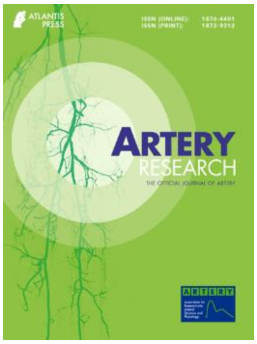

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P6.04: COMPARISON BETWEEN PULSE WAVE VELOCITY ASSESSMENT IN THE OBESE BY TRANSCUTANEOUS DEVICES COMPARED TO PHASE CONTRAST MAGNETIC RESONANCE IMAGING

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Methodological Aspects 2

P6.01
ULTRASOUND EVALUATION OF LOCAL ARTERIAL STIFFNESS: FEASIBILITY STUDY IN AN ANIMAL MODEL OF ADVANCED ATHEROSCLEROSIS

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Atherosclerosis is a pathological process affecting arterial elasticity. The rabbit is one of the most widely used animal models for atherosclerosis research. The aim of this study was to evaluate the feasibility of a method for the automatic assessment of local vascular stiffness in rabbits.

An off-line algorithm for the evaluation of arterial diameter (D) and distension (ΔD) from ultrasound image sequences was developed in Matlab and tested in 3 atherosclerotic and 2 control rabbits. Longitudinal scans of the aortic and carotid arteries of the rabbits were recorded in DICOM format. High frame-rate (330 Hz) image sequences (3 seconds) were acquired to track the rapid movement of the vessel (heart rate ∼ 240 bpm) using iE33 Philips ultrasound system. The probe was hold by a clamp. The measurement variability was assessed by performing two scans for each subject.

The high frame-rate provided a temporal resolution of 3 msec allowing the instantaneous tracking of the diameter curve for both carotid and aorta. As regards the variability, the coefficients of variation were: 3%±2% (D) and 7%±3% (ΔD) for the aorta (mean D = 3.2 mm) and 3%±2% (D) and 5%±4% (ΔD) for the carotid (mean D = 1.99 mm).

Our data demonstrate that the implemented ultrasound image processing algorithm is able to non-invasively assess the vascular instantaneous diameter both in control and atherosclerotic rabbits. The method, together with intra-central ear artery blood pressure measurement, could evaluate the effects of new therapeutic interventions on vascular stiffness in those pathological conditions characterized by arterial dysfunction, such as atherosclerosis.

P6.02
SIMULTANEOUS MEASUREMENTS OF THE AORTIC AND COMMON CAROTID DISTENSION WAVEFORMS BY MEANS OF ULTRASOUND

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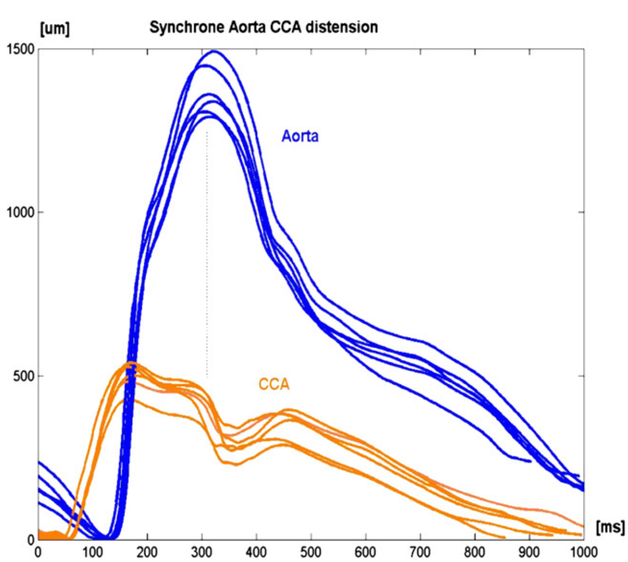

Figure 1 AA and CCA pulse waveform measured during 6 heartbeats in 1 volunteer.

Cardiac and arterial function is reflected in the distension (change in diameter) waveforms of central arteries.

For analyses, commonly the distension waveform of the common carotid artery (CCA) is used, as the CCA is superficial and easily accessible with ultrasound (US). However, the abdominal aorta (AA) is directly connected to the aortic root and a more pronounced influence of cardiovascular diseases on the AA pulse waveform is expected. The aim of this study is to compare the pulse waveforms in AA and CCA.

For this purpose, simultaneous assessment of the distension waveforms in the AA and CCA are performed on three healthy volunteers using two ultrasound scanners with ART.LAB functionality (Picus, Esaote Europe). The two systems are synchronised using ECG triggering. In addition, radial blood pressure is recorded continuously (Colin, USA).

Results show, that AA and CCA distension could reproducibly be measured. The ejection periods of the heart assessed from these pulse waves are equal. The maximum wall velocity is about 2.5 times higher in AA than in CCA. Approximated local blood pressure pulse is higher in AA than in CCA (58 mmHg and 44 mmHg respectively). Local pulse wave velocities, based on the distensibility coefficient, only slightly differ.

Future research will focus on analyzing the differences between both pulse waveforms with a 1D wave propagation model.

P6.03
SIMULTANEOUS UPPER ARM AND THIGH CUFF PULSE VOLUME RECORDING FOR RAPID ESTIMATION OF CENTRAL PULSE WAVE VELOCITY: COMPARISON WITH CAROTID-FEMORAL TONOMETRY

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Objectives: Aortic pulse wave velocity (PWV) is usually estimated by sequential (ECG referenced) carotid-femoral tonometry using the SphygmoCor system (Atcor, Australia). This can be technically challenging and operator dependant. Here we evaluate a simple, operator independent method of estimating central PWV based upon simultaneous recording from upper arm and thigh cuffs (Vicorder, Skidmore Medical, UK).
Methods: PWV was measured using the Vicorder and SphygmoCor systems (each measurement in triplicate) in 133 adults (mean age 53, range 21-70 years). SphymoCor PWV was calculated using the suprasternal notch (sn) to femoral distance. Two distances were used to calculate PWV from the Vicorder: cuff to cuff measured with arm at the side (cc) and sn to thigh cuff minus sn to arm cuff (notch to cuff difference, ncd). Reproducibility of the Vicorder was further assessed by repeat measures in 9 subjects.
Results: Mean values of PWV obtained by SphygmoCor, Vicorder (cc) and Vicorder (ncd) were 9.0 ± 1.6, 12.0 ± 2.8 and 8.7 ± 1.9 m/s respectively. Both Vicorder (cc) and Vicorder (ncd) were closely correlated with SphygmoCor PWV (each $r = 0.7$). The mean difference between SphygmoCor and Vicorder (ncd) was 0.2 ± 1.4 m/s. The within subject standard deviation for repeated measures for Vicorder (ncd) was 0.54 m/s.
Conclusion: There is a high correlation between values obtained using the Vicorder and SphygmoCor and good reproducibility for Vicorder measurements. Differences between the methods are likely due to errors in the estimation of path length. Vicorder PWV is quick and easy to perform with minimal training and offers a simple alternative to applanation tonometry.

P6.04
COMPARISON BETWEEN PULSE WAVE VELOCITY ASSESSMENT IN THE OBESE BY TRANSCUTANEOUS DEVICES COMPARED TO PHASE CONTRAST MAGNETIC RESONANCE IMAGING

L. Joly [1], A. Kearney-Schwartz [1], P. Salvi [1], D. Mandry [4], G. Karcher [2], P. Rossignol [3], P. Y. Marie [2], F. Zannad [3], A. Benetos [1]
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Background: Abdominal obesity is a clinical setting recognized as a difficult situation to assess transcutaneous pulse wave velocity (PWV). PWV measurement between carotid and femoral sites is considered as the gold standard measurement of aortic stiffness. Arterial stiffness is an important parameter to assess in obese patient to improve physiopathological knowledge about the link between abdominal adiposity and aortic elastic properties.
Method: We included prospectively 32 patients mean age of 55.7 ± 5.1 years, presenting abdominal obesity defined by a waist circumference >102 cm in men and >88 cm in women ($27 < \text{BMI} < 35$). Regional aortic

PWV was assessed in all patients first by a fast PC cine sequence of magnetic resonance imaging (MRI) between the ascending aorta and the descending thoracic aorta under the diaphragm and second by Pulsepen and Complior II between right carotid and femoral sites.
Results: Aortic MRI PWV value was 8.00 ± 2.66 m.s-1. Complior II PWV values were significantly lower than those obtained with Pulsepen, respectively 7.88 ± 1.38 m.s-1 vs 9.01 ± 1.64 m.s-1, $p < 0.0001$. There was a good correlation between Pulsepen PWV and aortic MRI PWV ($p = 0.005$, $r = 0.47$) and between Complior II PWV and aortic MRI PWV ($p = 0.01$, $r = 0.43$).
Conclusion: This is the first study to show the reliability of PWV assessment by transcutaneous devices in comparison to MRI PWV measurements in obese patients.

P6.05
MRI AORTIC THORACIC ELASTIC PROPERTIES ASSESSMENT COMPARED TO ARTERIAL STIFFNESS ASSESSMENT BY TRANSCUTANEOUS DEVICES

L. Joly [1], A. Kearney-Schwartz [1], P. Salvi [1], D. Mandry [2], P. Rossignol [3], G. Karcher [4], P. Y. Marie [4], F. Zannad [3], A. Benetos [1]
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Background: Aortic elasticity properties (aortic distensibility, compliance, elastic modulus, and stiffness index) can be evaluated by cross-sectional thoracic aorta areas measurements at 2 times of the cardiac cycle (peak systolic and end-diastolic phases) with PC-cine MRI series. Pulse wave velocity (PWV) measurement between carotid and femoral sites is considered as the gold standard measurement of aortic stiffness and elastic properties of aorta. Obesity is a difficult feature to assess aortic elasticity properties because of methodological problems due to the use of transcutaneous devices.
The aim of this study was to assess aortic elasticity properties with PC MRI and to compare the results with PWV assessed by two transcutaneous devices (Pulse pen and Complior II) in 32 consecutive patients presenting an isolated abdominal obesity defined by a waist circumference >102 cm in men and >88 cm in women ($27 < BMI < 35$).
Results: Aortic cross-sectional compliance assessed with MRI was inversely correlated with: Pulse Pen PWV ($p = 0.01$, $r = -0.44$), with the same trend for Complior PWV ($p = 0.07$, $r = -0.32$). Positive relationship was found between the above 2 PWV measurements and aortic stiffness index computed by MRI. Relationship was stronger for PWV assessed by MRI ($p = 0.02$, $r = 0.41$) and Pulse Pen ($p = 0.03$, $r = 0.38$). The relationship between aortic stiffness index and Complior PWV did not reach statistical significance ($p = 0.12$, $r = 0.28$).
Conclusion: In clinical difficult situation like obesity, aortic elasticity can be measured by PC MRI with a good correlation with peripheral PWV assessments.

P6.06
CAN WE LEARN ANYMORE ABOUT ARTERIAL FUNCTION FROM THE VALSALVA MANOEUVRE? WAVE INTENSITY ANALYSIS CAN INFORM US ABOUT RESERVOIR FUNCTION

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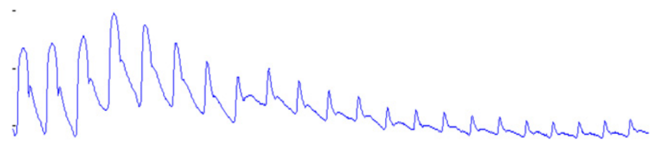
Background: The Valsalva manoeuvre (VM) is a physiological manoeuvre capable of generating profound changes in venous return. Although its physiology has been extensively described, the predominant focus has been on dynamic effects on cardiac preload with subsequent impact on cardiac output. However, analysis of the dramatic changes seen in arterial pressure and flow during this manoeuvre offers valuable insight into arterial function.
Methods: In 11 patients (9male, mean age 64 years), invasive measurement of pressure & Doppler flow velocity were made in the proximal aorta using sensor-tipped intra-arterial wires. Whilst recording, patients performed a controlled VM by blowing into a syringe. Calculation of pressure, aortic reservoir function and wave intensity were performed offline.
Results: Peak systolic blood pressure fell on average by 24% during sustained VM (157 ± 43mmHg to 122 ± 48mmHg, $p < 0.0001$). The peak reservoir pressure fell by an average of 65% (55 ± 17mmHg to 20 ± 13mmHg, $p < 0.0001$). The aortic pressure waveform during sustained VM assumes that morphology typically seen peripherally (Figure).



Conclusion: Prolonged VM is able to dramatically reduce both measured pressure and reservoir pressure in the proximal aorta and appears to produce a loss of this normal 'cushioning' effect. Is this simply a consequence of decreased stroke volume or are there other mechanisms involved?

Pressure waveform recorded invasively in proximal aorta during sustained Valsalva manoeuvre.

P6.07
METHODOLOGICAL ASPECT OF BRACHIAL FLOW MEDIATED DILATION: IMPROVEMENT OF REPRODUCIBILITY

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Brachial artery flow-mediated dilation (FMD) is the most widely used technique for assessing endothelial function in humans. FMD is reduced in the presence of cardiovascular risk factors and diseases and it is an independent predictor of events. However, its major limitation is the relatively low reproducibility. One of the main challenge is to maintain a stable scan plane during examinations, especially when the forearm cuff is inflated/deflated. The aim of this study was to evaluate the FMD reproducibility when resting diameter is calculated as the mean value measured from 8th to 9th minute after reactive hyperemia, when the vasodilation is concluded (BAS_POST), and to compare the results with those obtained with a standard assessment of resting diameter over 1 minute before cuff inflation (BAS_PRE). Thirty healthy subjects (age 25-45 years) underwent two FMD examinations 30 minutes apart. FMD to 5 minutes forearm ischemia was assessed by one trained operator using a clamp to hold the ultrasound probe in the same position and calculated as maximum percentage increase in diameter with respect to BAS_PRE and BAS_POST, by a real-time automatic edge-detection system (FMD Studio, Institute of Clinical Physiology, Pisa, Italy). FMD% variability was assessed as intra-session coefficients of variation (CV). Diameter was 3.56 + 0.66 mm in BAS_PRE and 3.57 + 0.66 mm in the BAS_POST. FMD% was 7.4 + 3.8% with BAS_PRE and 7.1 + 3.7% with BAS_POST. CV of FMD% was 15.61 + 10.9% in BAS PRE and 9.22 + 5.93% with BAS_POST calculation. These results suggest that FMD% calculated with BAS_POST can ensure a more reproducible measure of conduit artery endothelial function.

P6.08
CHARACTERIZATIONS OF THE ARTERIAL SYSTEM COMPARED

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Systolic pressure, P_s, and pulse pressure, PP, are determined by heart and arterial system. We here compare systemic arterial system characterizations alone, and mention their use and limitations (aspects).
1. *Peripheral resistance*, R_p. Required: Mean Pressure and Cardiac Output; Characterization: partial. Aspects: derivation simple; linear.
2. *Arterial Input Impedance*, Z_{in}. Required: Pressure, $P(t)$, and flow, $F(t)$; Characterization: complete and comprehensive. Interpretation: R_p, Total Arterial compliance, C, Characteristic impedance, Z_c. Aspects: Derivation difficult, data noisy; linearity.
3. Wave Transmission
a. Aortic Pulse Wave velocity, c, (Foot-foot wave speed). Required: two (uncalibrated) $P(t)$, (flows or diameters); Characterization: (Total) Arterial compliance. Aspects: Derivation simple, Aorta a uniform tube. Carotid-Femoral: not entire aorta; i.e., not total arterial compliance.
b. Waveform Analysis. Required: $P(t)$, $F(t) + Z_c$. Characterization: Amount and timing of reflections. Interpretation: diffuse (peripheral) and distinct reflections. Tube (aorta) with reflection site at end, no phase shift. Phase shift and c, change with age and effects may cancel. Aspects: Only timing and ratio $P_{backward}/P_{forward}$ give arterial characterization. Small error Z_c real.