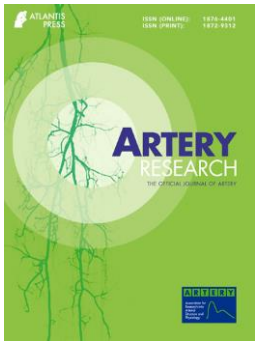

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P5.2: FROM THE WAVE PROPAGATION MODEL TO A TRANSFER FUNCTION: A POSSIBILITY FOR PERSONALISATION

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levels, and lipids profile were measured. Ambulatory blood pressure measurements and echocardiography were performed.
Results: LVH was detected in 34 out of 71 children. In children with LVH, significantly higher values of BP were observed in 24-hour measurements: systolic (119 vs. 109 mm Hg; p=0.002), diastolic BP (73 vs. 65 mm Hg; p=0.009) and MAP (89 vs. 81 mm Hg, p=0.004). These significantly higher BP values were observed within day and night. Increased cholesterol level was found in 25, LDL in 12, TGL in 28, and a decreased HDL in 20 children.
In children with LVH higher BMI (18.6 vs. 16.7 kg/m^2;p=0.039) and lower albumin (41.5 vs. 45.4 g/l; p=0.013), HDL (1.14 vs. 1.5 mmol/l; p=0.001) and Ca levels (2.36 vs. 2.47 mmol/l; p=0.03) were found. Obesity and low HDL level were independent LVH risk factors. The results indicate a 3-fold increase in the risk of LVH in children with hypertension (OR 3.18, p=0.045), rising up when 2-3 risk factors were present (OR 6, p=0.015).
Conclusions: Hypertension, a decreased HDL cholesterol level and overhydration have significant impact on the development of LVH in CKD children.

P4.20
ASSESSMENT OF BODY COMPOSITION USING BIOELECTRICAL IMPEDANCE ANALYSIS AND BLOOD PRESSURE IN HEALTHY SCHOOL CHILDREN

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Introduction: Bioimpedance analysis (BIA) is becoming more widely used in clinical practice to measure water body compartments. BIA allows to calculate: total body water (TBW), lean body mass (LBM), fat mass (FM), intra- and extracellular water (ICW, ECW).
Aim: The aim of this study was to evaluate the influence of body composition, measured by electrical bioimpedance, on blood pressure (BP) in children.
Methods: The study was performed in 72 children (32 girls and 40 boys) aged: 6-7 and 12-13 years. BIA measurements were taken using Nutriguard Data Input device. Blood pressure was measured twice using oscillometric method.
Results: 8 studied children had body weight <3rd percentile; 1 girl >97th percentile. A statistically significant correlation between systolic BP and TBW (r = 0.4023, p <0.000), LBM (r = 0.3600, p = 0.002), FM (r = 0.4725, p <0.000) ECW (r = 0.4598 p <0.000) and BMI (r = 0.4089 p <0.000) was found. Furthermore, diastolic BP significantly correlated with TBW (r = 0.3056, p = 0.011), LBM (r = 0.2783, p = 0.021), FM (r = 0.3956, p <0.000) ECW (r = 0.3869 p = 0.001) and BMI (r = 0.3550, p = 0.002). Elevated BP values > 95th percentile for gender, age and height were observed in 5 girls and 4 boys.
Conclusions: In the studied children systolic and diastolic BP values correlated with body composition parameters. The problem of unrecognized hypertension and malnutrition in children and adolescents is still underestimated in the Polish population.

P4.21
MICROCIRCULATION EFFECTS OF OBESITY AND/OR DIET: A PRELIMINARY STUDY IN MICE

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Obesity is becoming a global epidemic and is associated with cardiovascular disease. Genetic factors play a significant role in the disease etiology but less is known about the interaction between genes and diet composition. This study is aimed to investigate the effect of diet and/or genotype on microcirculation in mice.
Five groups of male mice (28 weeks) were examined using micro-ultrasound (Vevo2100, VisualSonics): 5 wild type mice on standard diet (WT_DS), 7 wild type mice on high-fat diet (WT_HF), 7 OB/+ mice on standard diet (OB/+_SD), 5 OB/+ mice on high-fat diet (OB/+_HF) and 4 OB/OB mice on standard diet (OB/OB_SD). The high-fat diet (45% energy as fat) groups were treated for 18 weeks before US scans. Infrarenal vasculature was imaged using Power-Doppler mode and Pulsed-Wave Doppler signals were acquired at the segmental level; Resistivity Index (RI) and Pulsatility Index (PI) were then assessed.
Both RI and PI were significantly lower in WT_DS than in WT_HF (0.57±0.03vs0.67±0.06 and 0.86±0.04vs1.10±0.09, respectively). The same result was found for the comparison between OB/+_SD and OB/+_HF (0.63±0.06vs0.72±0.04 and 1±0.12vs1.22±0.09, respectively). RI and PI values were significantly different between WT_HF and OB/+_HF mice, while no differences were found for WT_DS-OB/+_DS, WT_HF-OB/OB_SD and OB/+_HF-OB/OB_SD comparisons.
The high-fat diet has effects on the microvasculature of both WT and OB/+ mice. The two genotypes respond differently to the high-fat diet but not to the standard one. Moreover, if treated with high-fat diet, WT and OB/+ animals are not different from OB/OB mice (standard diet) in terms of microcirculation.

P5.1
FROM AORTIC FLOW VELOCITY TO CENTRAL PRESSURE: A NON-INVASIVE PROOF OF CONCEPT

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Estimation of aortic and left ventricular (LV) pressure usually requires measurements that are difficult to acquire during the imaging required to obtain concurrent LV dimensions essential for determination of LV mechanical properties. We describe a novel method for deriving aortic pressure from the aortic flow velocity. The target pressure waveform is divided into an early systolic upstroke and a diastolic decay, interposed by a late systolic portion described by a second-order polynomial. Pulse wave velocity (PWV), mean arterial pressure, diastolic pressure and diastolic decay are required inputs for the algorithm. The algorithm was tested using a) pressure data derived theoretically from pre-specified flow waveforms and properties of the arterial tree using a single-tube 1-D model of the arterial tree and b) experimental data acquired from a pressure/Doppler flow velocity transducer placed in the ascending aorta (n=18, mean+/-SD, age: 63+/-11 years, aortic BP: 136+/-23 / 73+/-13 mmHg) at the time of cardiac catheterisation. For experimental data, PWV was calculated from measured pressures/flows and mean, diastolic pressures and diastolic decay were taken from measured pressure. Pressure reconstructed from measured flow agreed well with theoretical pressure: mean+/-SD root mean square (RMS) error 0.7+/-0.1 mmHg. Similarly, for experimental data, pressure reconstructed from measured flow agreed well with measured pressure (mean RMS error 2.4+/-1.0 mmHg). First systolic shoulder and systolic peak pressures were also accurately rendered (mean+/-SD difference 1.4+/-2.0 mmHg for peak systolic pressure). This is the first non-invasive derivation of aortic pressure based on fluid dynamics (flow and wave speed) in the aorta itself.

P5.2
FROM THE WAVE PROPAGATION MODEL TO A TRANSFER FUNCTION: A POSSIBILITY FOR PERSONALISATION

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Since aortic pressure cannot be measured noninvasively, pressure signals are often measured at more superficial arteries and a transfer function is applied to obtain a surrogate for the central pressure curve. These transformations are usually derived from measurements in a specific group of subjects and a generalised transfer function is calculated thereof. In contrast, in this work a one-dimensional wave propagation model is used to derive a patient-specific transfer function.
A model of the arterial tree is combined with the theory from Womersley for blood flow in elastic vessels. This approach allows an explicit solution of the wave equations. Thus the pressure at each location in the arterial tree can be calculated from a stationary component and forward and backward travelling waves. To obtain a transfer function, it is sufficient to derive the transfer function from one arterial segment to its parent vessel by relating forward and backward travelling waves via the reflection coefficient of the

corresponding bifurcation. An extension to further segments can then be achieved by multiplication of the associated functions. This leads to an analytical transfer function which incorporates all model parameters and enables a patient-specific choice of these parameters reflecting arterial properties (eg. arterial lengths, radii, stiffness).
The transfer function based on an arterial tree model and wave propagation theory can be personalised by optimising model parameters to fit a specific patient. This may provide more accurate estimates of central pressure curves and thus could enhance the precision of pulse wave analysis and its clinical value.

P5.3

CHARACTERIZATION OF THE BIOMECHANICS OF THE RAT XENOGRAFT MODEL OF ABDOMINAL AORTIC ANEURYSM BY RING TEST

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Setting up new strategies to prevent the growth and fatal rupture of aneurysms remains a challenge. The rat xenograft model of abdominal aortic aneurysm (AAA) has been used to develop gene and cell therapies with the aim of countering the expansion of the diseased arterial wall. It is of primary importance to characterize the mechanical behavior of this model before studying the effects of those therapies.
Ring tests were performed on 34 samples extracted at several locations along rat AAAs and 8 samples from native healthy rat aortas (NA). The circumferential ultimate strength and extensibility were measured. Material parameters from an exponential isotropic hyperelastic strain energy density function were identified by a finite-element inverse approach. The changes of mechanical properties along the axial direction of AAA were analyzed through the correlation between parameters and external radius.
AAAs display significantly higher radius and thickness than NAs and appear weaker, with circumferential ultimate strength and extensibility significantly lower. Best-fit values for material parameters show significant differences between both groups. We reveal strong correlations between ultimate strength and external radius ($r=-0.58$, $p<0.001$). As well as between the material parameter accounting for non-collagenous matrix response and external radius ($r=-0.79$, $p<0.001$). These associations are explained by the degradation and loss elastin, which are more important as we get closer to the zone of maximal dilatation.
These results indicate that the most dilated parts are the most prone to rupture. Further studies should evaluate stress distributions within the arterial wall in order to better predict rupture risk.

P5.4

CENTRAL PRESSURE APPRAISAL: CLINICAL VALIDATION OF A SUBJECT-SPECIFIC MATHEMATICAL MODEL

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Increased blood pressure represents a major cardiovascular risk factor for western populations. Usually blood pressure is measured peripherally, but current evidence suggested that central blood pressure better predicts cardiovascular events. However, central blood pressure measurement is not feasible in daily clinical practice. New instruments can estimate non-invasively central blood pressure from applanation tonometry at peripheral sites and transfer function. Accuracy of this evaluation has been questioned. Remarkable development in medical imaging and computation techniques granted the opportunity to explore mathematical models describing the cardiovascular functioning.
Aim of the present study is the clinical validation of a mathematical model for appraisal of central blood pressure from subject-specific non-invasive measurements (i.e. brachial pressure, age, height, weight, ESV, EDV, etc.). A total of 52 healthy young male were selected for the present study. Central pressures were estimated with subject-specific model and compared with a common non-invasive technique (Sphygmocor).
Model estimated systolic and diastolic blood pressure resulted to be significantly related to Sphygmocor central systolic (r 0.65 $p<0.0001$) and diastolic (r 0.84 $p<0.0001$) blood pressure. The model showed a significant over-estimation of systolic (+7.8 [-2.2;14] mmHg, $p=0.0003$) and under-estimation of diastolic (-3.2 [-7.5;1.6], $p=0.004$) values.
In conclusion, the proposed mathematical model allows non-invasive prediction of central aortic pressure with good accuracy in more than one half of this population. Both the systematic over-estimation of aortic systolic pressure and the under-estimation of diastolic values compare well with the error reported by large meta-analysis when Sphygmocor is used with non-invasive calibration.

P5.5

COMPENSATORY EFFECT BETWEEN AORTIC STIFFENING AND REMODELLING DURING AGEING

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The arterial tree exhibits a complex spatio-temporal wave pattern, whose healthy behaviour depends on a balance between mechanical and geometrical properties. Several clinical studies demonstrated that this balance progressively breaks down during ageing, when the aorta stiffens and remodels. This dual mechanism is investigated by a validated multi-scale model aiming to elucidate how aortic stiffening and remodelling quantitatively impact the waves pattern in the aorta.
The detrimental increase of maximum pressure and left-ventricular work during ageing is here shown to results from the impairment of fluid dynamic balance between generation-propagation of forward waves and reflections- damping of backward waves. Our quantitative outcomes confirm several clinical studies results. Our results shed light on how ageing-induced aortic stiffening and remodelling affect this balance: the former enhances first pressure pulse at ventricular-aortic interface during ejection, while the latter damps it; although stiffening tends to decrease reflection coefficients at bifurcations, their remodelling-induced growth prevails; aortic remodelling undermines the protective wave-trapping mechanism while stiffening enhances it; aortic stiffening reduces pulse pressure amplification while remodelling augments it; by contrast, both stiffening and remodelling contribute to limit the growth of left-ventricle work with age.
These results suggest that an excessive imbalance between aortic stiffness and geometric remodelling during clinical treatment of elderly subjects should be avoided. Our results show how a dramatic reduction of the pulse wave velocity in a dilated aorta can lead to an increase of pulse pressure amplification, with potential detrimental effects on organs such as the kidneys.

P5.6

CORONARY FLUID MECHANICS IN AN AGEING CARDIOVASCULAR SYSTEM

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Coronary artery diseases are the most common type of cardiovascular diseases and have an increasing prevalence with age. Epidemiological studies demonstrated that coronary failure is associated with several pathologies (as atherosclerosis, hypertension, diabetes, endothelial dysfunction, renal insufficiency). Since the majority of these pathologies has an increasing prevalence with age, little is known about the effect of ageing alone on the coronary circulation.
In this context, the aim of the present work is to isolate the impact of ageing on the coronary flow. A fluid mechanics-based approach is adopted, based on the coupling of the mathematical model of the systemic circulation we proposed and validated with a model of the coronary circulation proposed and validated by Mynard et al (Am J Physiol, 2014). The resulting evolution of coronary pressure/flow waveforms and their coupling with the left-ventricular condition are analysed using impedance analysis and wave intensity analysis.
Confirming results from several clinical studies, we highlight a complex spatiotemporal coronary wave pattern, where intense waves originate from the aorta and from the deep myocardium, during both isovolumic compression and diastolic phase. The subendocardial viability ratio decreases with age, total coronary flow is slightly reduced, and left-ventricular work increases. Consequently, the left-ventricular work per unit of blood flow increases, thus limiting cell oxygen availability abundance, therefore increasing the risk of myocardial infraction.
Our results highlight a physiological age-induced supply/demand unbalance in the coronary arteries, which can augment the risk of myocardial ischemia and can contribute to pave the way to other coronary pathologies.