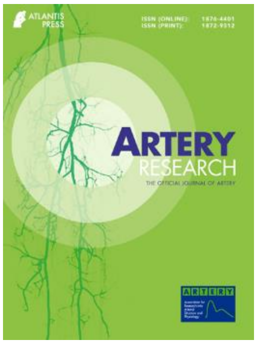

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P1.08: THE BRACHIO-TO-RADIAL PULSE PRESSURE AMPLIFICATION AND ITS CONTRIBUTION TO CENTRAL-TO-PERIPHERAL PULSE PRESSURE AMPLIFICATION

G. Pucci, J. Cheriyan, L. Whittaker, S.S. Hickson, G. Schillaci, C.M. McEniery, I.B. Wilkinson

high resolution, the near wall thickness (NW-IMT) is still challenging. New ultrasound software (CAAS-US, Pie medical Imaging) was developed for NW-FW-IMT measurement from radiofrequency signal.

Objectives: To compare CCA IMT between CAAS-US and standard Artlab, and to assess CAAS-US determination of NW-IMT and both near and far wall IMT variations during the cardiac cycle, in 38 treated hypertensive (HT) and 18 normotensive (NT) patients.

Methods: Diastolic outer diameter (Dd) and FW-IMT were determined with CAAS-US and Artlab. Bland-Altman test and Pearson's correlation coefficient (R) were used to compare methodologies. With CAAS-US, NW-IMT and FW-IMT were compared. Systolo(s)-diastolic(d) variations of IMT and outer D were calculated: ΔIMT ((IMTs - IMTd)/IMTd) of NW and FW were compared to ΔD ((Ds - Dd)/Dd).

Results: No significant differences in CCA Dd and FW-IMTd were observed between two methods (R=0.97, RMSE=0.124 mm and R=0.91, RMSE=0.065 mm, respectively p<0.0001). IMTd between near and far wall are significantly correlated (R=0.73, RMSE=0.117 mm, p<0.0001). FW ΔIMT is significantly correlated to ΔD (R=0.57, RMSE=0.036 mm, p=0.0002) whereas NW ΔIMT is not (R=0.30, RMSE=0.073 mm, p=0.065).

Conclusion: CAAS-US allows determination of both near and far wall CCA IMT. Whereas FW-IMT variation during the cardiac cycle is measurable, NW-IMT is less precise and remains a challenging. These findings added to CAAS-US plaque contours ability may be useful to estimate more completely the real state of the carotid artery atherosclerotic process.

P1.05

COMPARING AORTIC PULSE WAVE VELOCITY BY MAGNETIC RESONANCE IMAGING AND THE NEW OSCILLOMETRIC METHOD ARTERIOGRAPH

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Aims: Comparing aortic pulse wave transit time (TT) and velocity (aPWV) between magnetic resonance imaging (MR) and the oscillometric method Arteriograph (AG) that has potential for outpatient use.

Methods: MR phase-contrast transverse slices were sequentially taken at aortic arch (pulmonary bifurcation level), and 2 cm above aortic bifurcation in 49 men (age: 53±6 yr). TT was calculated using 10% of the MR flow wave amplitudes as wave-feet. The aortic root to bifurcation (aoLength) was measured in 3D volumes rendered from serial sagittal slices. Supine left-arm AG measurements were made post-MR, estimating aoLength from suprasternal-notch to symphysis-pubis surface length. Results are mean differences (95%CI).

Results: TT_{MR} and $aPWV_{MR}$ covered a mean 85% of aoLength partly omitting the proximal ascending aorta. TT_{AG} (71±10 ms) was 6.6(3.8-9.3) ms (10%) higher than TT_{MR} (64±10 ms) and correlated (r=0.54, p<0.001). $aPWV_{AG}$ (7.9±1.4) was 1.3(0.9-1.7) m/s higher than $aPWV_{MR}$ (6.6±1.3) and correlated (r=0.50, p<0.001). AG's sternum-pubis length was 70(59-81) mm higher than MR's aoLength (r=0.55, p<0.001).

A regression model was derived from 29 cases predicting measured $aoLength_{MR}$ using age and height. When tested in the remaining 20 cases, the *predicted* $aoLength_{MR}$ was within 5.3(-22-11) mm of that *measured* by MR. Compared with original $aPWV_{AG}$, recalculated $aPWV_{AG}$ using TT_{AG} and the regression-predicted aoLength was less different (0.31(0.01-0.61) m/s — p=0.02), and more closely correlated with $aPWV_{MR}$ (r=0.62).

Conclusions: TT estimations by AG and MR are close, given omitted proximal lengths by MR. More accurate length estimation can significantly improve AG's aPWV measurement using MR as a reference.

P1.06

THE ARTERIOGRAPH: CORRELATED TO AORTIC STIFFNESS, BUT MEASURING AXILLO-BRACHIAL ARTERY STIFFNESS?

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The Arteriograph (Tensiomed) is a device that determines aortic pulse wave velocity (PWV) by recording a brachial blood pressure waveform during supra-systolic inflation of a brachial cuff. We validated the working principle of the Arteriograph in a validated 1D computer model of the arterial tree, and found an excellent correlation between Arteriograph (PWV_{ATG}) and carotid-femoral ($PWV_{car\text{-}fem}$) PWV (r = 0.98, p<0.01) when homogenously altering stiffness parameters over the complete arterial network. However, selectively altering the stiffness of the aortic or axillo-brachial pathway demonstrated that PWV_{ATG} is determined solely by axillo-brachial stiffness and not by aortic stiffness. Furthermore, wave intensity analysis shows that the secondary forward compression wave picked up by the Arteriograph and used to assess the travel time of the pressure wave over the aorta is not caused by a reflection from the lower body. Instead, this wave is the result of "trapping" of the initial forward compression wave between the occluding cuff and the axillo-aortic junction. Thus the Arteriograph measures axillo-brachial stiffness, and the good correlation between PWV_{ATG} and $PWV_{car\text{-}fem}$ is driven by the fact that axillo-brachial and central stiffness were changed to the same extent in the model. Combining these results with earlier findings in literature of good in vivo correlations between PWV_{ATG} and $PWV_{car\text{-}fem}$, axillo-brachial and aortic stiffness are likely to be related. However, this does not necessarily imply that axillo-brachial and aortic segments change similarly with age (or disease). We conclude that PWV_{ATG} is, at best, an indirect and unspecific estimate of aortic stiffness.

P1.07

ULTRASOUND EVALUATION OF CAROTID STIFFNESS IN HEALTHY VOLUNTEERS DURING EXERCISE: A PILOT STUDY

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The study of cardiovascular parameters in exercise is intriguing, since this evaluation could provide information about dynamic conditions, mimicking patient's real life. Therefore, we evaluated carotid cross-sectional distensibility coefficient (DC), systemic vascular resistance corrected by cardiac frequency ($SVRI_T$), arterial elastance (Ea) and left-ventricular elastance (Elv) during graded bicycle semi-supine exercise test.

In 18 healthy subjects (9 men, 34±3 years) cardiac volumes were estimated from 2D transthoracic echocardiography, right carotid diameter and distension by an automatic system (Carotid Studio, IFC-CNR) applied to ultrasound B-mode image sequences and central pressures by tonometry. All measurements were performed at 60%, 70%, 80% and 85% (peak) of the age-dependent maximal heart rate.

During exercise DC decreased (peak versus rest: -17.8% and p<0.05), and $SVRI_T$ did not significantly change. Ea increased (+21.3%, p<0.01) and, since Elv presented a greater variation (+69.2%, p<0.001), arterial ventricular coupling (Ea/Elv) decreased (-22.6%, p<0.05). As expected, central pulse pressure was significantly increased (+81.8%, p<0.01).

In conclusion, carotid stiffness increased during exercise, possibly due to the recruitment of more collagen fibers and the consequent different mechanical behavior of arterial walls at higher pressures. Since $SVRI_T$ did not change significantly, the increased arterial stiffness, observed at carotid site, might represent the main determinant of Ea variation. Finally, a decrease in arterial-ventricular coupling during exercise was confirmed.

Our results show the feasibility of a simultaneous multi-sites approach that could help in the understanding of arterial physiology and patho-physiology in stress conditions.

P1.08

THE BRACHIO-TO-RADIAL PULSE PRESSURE AMPLIFICATION AND ITS CONTRIBUTION TO CENTRAL-TO-PERIPHERAL PULSE PRESSURE AMPLIFICATION

G. Pucci [1,2], J. Cheriyan [2], L. Whittaker [2], S. S. Hickson [2], G. Schillaci [1], C. M. McEniery [2], I. B. Wilkinson [2]
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Pulse pressure amplification (PPa) is the phenomenon by which systolic blood pressure (SBP) increases from aorta to periphery, whether mean (MAP) and diastolic pressure (DBP) remain constant along the arterial tree. Controversy exist in defining the extent of brachio-radial PPa and how much it contributes central-to-peripheral PPa. The SphygmoCor estimates central PP (cPP) by a transfer function applied to the radial waveform calibrated to brachial SBP/DBP, or to brachial MAP/DBP. If brachio-radial PPa was irrelevant, calibrating radial waveform to bSBP/bDBP or to bMAP/bDBP would have no measurable impact on estimated cPP.

In order to assess brachio-radial PPa and its determinants, 93 healthy subjects (42±20 years, 53% men) were studied after 10 minutes of supine rest.

Oscillometric bSBP/bDBP was used for brachial waveform calibration. Radial and brachial waveforms were consecutively obtained with applanation tonometry. Brachial MAP (bMAP) was derived from brachial tonometry by area method. Radial waveforms were calibrated to bSBP/bDBP and to bMAP/bDBP; cPP values were obtained for each calibration method, PPa was calculated as bPP/cPP, and brachio-radial PPa was the difference between the two PPa values.
On average, bSBP/bMAP/bDBP was 129/94/72±16/12/9mmHg. PPa was 1.42±0.25 when radial wave was calibrated to bSBP/bDBP, and 1.20±0.13 after calibration to bMAP/bDBP. Brachio-radial PPa was 0.22±0.17, and on average represented 52±18% of central-to-peripheral PPa. In a multivariate regression model, age, male gender, heart rate and cPP were all independent predictors of brachio-radial PPa.
Conclusions: Results suggest that brachio-radial PPa may represent a significant proportion of central-to-peripheral amplification. These findings require confirmation with invasive measurements.

	B	β	Multiple R	p
Heart rate, bpm	0.01	0.43	0.21	<0.01
Age, years	-0.01	-0.62	0.28	<0.01
Central PP, mmHg	0.01	0.58	0.49	<0.01
Gender, M	0.09	0.18	0.52	0.02

Stepwise multiple linear regression Constant is -0.86
Brachio-to-radial PP amplification as dependent variable
BMI, height, hypertensive status: n.s.

P1.09

VALIDATION OF A NEW NON-INVASIVE TONOMETER FOR DETERMINING AORTIC PULSE WAVE VELOCITY IN RATS

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Carotid-femoral pulse wave velocity (PWV) is an established method for characterizing aortic stiffness. At present, to determine PWV in rats, the gold standard method is a surgical invasive measurement; inevitably this leads to the animal's death. The objective of this study is to validate a new device for determining non-invasive PWV measurements which allows longitudinal studies in rats.
The PulsePenLab (DiaTecne), the device validated in this study, was derived from the PulsePen model, a validated high-fidelity tonometer, currently used to assess PWV non-invasively in humans. Two PulsePen tonometers recorded simultaneously carotid and femoral blood pressure pulse wave. The probes were positioned and fixed on the arteries by means of mechanical arms. The acquisition sample rate was 1KHz. Carotid-femoral PWV was determined by two operators, and measurements were repeated after a week. Immediately after this second test, a surgical invasive measurement of PWV was performed. The real sternum-carotid and sternum-femoral distances were compared with the external distances previously acquired by the two operators.
Now we present the preliminary data concerning the early 8 rats (Zucker fa/fa and Fa/Fa) included in this study. PWV determined by the PulsePenLab was compared with the traditional invasive measurement: the difference between the values of two measurements was 0.13±0.66 m/s, R=0.71. All values of difference were <1.0 m/s. Reproducibility of measurements was determined by inter-observer coefficient of repeatability (0.92 m/s) and coefficient of variation (9.79%).
These preliminary data suggest that PulsePenLab is an efficient device for determining a non-invasive measurement of PWV in rats.

P1.10

LOCAL AORTIC STIFFNESS ESTIMATED BY A BIOELECTRICAL IMPEDANCE TECHNIQUE

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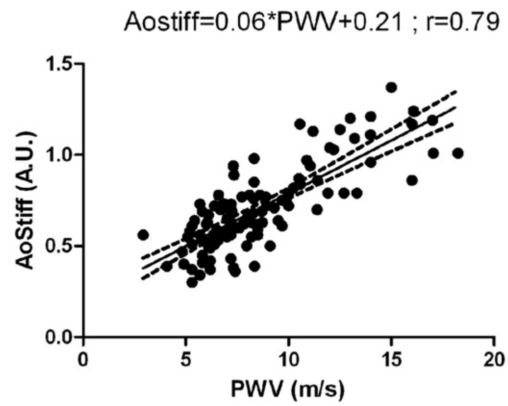
To date, aortic stiffness is evaluated by the reference tonometric technique via the pulse wave velocity (PWV) measured in two points (i.e. regional aortic stiffness): the carotid and the femoral arteries. Based on a bioelectrical impedance signal processing recorded at the chest level, we have developed a new method for the determination of the aortic stiffness in one point (i.e. local aortic stiffness). The local aortic stiffness (AoStiff) was computed from two basic indices: The aortic flux resistance (AoRes) and the aortic distensibility (AoDist) indices.
The study was carried out on 129 consecutive patients at rest (89 men, mean age 50 ± 13) recruited on the occasion of a vascular screening for atherosclerosis. Carotid-femoral PWV was determined by a trained operator and bioelectrical impedance signals were recorded at the chest for 2 min for AoStiff, AoRes and AoDist determination. Brachial arterial blood pressure was taken at the same time. Relationship between AoStiff index and PWV was evaluated by linear regression.
A Pearson's correlation coefficient of r=0.79 was found between both variables (95% confidence interval 0.71-0.85; P<0.0001; AoStiff= 0.06*PWV+0.21).
Our results show that the local and the regional methods can provide a reliable estimate of the aortic stiffness. The variability between both variables is likely explained by differences between the local and the regional elastic properties along the aortic tree.



P1.11

A PHOTOPLETHYSMOGRAPHIC PULSE WAVE ANALYSIS FOR ARTERIAL STIFFNESS IN EXTREMITIES

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Peripheral arterial disease (PAD) is a problem over the world. It manifests in extremities as arterial stiffness. The diagnosis of the PADs it can be done by photoplethysmography (PPG). PPG is a non-invasive optical technique for detecting the arterial pulse waves and changes of waves. The PPG signal can contain clinically valuable information about status of conducting arteries and veins.
In this study, we present an examination of the pulse wave analysis by its time domain features for characterizing and quantifying arterial pulse wave components which were measured by a new PPG device. The issue of wave component separation by logarithmic normal function (LNF) both index finger and toe tip PPG in parallel measurements on healthy subjects are addressed. A comparative test procedure for pulse wave analysis based on a wave component separation was applied in addition to a second derivative method of the PPG signal (SNPPG), and a Lissajous-like plot. These tests were applied to arterial pulse wave time series for human ages between 5 and 81 years on 85 subjects. The results show good correlation of pulse wave changes as a function of age, thus support on the arterial pulse wave analysis based on blood pressure. The LNF model fitted to the PPG signals according to the correlations over 0.995 and residues represent the difference to be almost zero between the LNF and the PPG data points. The Lissajous plots demonstrate a high asymmetry dependent on age.

P1.12

COMPARISON OF CLINICAL USEFULNESS BETWEEN STIFFNESS PARAMETER BETA (SPB) AND PULSE WAVE VELOCITY (PWV)

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Aims: Brachial-ankle PWV (baPWV) is widely used to evaluate arteriosclerosis, however, it is easily influenced by occasional blood pressure (BP).