was to compare the effects of 5 selected drugs on arterial stiffness and matrix metalloproteinases (MMPs) plasma activity in patients with essential arterial hypertension (HT).Material and methods: 95 pts. with HT stage 1 and 2, (N=19 in each treatment group) were treated for 6 months by: quinapril 20-40 mg/d (group-1), amlodipine 5-10mg/d (group-2), hydrochlorothiazide 12,5-25mg/d (group-3), losartan 50-100 mg/d (group 4), bisoprolol 5-10 mg/d (group-5). Before and then after 1,3 and 6 months of treatment office blood pressure (BP) was measured using Omron M5-I device. Carotid femoral pulse wave velocity (PWV) was measured using 3 devices Complior®, Sphygmocor® and Arteriograph™. Plasma concentration of (MMPs): MMP1, MMP2, MMP3, MMP9 and MMPs tissue inhibitor (TIMP1) was measured twice i.e. before and after 6 months of treatment using micro- ELISA method. Results: At the baseline no differences between groups were observed in BP, PWV and MMPs activity. ANOVA for repeated measurements revealed for all groups during treatment significant decrease in systolic BP ($p<0.001$), diastolic BP ($p<0.001$), PWV ($p<0.001$), MMP2 ($p<0.05$) and MMP3 ($p<0.001$) and increase of TIMP1 ($p<0.001$) plasma concentration. No between treatment groups differences were observed in above mentioned effects. Decrease of PWV was in significant relation to its baseline value ($B=0.498$, $p=0.00041$), decrease of MMP3 ($B=0.211$, $p=0.0021$ and increase of of TIMP1 ($B=0.263$, $p=0.0052$). Conclusion:Antihypertensive treatment reduces arterial stiffness proportionally to its baseline value and independently of the used drug. The reduction of arterial stiffness depends on decrease of extracellular matrix degradation.

**P10.11**

**THE EFFECT OF WALL MOTION ON THE HAEMODYNAMICS OF MIDDLE CEREBRAL ARTERY (MCA) ANEURYSM**

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External forces, accelerations and displacements, due to sudden motions of head or traumas, may affect the haemodynamics and flow patterns in a cerebral aneurysm. Despite several studies on blood flow dynamics and arterial wall mechanics in intracranial aneurysms, limited investigations considered the external forces or motion of the arterial wall. Therefore in this study, we have numerically analyzed the effects of wall movement on cerebral aneurysms with the fluid and structure interaction (FSI) theories. A 3Dimentional Model of Middle Cerebral Artery (MCA) aneurysm (geometry adopted from R. Torii et al., *Int. J. Numerical Methods in Fluids*, **54**:995–1009, 2007) was constructed and exposed to a realistic head motion in sagital plane. Blood was considered as a homogeneous, incompressible

and Newtonian fluid and arterial wall assumed to be elastic, incompressible and isotropic. The governing equations were, continuity and Navier-Stokes equations for fluid domain and equilibrium equations and Hooke's Law for arterial wall. The flow was steady and motion was applied to the arterial wall. Simulations were carried out using the commercially availed finite element software. The effect of wall motion on flow patterns and wall shear stress, strain and effective stress distributions have been discussed. The results show that arterial wall motion doesn't change the magnitude of major hemodynamic factors and wall stress and strain distributions considerably and won't lead to aneurismal rupture directly, but obviously affects the blood flow patterns in cerebral aneurysms.

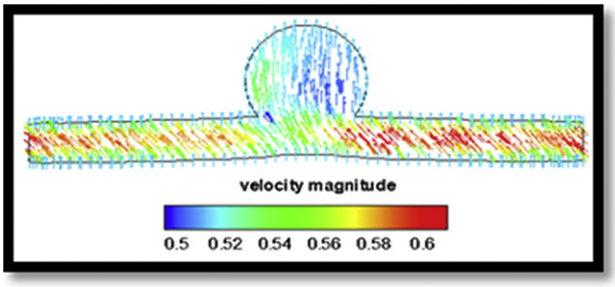


**Figure 1** Velocity vectors in model with arterial wall motion

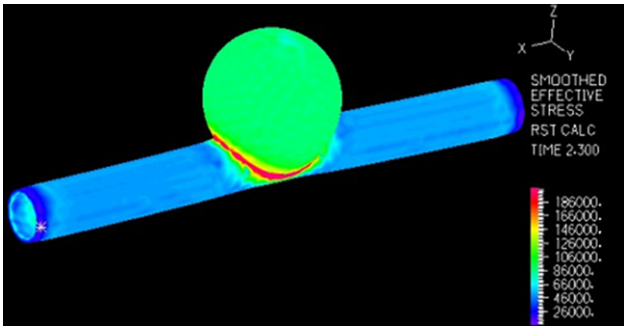


**Figure 2** Effective stresses distribution in model with artery wall motion

### P10.12
### COMBINED B-MODE, ACOUSTIC RADIATION FORCE (ARF), AND DOPPLER REAL-TIME IMAGING SYSTEM FOR ASSESSING CARDIOVASCULAR MECHANICS AND BLOOD FLOW HEMODYNAMICS

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In efforts to monitor the progression of atherosclerosis using ultrasound, Acoustic Radiation Force Impulse (ARFI[1]) and Shear Wave Elasticity Imaging (SWEI[2]) have been implemented to measure the mechanical stiffness of vascular tissue while colorflow Doppler and spectral Doppler techniques have been used to monitor the associated blood flow hemodynamics.

Towards creating an imaging system capable of collecting both the mechanical and hemodynamic information within one acquisition, a series of combined Bmode/ARFI/Doppler imaging tools were developed. These tools acquire multiple frames of co-registered Bmode echogenicity, ARF induced on-axis displacements and transverse wave velocities, along with blood flow velocity estimates and wall-shear rate (WSR) at frame rates up to 20 Hz over several cardiac cycles. Implemented on a diagnostic ultrasound scanner connected to a laptop for off-line processing, the carotid arteries of patients with and without known carotid artery plaques were scanned.

Processed images were temporally and spatially stable across multiple frames and acquisitions. Cyclic variations across the cardiac cycle were observed, depicting increased vessel wall stiffness and increased WSR during systole compared to diastole. For combined Bmode/ARFI configurations, overall data acquisition and image processing frame rates of 1 Hz were achieved, enabling feedback during the exam. A series of acquired *in vivo* image sequences will be presented.

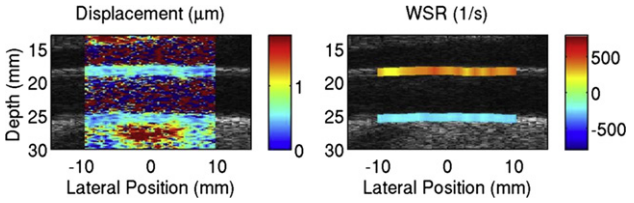


**Figure 1** Co-registered ARFI displacement image (left) and WSR image (right) shown overlaid on a B-mode image obtained *in vivo* using a combined B-mode/ARFI/Doppler system.

[1]Nightingale et al. J. Acoust Soc Am. 110(1). 2001, 625-634.
[2]Sarvazyan et al. Ultrasound Med Biol. 24(9). 1998, 1419-1435.

## P11 — Clinical Science 2

### P11.01
### AUGMENTED AORTIC FORWARD PRESSURE WAVE AMPLITUDE CONTRIBUTES TO INCREASED LEFT VENTRICULAR MASS IN OVERWEIGHT ADOLESCENTS

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We hypothesized that aortic forward pressure wave amplitude, which is determined by characteristic impedance (Zc) and peak flow in the proximal aorta, contributes to increased left ventricular (LV) mass observed in overweight (OW) adolescents. Aortic pulsatile hemodynamics were measured non-invasively in sixty healthy adolescents (age 14-19 yrs; 42% male) by sequential recordings of pulse waveforms via tonometry, brachial BP, and pulsed Doppler and diameter of aortic outflow tract using 2D echocardiography. LV structure and function was assessed by 2D echo. OW adolescents ($n=23$; age $16.0 \pm 0.3$ yrs; BMI $\geq 85^{th}$ percentile) had higher LV mass index (LVMI), brachial and carotid systolic BP and PP (all $P<0.05$), but not mean BP, carotid-femoral PWV or augmentation index compared with normal-weight (NW, $n=37$; $16.7 \pm 0.3$ yrs; BMI $<85^{th}$ percentile) ($P>0.05$). OW demonstrated lower resistance (Z0, $1512 \pm 91$ vs. $1786 \pm 70$ dyne x sec/cm$^5$) and higher Zc normalized to Z0 ($0.13 \pm 0.01$ vs. $0.11 \pm 0.01$) and forward wave amplitude (Pf, $48 \pm 3$ vs. $40 \pm 2$, mmHg) compared with NW (all $P<0.05$). Adjusting for age and sex, LVMI correlated with brachial and carotid systolic BP and PP ($r=0.26$-$0.30$), Z0 ($r=-0.27$), Zc normalized for Z0 ($r=0.29$), and Pf ($r=0.32$) (all $P<0.05$). Stepwise multiple regression revealed that BMI ($\beta \pm$ SE; $0.69 \pm 0.19$; $R^2=0.26$) and Pf ($0.23 \pm 0.07$; $R^2$ change $=0.11$) were the best predictors of LVMI (total $R^2=0.37$, $P<0.01$). These findings suggest that augmented Pf is a major hemodynamic determinant of increased LV mass with obesity in adolescents.

### P11.02
### INFLAMMATION AND PRE-ATHEROSCLEROTIC VASCULAR CHANGES IN HEALTHY 5 YEAR OLD CHILDREN

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***Background:*** Inflammation is important in atherosclerosis development. Whether common causes of inflammation, like common infections and allergies, contribute to vascular changes already in childhood remains unknown.
***Methods:*** In the first 345 five-year-olds of the WHISTLER birth cohort, carotid intima media thickness (CIMT), distensibility and Elastic Modulus (EM) were obtained ultrasonographically. Information on primary health care consumption for infections and allergies was obtained from the general practitioners' electronic files. Moreover, parental history of allergies was collected.
***Results:*** Neither lifetime nor recent consultations for infections, nor the number of visits for more severe infections was associated with vascular measures (adjusted for age, gender, BMI, parental smoking, gestational age, infant feeding and allergies). Lifetime prescription of antibiotics was not related to vasculature, but antibiotic prescription in the last 3 months was associated with a 18.1 μm increased CIMT (95%-confidence interval (CI): 1.2 — 35.1).