P.043: APPLICATION OF WOMERSLEY THEORY: ESTIMATION OF PULSE VOLUME FLOW AND WALL SHEAR STRESS IN LARGE ARTERY USING ULTRASOUND

C.A.D. Leguy*, E.M.H. Bosboom, A.P.G. Hoeks, P. Boutouyrie


To link to this article: https://doi.org/10.1016/S1872-9312(07)70066-2

Published online: 21 December 2019
A MODIFIED AUGMENTATION INDEX (AIX) USING WAVE INTENSITY ANALYSIS

A.W. Khir1, A.D. Hughes2, K.H. Parker2, Brunel University, Uxbridge, United Kingdom, Imperial College, London, United Kingdom

Augmentation index (AIX) is widely used as a measure of wave reflection in clinical studies. The validity of AIX results rests on the ability to quantify the magnitude of the reflected pressure wave (P-). In relation to the pressure pulse (PP), and this is traditionally carried out by determining the inflection point (Ip) on the pressure waveform. In this study we investigate the results of AIX and propose a modified augmentation index (mAIX) that is more sensitive to loading conditions.

In 11 anaesthetised dogs, total superficial occlusions were produced at 3 aortic sites (thoracic, diaphragm, abdominal), and at the left iliac artery. Pressure and flow were measured in the ascending aorta before and during the occlusion at each site, and Ip was ascertained using the 4th derivative of the pressure waveform allowing for the determination of AIX. Magnitude of P- was calculated using wave intensity analysis (WIA), and divided by PP giving a modified augmentation index (mAIX = P- / PP).

AIX during control were surprisingly not different from those determined with a measure of wave reflection, and that those values were comparable with AT, distension waveforms, obtained with high definition echotracking device at the central level, has been criticized because of artefacts induced by

Arterial tonometry (AT), used for measurement of augmentation index (AIx) during control were surprisingly not different from those determined with a measure of wave reflection, and that those values were comparable with AT, distension waveforms, obtained with high definition echotracking device at the central level, has been criticized because of artefacts induced by


CV risk. Carotid IMT is a prognostic marker for high CV risk.

Conclusions:

SI, FMD and ABI, only carotid IMT correlated significantly with SCORE risk (p = 0.052, p = 0.110 and p = 0.937 was evaluated by SCORE system.

Methods: We studied 160 subjects without cardiovascular disease (aged ⩾ 49.91 ± 7.16 years, 69 males). Traditional risk factors, carotid IMT, carotid radial pulse wave velocity (crPWV), stiffness index (SI), measured by phonoplethysmography, brachial artery FMD and the ABI were assessed. Laboratory tests included serum lipid and glucose profile. The total CV risk was evaluated by SCORE system.

Results: By multivariate analysis carotid IMT (p = 0.001) and SI (p = 0.008) were correlated with SCORE risk. Brachial artery FMD, ABI and crPWV didn't correlate significantly with SCORE risk (p = 0.052, p = 0.110 and p = 0.937 respectively). In stepwise regression models that include carotid IMT, crPWV, SI, FMD and ABI, only carotid IMT ≥ 0.9 mm correlated with high total CV risk (SCORE ≥5%). Odds ratio for increased CV risk was 8.56 (CI 95%: 3.109–23.567). The IMT cut-off point at 0.9 mm predicts high CV risk (sensitivity 67.4%, specificity 78.6%).

Conclusions: Carotid artery IMT and arterial stiffness marker SI predict total CV risk. Carotid IMT is a prognostic marker for high CV risk.

FLOW AND WALL SHEAR STRESS IN LARGE ARTERY USING ULTRASOUND APPLICATION OF Womersley THEORY: ESTIMATION OF PULSE VOLUME FLOW AND WALL SHEAR STRESS IN LARGE ARTERY USING ULTRASOUND

C.A.D. Leguy3, E.M.H. Bosboom1, P. Hoeks1, P. Boutouyrie2.

Eindhoven University of Technology, Eindhoven, Netherlands, 1University Hospital, Maastricht, Netherlands, 2Cardiovascular Research Institute, Maastricht, Netherlands, 3Department of Pharmacology and INSERM U 652, Paris, France

In order to assess pulse volume flow (PVF) and wall shear stress (WSS) in large arteries by the means of ultrasound, a Womersley theory based iterative method is proposed. Firstly, the PVF is computed by integrating the estimated velocity profiles obtained from multi-gate ultrasound Doppler; the vessel diameter was assessed through M-mode ultrasound. Secondly, an algorithm was applied in order to determine the PVF that gives the optimal fit of the core velocities estimated by ultrasound to the ones obtained through Womersley theory applied for tubes with non moving walls. The WSS is consequently computed from the fitted Womersley profiles. The PVF and WSS obtained through this method were compared to the ones given by Poiseuille theory. The method was applied on measurements performed on the brachial artery, repeated at least three times, of 9 presumed healthy volunteers. The results displayed a large relative difference in average maximal PVF (27.7%, p < 0.01) and WSS (72.36%, p < 0.01), the intra individual variations being 4.9% for the PVF and 11.6% for the WSS. In the case of the mean either performed at carotid (RSP-AI) or on the radial artery (RSP-AI), using the generalized transfer function (GTF) of Schygmylocor system. A group of 48 subjects with various diseases was studied. For WTS-AI, inflexion point was determined from the 0 crossing of the 3rd derivative. For CSP and RSP-AI, standard reports of Schygmylocor were used. WTS-AI could be determined with good precision from all tracings in all patients. Agreement between WTS-AI and CSP-AI was good (R2 = 0.83, RMSE = 5.8), with a 35% systematic underestimation by Schygmylocor: slope = 0.65 [0.56–0.73]. Agreement between WTS-AI and RSP-AI was good (R2 = 0.71, RMSE = 6.9), with comparable underestimation. This underestimation was not due to GTF, but to the applanation process since bypassing GTF had no influence on it and because AI, estimated with another type of tonometer, was exactly scaled with CSP-AI (slope 0.93 [0.81–1.05]). CSP-AI and RSP-AI were not in good agreement (R2 = 0.66, RMSE = 10.7), but correctly scaled (slope = 0.87 [0.81–1.05]). In conclusion, wave reflections can be assessed from distension waveforms with good accuracy with application techniques rather than from underestimation with distension waveforms.

MULTIAXIAL MECHANICAL CHARACTERISTICS OF CAROTID PLAQUE: ANALYSIS BY MULTI-ARRAY ECHOTRACKING SYSTEM.


REFERENCES

1European Hospital Georges Pompidou and INSERM U 652, Paris, France, 2Sainte-Antoine Hospital, Paris, France, 3Institut Superior des Biosciences de Paris, Creteil, France

Carotid plaque rupture depends on the various types of mechanical stresses. Our objective was to determine the multiaxial mechanical characteristics of atherosclerotic plaque and adjacent segment of the common carotid artery (CCA).

A novel non-invasive echotracking system was used to measure intima-media thickness, diameter, pulsatile strain, and distensibility at 128 sites on a 4 cm long CCA segment. The study included 62 patients with recent cerebrovascular ischemic event and either a plaque on the far wall of CCA (n = 25) or no plaque on the same vessel (n = 37). Multiaxial mechanical characteristics of the carotid segment devoid of plaque did not differ between the two groups. Among patients with plaque, 16 had a larger radial strain at the level of plaque than at the level of adjacent CCA (pattern A: outward bending strain). The 8 patients who had an opposite pattern (inward bending strain) were more often dyslipidemic (100% vs 56% P = 0.03) and type 2 diabetic (63% vs 12%, P = 0.04) than pattern A patients. Strain gradient significantly decreased in parallel with the presence of dyslipidemia and/or type 2 diabetes. Longitudinal gradients of distensibility and Young's elastic modulus were consistent with strain gradients.

In conclusion, type 2 diabetes and dyslipidemia were associated with a stiffer carotid at the level of the plaque than in adjacent CCA, leading to an inward bending stress. The analysis of plaque mechanics along the longitudinal axis may afford useful information, since repetitive bending strain of an atherosclerotic plaque may fatigue the wall material and result in plaque rupture.

APPLICATION OF Womersley THEORY: ESTIMATION OF PULSE VOLUME FLOW AND WALL SHEAR STRESS IN LARGE ARTERY USING ULTRASOUND

C.A.D. Leguy3, E.M.H. Bosboom1, A.P.G. Hoeks1, P. Boutouyrie2.

1Eindhoven University of Technology, Eindhoven, Netherlands, 2Cardiovascular Research Institute, Maastricht, Netherlands, 3Department of Pharmacology and INSERM U 652, Paris, France

In order to assess pulse volume flow (PVF) and wall shear stress (WSS) in large arteries by the means of ultrasound, a Womersley theory based iterative method is proposed. Firstly, the PVF is computed by integrating the estimated velocity profiles obtained from multi-gate ultrasound Doppler; the vessel diameter was assessed through M-mode ultrasound. Secondly, an algorithm was applied in order to determine the PVF that gives the optimal fit of the core velocities estimated by ultrasound to the ones obtained through Womersley theory applied for tubes with non moving walls. The WSS is consequently computed from the fitted Womersley profiles. The PVF and WSS obtained through this method were compared to the ones given by Poiseuille theory. The method was applied on measurements performed on the brachial artery, repeated at least three times, of 9 presumed healthy volunteers. The results displayed a large relative difference in average maximal PVF (27.7%, p < 0.01) and WSS (72.36%, p < 0.01), the intra individual variations being 4.9% for the PVF and 11.6% for the WSS. In the case of the mean
PVF and WSS, relative difference of 6.6% (p = 0.05) and -1.15% (p < 1) respectively were evidenced. The estimations based on Pulsatile theory present a significant underestimation of both maximum and mean PVF as well as maximum WSS by comparison to the results obtained through Womersley profiles fitting. No significant difference was observed for the mean WSS.

P.044

ROLE OF INTEGRIN α1β1 IN THE CARDIOVASCULAR EFFECTS OF ANGIOTENSIN II

H. Louis1, D. Rouy1, A. Kakou1, Z. Li1, C. Labat1, H. Gardner4, D. Wagner1, P. Lacolley1, 1Insens U684, Vandœuvre les Nancy, France, 2Cardiovascular Research Laboratory CRP-Santé, Luxembourg, Luxembourg, 3University Paris 6, Paris, France, 4Department of Research Pathology, Biogen Idec, Cambridge, United States

Integrin α1 knockout mice (α1−/−) were used to investigate the role of the integrin α1β1 in the cardiac and vascular functions of angiotensin II (AngII)-induced hypertension. Carotid artery (CA) elasticity was measured by incremental elastic modulus (Einc)-wall stress curves using an ultrasonic echo-tracking device and the measurement of medial cross-sectional area (MCSA) to evaluate in vivo CA mechanical properties. Cardiac function was studied by echocardiography in anaesthetized animals. Infusion of Ang II (200ng/kg/min) in α1−/− mice and their control (α1+/+) for 4 weeks led to similar hypertensive effect (SAP +31 vs +37mmHg). In α1−/−: Ang II failed to increase MCSA of CA whereas it did in α1+/+ mice. The Einc-stress curve of Ang II-treated α1−/− was shifted to the right compared to Ang II-treated α1+/+, indicating a decreased arterial stiffness. The α1−/− had an increased cardiac hypertrophy, evaluated by an increase of the end diastolic thickness of the septum (IVSd: 1.2 ± 0.8 mm) without modification of the posterior wall (LVPWd: 0.10 ± 0.08 mm) compared with the α1+/+ mice. This sepal hypertrophy was not found in the α1−/− mice in response to Ang II. Cardiac fibrosis measured by collagen quantification (total, and type I and III), was lower in the α1−/− mice, compared with the α1+/+ mice.

In conclusion, our results show an impaired of cardiovascular response to Ang II-induced hypertension in the integrin α1 knockout mouse. These results suggest the involvement of this integrin in the cardiovascular effects of Ang II.

P.045

STABLE THE REFLECTIVE PROPERTIES OF THE ARTERIAL SYSTEM IN RENAL TRANSPLANTATION (RTX) PATIENTS AT ONE YEAR FOLLOW-UP

N.G. Mardare1, P. Guszth-Tatomir1, A. Covic. 1Dr. Cl Prahon University Hospital, Dialysis and Transplantation Center, Iasi, Romania

Background: Successful RTx from living-related donors, by removal of the uremic milieu and improvement in cardiovascular risk factors can be associated with improvement in indices of arterial stiffness. The aim of this study was to assess the arterial stiffness after one year of follow-up in live related RTx patients.

Methods: The augmentation index (Aix) was determined from arterial waveforms contour analysis recorded by applanation tonometry using SphygmoCor® device in 31 living related RTx (19 M, age 34.6 ± 6.7 yrs, RTx duration 29.7 ± 24.8 Mo, mean Crl.C = 69.2 ± 1.2 ml/min). All studies were performed before CsA administration, at baseline and at one-year follow-up. As a surrogate marker of the pulse wave velocity (PWV) we used the time to shoulder (TTS) parameter on the reconstructed central pulse pressure contour waveform.

Results: Overall, during follow-up, mean Aix increased from 13.5 ± 13.3% to 15.6 ± 10.5% (p = NS). TTS increased from 107.7 ± 9.5 ms at baseline to 109.3 ± 12.0 ms at follow-up (p = NS). Biochemical parameters, blood pressure and heart rate remained unchanged over the follow-up period. On univariate analysis, at both moments, Aix and TTS correlated with anthropometric parameters (height and weight) and serum creatinine (independent predictor at baseline R2 = 0.443; p < 0.05). There was no correlation of the arterial stiffness parameters with creatinine clearance or CsA therapy (dosage/levels).

Conclusions: In our study we demonstrate that there are no significant overall changes in arterial stiffness properties after one-year follow-up in stable renal transplant patients.

P.046

INSIGHTS FROM PULSE WAVE VELOCITY ACROSS CONTRASTING DISEASES

S. do Vale1, J. Martin Martins1, C. Saldanha1, J. Martins e Silva1, 1Chemical Biopathology Institute, Lisbon Medical School, Lisbon, Portugal, 2Endocrine Department, Santa Maria Hospital, Lisbon, Portugal

Objectives: Several disease conditions are associated with an increased risk of vascular events. Direct evaluation of arterial structure and function remains elusive at the clinical level. We now report the results of pulse wave velocity in contrasting diseases.

Patients and Methods: We studied 200 consecutive patients assisted at the out-patient department of a public central hospital: (1) Obesity (OB, n = 60); (2) Type 2 Diabetes Mellitus (DM2, n = 60), Sexual Erectile Dysfunction (SED, n = 80). Patients were compared to controls (C, n = 40). Pulse wave velocity was measured between the carotid-radial arteries (CR) and between the carotid-femoral arteries (CF). Pulse wave velocity was measured across the carotid-femoral arteries with a computerized pressure transducer device (Complior®).

Results: Compared to controls, values at both sites were significantly increased in every disease condition: CR (m/s): (C) 7.03 ± 1.67; (OB) 8.21 ± 2.08; (DM2) 8.44 ± 3.10; (SED) 9.63 ± 2.10; CF (m/s): (C) 5.87 ± 1.92; (OB) 7.80 ± 2.04; (DM2) 11.31 ± 3.27; (SED) 13.08 ± 4.26. CR and CF PWV were directly and significantly related. Higher CR than CF levels were found only in the C group, with no difference in the OB group, and higher than CR levels observed in DM2 and SED groups (p < 0.05).

Body volume was a general significant factor for PWV, across diagnostic groups.

Discussion: Non invasive assessment of arterial stiffness by measuring PWV establishes arterial dysfunction in several pathologic conditions associated with increased cardiovascular risk, even when this is still a matter of debate, namely OB and SED. Increased arterial stiffness is most marked in larger elastic arteries like the aorta (CF-PWV) and reverses the normal PWV gradient against smaller-muscular arteries (CR-PWV).

P.047

CCR5-DEL32 GENOTYPE MODIFIES PRO-INFLAMMATORY/ANTI-INFLAMMATORY CYTOKINE RATIO; POSSIBLE ROLE IN Atherosclerosis


CCR5 is a receptor for several chemokines and is highly expressed on the cells involved in atherogenesis. A 32 bp deletion mutation of CCR5 prevents expression of this molecule on cell surface and is associated with reduced risk of premature coronary artery disease. It was shown that IL-6/IL-10 ratio could be a predictor of further coronary artery events in patients with Non-ST elevation acute coronary syndrome. In the present study we investigated the effect of CCR5-del32 mutation on production of pro-inflammatory and anti-inflammatory cytokines by lymphocytes in basal or stimulated conditions. Subjects were from a cohort of patients admitted to undergo coronary artery bypass graft surgery. Samples from 7 patients who were homozygote for wild type CCR5 allele (CCR5/CCR5) and 7 patients who were heterozygote for CCR5-del32 allele (CCR5/CCR5-del32) were used. Peripheral mononuclear cells (PMNC) were separated from whole blood by density gradient centrifugation. The PMNC cultures were either left untreated or incubated with lipopolysaccharide (LPS) or oxidative low density lipoprotein (OxLDL) for 24 hours before collecting their supernatant for cytokines measurement. PMNC carrying del32 produced significantly more IL-6 at baseline and after LPS stimulation. They also produced more IL-10 when stimulated with LPS and OxLDL. However, pro-inflammatory/anti-inflammatory ratio (IL-6/IL-10 and TNFα/IL-10) tend to be lower under stimulation by LPS and OxLDL in the group with del32 genotype. We concluded that some aspects of the protective effect of CCR5-del32 mutation against premature atherosclerosis can be attributed to modulation of pro-inflammatory and anti-inflammatory cytokine response in inflammatory cells particularly in PMNC.

P.048

ACUTE SYSTOLIC BLOOD PRESSURE: ESTIMATION FROM THE POINT OF SYSTOLIC AUGMENTATION IN THE DIGITAL ARTERY WAVEFORM

S.M. Munir1, A.Y. Guichler, B. Clapp, S. Redwood, P.J. Chowienyczky. Cardiovascular Division, King's College School of Medicine, London, United Kingdom

Introduction: Central and peripheral blood pressure and waveforms differ due to effects of wave reflection and amplification. Use of a mathematical transform function to predict central pressure remains controversial. It may be possible to estimate central systolic pressure directly from a peripheral