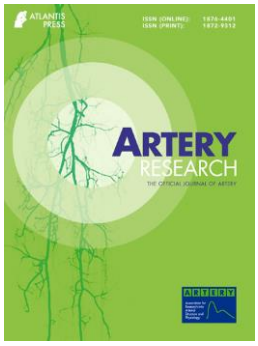

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P2.19: VALIDATION OF A NEW SYSTEM FOR THE ASSESSMENT OF FLOW MEDIATED DILATION: COMPARISON WITH A REFERENCE METHOD

F. Faita, S. Loukogeorgakis, V. Gemignani, M. Okorie, E. Bianchini, L. Ghiadoni, J.E. Deanfield, M. Demi

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Results: The overall mean (±SD) difference between cSBP and SBP_2 calibrated using the Omron 750IT was 1.4±11.8 mmHg. When SBP_2 was calibrated from aortic MAP and DBP the difference between cSBP and SBP_2 was -1.1±5.6 mmHg.
Conclusion: These results suggest non-invasive calibration does not produce a major systematic error in estimation of cSBP from SBP_2 but does introduce greater variability when compared to invasive calibration.

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P2.15
A COMPARISON OF SHEAR STRESS ESTIMATES IN THE COMMON CAROTID ARTERY IN HYPERTENSIVES

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Shear stress (SS) is associated with the formation of localised atherosclerosis. Due to the complexities of flow accurate determination of shear stress is difficult. Whilst 2D methods of deriving SS are widely used, computational fluid dynamic (CFD) modelling allows modelling of flow within complex geometry of the carotid bifurcation (CB).
This study compared mean SS using ultrasound based Womersley's solution and MRI based CFD.
9 untreated hypertensive subjects [median age 42 (range 35-52) yrs] in a double-blind, placebo controlled, randomised, 3 way crossover trial using amlodipine or lisinopril underwent ultrasound examination of the right common carotid (CC) using a 7.5 MHz ultrasound transducer (L12-5 scan-head, HDI 5000, ATL, Bothell, Washington). Pulse wave Doppler was performed using a 1.5mm sample volume placed in the centre of CC 2cm proximal from the carotid bulb. Mean Womersley shear stress was calculated from these data using custom written software.
MRI of the CB was performed (Siemens Magnetom Sonata 1.5 T scanner) using a 2D TOF protocol and 3D PC sequence for flow measurements. These data were combined with custom refined CFD codes (CFX4.4 (AEA Technology, Didcot, Oxfordshire UK).
Mean difference was -0.242 Pa (SD 0.314; 95% limits of agreement -0.856, 0.373]; Lin's concordance correlation coefficient (rho_c 0.16; SE 0.13; $p = 0.21$); Pearson's $r = 0.244$; $p = 0.219$.
Overall the data indicate poor agreement between WSS measured by ultrasound/Womersley and MRI/CFD and underscore the limits of using 2D methods in the investigation of the relationship between SS and atherosclerosis in the CC.

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P2.16
PRESSURE PROFILE ANALYSIS AT HEMODIALYSIS NEEDLE: A NEW METHOD FOR EARLY DETECTION OF VASCULAR ACCESS STENOSES

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Hemodialysis vascular access stenosis remains a frequent complication. However; early detection is challenging and costly. The aim of this in-vitro study was to assess the value of a new detection method based on pressure profile analysis at the hemodialysis needle.
A silicon model of a radio-cephalic arteriovenous fistula was built (4mm artery connected by an end-to-side anastomosis with a 7mm vein). A water-glycerine mixture was used as blood mimicking fluid. Pressure profiles were measured at the arterial hemodialysis needle (4cm downstream the anastomosis) and in the feeding artery 20cm upstream the anastomosis. Stenoses (50% diameter reduction) were created 10cm upstream the anastomosis (proximal artery (PA)) and 3.5cm and 8cm downstream the arterial needle (distal vein (DV) and proximal vein (PV) respectively). The pulse pressure (maximum minus minimum) at the needle was divided by the pulse pressure at the feeding artery to obtain a dimensionless ratio, %PP. Experiments were conducted at different blood flow (500 to 1200 ml/min) and heart rates (60 to 90 beats/minute) to test this new index over a wide range of hemodynamic conditions.
In the control model (no stenosis), %PP was 20.26±4.55%. PA stenosis significantly decreased %PP to 7.69±2.08% ($P<0.001$), while presence of stenosis in the distal (36.20±2.12%) and proximal (32.38±2.17%) vein lead to significantly higher values of %PP ($P<0.001$).
This in vitro study shows that the analysis of the pressure profile at the dialysis needle is useful for early detection and localization of hemodialysis vascular access stenosis, independent of heart rate and flow level.

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P2.17
ASSESSMENT OF THE BRACHIAL ARTERY FLOW-MEDIATED DILATION WITHOUT ECG GATING

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The methods commonly used for non-invasive ultrasound assessment of endothelium-dependent Flow-Mediated Dilation (FMD) require an ECG signal in order to synchronize the measurement with the cardiac cycle. In this study we present a method for assessing FMD which does not require ECG gating. The approach is based on filtering of the diameter-time curve, which is obtained by means of a B-mode image processing system. Since diameter changes due to vasodilation/vasoconstriction mechanisms and diameter changes induced by the cardiac cycle happen at different frequencies (fractions of Hz for the former; more than 1 Hz for the latter), frequency filtering was used to separate the two components and obtain only the desired information.
The method was tested on 22 healthy volunteers without cardiovascular risk factors and the measurements obtained with the proposed approach were compared with those obtained with ECG gating. Diameter values computed with the new method were very similar to those obtained with ECG gating (3.90±0.75mm and 3.88±0.75mm respectively). %FMD values obtained with the two methods were compared with Bland Altman plot: the bias was negligible (0.02%) and the SD of the difference was 0.24%, a value which is largely acceptable for this measurement.
In conclusion, the new method showed a good agreement with ECG gated measurements. Moreover, since it is based on a larger number of measurements, it provided a higher precision. Further advantages were also found both in terms of reliability of the measure and simplification of the instrumentation.

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P2.18
NON INVASIVE MEASUREMENT OF ENDOTHELIAL DYSFUNCTION BY DIGITAL VOLUME PULSE ANALYSIS TECHNIQUE: APPLICATION & UTILITY IN CLINICAL PRACTICE

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Background: The assessment of endothelial function has been accepted as an independent surrogate marker of cardiovascular disease (CVD), having both positive prognostic and diagnostic implications. The Digital Volume Pulse (DVP) analysis technique is a non—invasive approach to derive endothelial function. However, the utility and clinical application of this analysis technique has not been established.
Methods: we determined the discriminatory performance of the DVP analysis technique in identifying the people with established risk indices compared to a healthy population (West Midlands of the UK). Endothelial dependent and independent vessel function (Δ RI) was calculated by analyzing the change in digital pulse wave forms obtained by DVP photoplethysmography technique(Micro Medicals)
Results: Of our cohort of ($n=225$) (60.1% male; mean age 53.7 (SE 1.5) years), 155 had established CVD risk factors and had significantly ($P<0.001$) impaired endothelial function (Δ RI% (SE) [Diabetes : 4.6%(0.3), Hypertension: 6.9(0.6), hypercholesteremia 6.4(0.6)] compared to healthy controls [10.5(0.5)]. On univariate analysis, endothelial function was strongly associated with glycaemic status (R:-0.38, $P= <0.001$) In multivariate analysis, after adjusting for age and other risk factors, glycaemic status independently predicted endothelial function (Beta: -2.32(95% CI:-4.36—0.03), $P=0.04$) In ROC analysis Δ RI was a better discriminator (AUC(SE): 0.7(0.06) compared to individual CVD risk factors such as mean blood pressure, wait hip ratio and total serum cholesterol level.
Conclusion: Measurement of endothelial function by DVP analysis technique provides a non- invasive method of measuring endothelial function in clinical practice for the discrimination of people with established risk factors and may aid more precise cardiovascular risk stratification.

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P2.19
VALIDATION OF A NEW SYSTEM FOR THE ASSESSMENT OF FLOW MEDIATED DILATION: COMPARISON WITH A REFERENCE METHOD

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Endothelial function is linked to cardiovascular risk factors, provides prognostic information when studied non-invasively by measurement of flow-mediated dilation (FMD). Despite the large effort to standardize the methodology, the FMD examination is still characterized by problems of reproducibility and reliability that can be overcome with the use of automatic systems. In our lab, we developed a system for the assessment of brachial FMD from ultrasound images which is able to automatically evaluate the brachial artery diameter in real-time. In order to validate our system, we carried out a comparison with another automatic method, available at the Vascular Physiology Unit of the Institute of Child Health (London), that it is considered as a reference method in FMD assessment. Two protocols have been followed in order to evaluate the agreement between the systems.
Protocol 1: 47 VCR recorded FMD sequences have been analyzed. Mean baseline (Basal), maximal (Max) brachial artery diameter and FMD, as maximal percentage diameter increase (%FMD) have been evaluated for each sequence.
Protocol 2: brachial artery diameter (Diam) has been evaluated in 618 frames from 12 sequences. Diam value and %FMD have been considered for each frame. Bland-Altman analysis has been used. As shown in the table, the bias is negligible and the SD of the differences is satisfactory. In conclusion, the compared systems show a optimal grade of agreement and they can be used interchangeably. Thus, the use of a system characterized by real-time functionalities would represent a referral method for assessing endothelial function in clinical trial.

	PROTOCOL 1			PROTOCOL 2	
	Basal	Max	%FMD	Diam	%FMD
Mean of Diff.	-0.014 mm	-0.024 mm	-0.31 %	-0.093 mm	-0.26 %
SD of Diff.	0.028 mm	0.037 mm	0.58 %	0.028 mm	0.61 %

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P2.20
ASSESSMENT OF THE CAROTID DIAMETER AND INTIMA-MEDIA THICKNESS FROM ULTRASOUND DATA: COMPARISON BETWEEN TWO METHODS

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The aim of this study was to compare a new device for the automatic evaluation of carotid diameter (D) and intima-media thickness (IMT) from ultrasound B-mode image sequences, with a RF echotracking system (RFES). A total of 90 scans of the right/left common carotid artery from 21 patients with various cardiovascular risk factors and 12 healthy volunteers were analysed. The measurements were performed in real-time by using the two systems sequentially. Different Regions of Interest (ROI) were adopted, as our device best works on 1cm width ROI and the other on 4cm width ROI; a subgroup of scans (31) were analyzed using the same ROI width for the two systems. Moreover, on the healthy volunteers the analysis was repeated twice with each device in order to evaluate the intraobserver variability.
The agreement between the two systems was evaluated by Bland-Altman analysis; the bias and the standard deviation were 0.100mm and 0.190mm for D and 0.003mm and 0.057mm for IMT respectively. Moreover, in the subgroup where the same ROI width was adopted the bias and the standard deviation were: 0.060mm and 0.110mm for D and -0.006mm and 0.039mm for IMT. The coefficients of variation of the intraobserver measurements were: 2%±2% (D) and 5%±5% (IMT) for the RFES and 2%±1% (D) and 6%±6% (IMT) for our device.
In conclusion, although it is common opinion that B-mode based devices have lower precision than the RF based ones, our system shows reproducibility comparable to that of the RFES and good agreement with it.

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P2.21
COMPLEXITY OF 3D CAROTID BIFURCATION BLOOD FLOW PATTERNS IS NOT ADEQUATELY CAPTURED BY CURRENTLY USED ULTRASOUND MODALITIES

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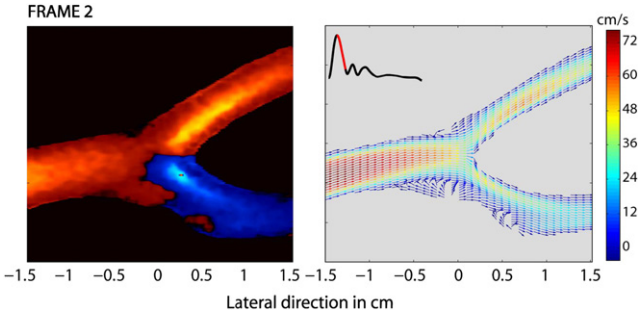
Background: Ultrasound is still the preferred method for non-invasive investigation and blood flow visualization in the carotid artery, using pulsed Doppler and color flow imaging. These techniques are widespread, and data are often displayed in a (color-coded) format allowing easy interpretation. Nevertheless, in currently applied techniques, not all aspects of blood flow are captured, especially in regions with complex anatomical shapes such as the carotid bifurcation, and when flow is further complicated by presence of plaque.
Methods and Results: We developed a 3D anatomically correct computer model of a carotid bifurcation with plaque, and calculated the complex flow field using numerical techniques (CFD; Computational Fluid Dynamics). Next, we coupled these data to an ultrasonic model (Field II) allowing simulation of ultrasound data based on the computed flow field. The pulsed Doppler simulations showed good agreement between the ultrasound velocities and the computed flow field. Simulated color flow images demonstrated that flow patterns are generally well obtained but that vortex formation in the bifurcation, internal carotid artery and downstream of the plaque are not easily discernable. These results were also confirmed in an experimental validation study.



Discussion: Currently used ultrasound imaging modalities have important limitations to assess complex flow in the carotid artery. This complicates the use of these images to extract quantitative data related to flow such as wall shear stress. This virtual ultrasound environment is a powerful tool to assess limitations of currently used ultrasound imaging modalities and to develop new algorithms of upcoming techniques such as 3D ultrasound.

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P2.22
COMPARING COMPUTATIONS OF VASCULAR WALL PARAMETERS IN THE ABDOMINAL AORTA (AO) BASED ON PRESSURE CURVE FORMS FROM THE AO AND BRACHIAL ARTERY

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With aid of the pulse pressure and radius wave form of the AO as input to a mechanical model, a set of aortic wall parameters can be identified describing different properties of the aortic wall, e.g. elastin, collagen content and distribution. This makes it possible to perform a deeper analysis of the components in the wall and the acting forces (VaMoS) [1]. To facilitate the use of VaMoS it would be preferable to use a more accessible arterial pressure wave form as indata. The aim was to test if pressure curves taken