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### **P2.4: FEASIBILITY OF AORTIC ARCH MECHANICS - A STUDY IN NORMAL SUBJECTS**

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$\geq 1$  m/s from baseline (G3). The groups were similar by age and all risk factors. The baseline (154,8 $\pm$ 7,3/91,7 $\pm$ 10,2, 152,7 $\pm$ 12,1/92,3 $\pm$ 8,3 and 149,3 $\pm$ 8,1/91,7 $\pm$ 6,04 mmHg) and achieved CBP (128,4 $\pm$ 7,26/80,1 $\pm$ 4,55, 125,6 $\pm$ 11,4/79,2 $\pm$ 6,5 and 126,6 $\pm$ 8,4/78,5 $\pm$ 5,97 mmHg) were similar. There was significant difference in baseline PWV (G1 15,9 $\pm$ 2,5 vs G2 13,6 $\pm$ 1,9 vs G3 10,9 $\pm$ 1,7 m/s,  $p < 0.05$ ), but at the end of the study PWV was similar: respectively, 13,0 $\pm$ 2,1, 13,6 $\pm$ 1,9 and 13,4 $\pm$ 1,9 m/s. 72,7% pts in G1 and 66,7% in G2 received the highest recommended doses of RAAS-inhibitors and A10mg vs 28,6% in G3 (Pearson  $\chi^2 = 9,0$ ;  $p < 0,05$ ). Indapamide SR 1,5mg was added in 36,4%, 20% and 9,5%, respectively. Correlation and multiple regression analysis revealed the association between PWV decrease and doses of RAAS-inhibitors and amlodipine ( $r = -0,5$ ,  $\beta = -0,45$ ,  $p < 0,05$ )

**Conclusion:** There is modulating effect of target pressure achievement on PWV in hypertensive subjects. PWV reduction is associated with higher doses of RAAS inhibitors and amlodipine.

## P2.1

### CAROTID PLAQUE MICROVASCULATURE ASSESSED USING DYNAMIC CONTRAST-ENHANCED MRI: COMPARING DIFFERENT REGIONS OF THE VASCULAR WALL

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**Background:** Pharmacokinetic modeling in Dynamic Contrast-Enhanced (DCE-)MRI has been introduced to non-invasively assess microvasculature in carotid atherosclerotic plaques, a marker for plaque vulnerability. The main model-parameter,  $K^{trans}$ , can be assessed in the outer region of the vessel (adventitia) or in the entire vessel wall (including plaque and adventitia) and already showed association with histology and features of plaque vulnerability, respectively. We investigated systematically the correlation between  $K^{trans}$  of these various regions of the vascular wall and their individual correlation with histology as gold standard.

**Methods:** 45 symptomatic patients with 30-99% carotid stenosis underwent 3T DCE-MRI (0.1mmol/kg Gadobutrol, 0.5ml/sec). Quantitative modeling was performed to determine  $K^{trans}$  of the entire vessel wall, adventitia, and plaque region, separately. For 10 patients, CD31 immunohistochemistry was performed on specimens (containing mainly plaque) removed during carotid endarterectomy to quantify the endothelial microvessel area.

**Results:** Adventitial  $K^{trans}$  showed weak correlation with plaque  $K^{trans}$  ( $r = 0.64$ ,  $p < 0.001$ ) and was 17.3% higher ( $p < 0.001$ ), coinciding with decreased uncertainty in parameter estimation ( $p = 0.015$ ). Significant positive correlation between the endothelial microvessel area and adventitial  $K^{trans}$  ( $r = 0.854$ ,  $p = 0.002$ ), but not from the plaque ( $r = 0.438$ ,  $p = 0.2$ ) was observed. Entire vessel wall  $K^{trans}$  showed intermediate results for the various analyses.

**Discussion:** Although  $K^{trans}$  assessed over various regions within the vascular wall are correlated, absolute values differ significantly. Adventitial  $K^{trans}$  seems to be a better measure for plaque microvasculature compared to other vascular regions, coinciding with a lower uncertainty in parameter estimation. Comparison with histology in a larger number of patients is recommended for definitive conclusions.

## P2.2

### ULTRASOUND SPECKLE TRACKING HELPS IDENTIFY VULNERABLE CAROTID PLAQUES

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Ultrasound Speckle Tracking, a novel technique used to assess regional mechanics of carotid wall and plaques. We hypothesized that vulnerable carotid plaques have higher intraplaque stretch which resulted in an increased difference in deformation between cap and core

**Methods:** Study population consisted of 39 patients with carotid atherosclerosis: 11 with acute atherothrombotic stroke and 28 asymptomatic patients with similar demographics and risk factors. For each plaque, maximum circumferential and longitudinal strain ( $Sc_{-Sl}$ ) and strain rate ( $SR_{C-SRL}$ ) were measured for cap, core and base. Plaque characteristics (echogenicity,

degree of stenosis, surface, etc) were assessed. All plaques were divided into hyperechogenic(19) and echolucent(20) ones.

**Results:** Echolucent plaques underwent significantly higher deformations than hyperechogenic ones ( $Sc = 4.06$  vs  $3.25$ ,  $p < 0.05$ ) and they had significant difference in deformation between cap and core ( $p < 0.05$ ) whereas hyperechogenic plaques had no difference in deformation between segments ( $Sc = 5.2_4.2_2.8$  and  $3.5_3.1_3.2$  for cap, core and base of echolucent and hyperechogenic plaques, respectively). Moderate negative correlations were observed between echogenicity and deformations ( $r = -0.35$ ,  $p < 0.001$  for cap\_Sc). Symptomatic plaques had higher difference between cap and core Sl. Plaque internal deformation coefficient,  $Cpid = [(cap_{-Sl} - core_{-Sl}) / (core_{-Sl} + base_{-Sl})] \times 100$  was developed to quantify the relative deformation of different plaque segments. Based on ROC-analysis, plaques with  $Cpid > 22.2$  were associated with an ischemic event (sensitivity-55%, specificity-87%,  $AUC = 0.693$ ,  $p = 0.0485$ ). Logistic regression confirmed that  $Cpid > 22.2$  is an independent predictor of plaque vulnerability,  $OR = 3.7$ ,  $95\% CI = 0.8-22.8$ , controlling for age, gender, plaque length, degree of stenosis, echogenicity.

**Conclusions:** Mobility of echolucent plaques exceeds those of hyperechogenic ones. Difference in mobility between plaque segments may help identify plaque vulnerability.

## P2.3

### SUBCLINICAL ATHEROSCLEROSIS AND CARDIOVASCULAR RISK FACTORS: TEN YEARS OF EXPERIENCE WITH IMT PLUS® IN THE NETHERLANDS

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**Purpose:** Atherosclerosis has become a global disease and risk factor mitigation has been a priority in counties like the Netherlands. We assessed the impact of this new approach on cardiovascular subclinical atherosclerosis and cardiovascular risk factors.

**Methods:** A quantitative standardized sonographic carotid intima media thickness and plaque formation (IMTplus®). IMT plus® distribution was done in accordance with the previously published protocol. (A, being a value lower than the P50,  $< 0.700$  mm; B, being a value between P50 and P90, 0,700 and 0,850 mm; C, being a value between P90 and P125, 0,851-0,948 mm ;D, being P125 and P200 with values between 0,948 -1,300 mm and an E, value above P200  $> 1,300$  mm; P means percentile). (Prevention Concepts® Database)

**Results:** Distribution of IMT Plus® categories in the Netherlands and VS The Netherlands (mean age 53 years, 60 % men) Total number of cases per category:

Total:N=18.703(100%);A:N=2685(14.4%);B:N=6425(34.4%);C:N=6600(35.3%);D:N=2372(12.7%);E:N=571(3.0%).

US (mean age 50 years 49% men) Total number of cases per category: Total:N=29.894 (100%);A:N=6001(15%);B:N=10403(26%);C:N=13199(34%);D:N=7888(19%);E:N=2403 (3%).

**Conclusions:** The benchmark of ten years of IMT Plus® results in the Netherlands with the US shows a different picture category A (normal risk), but a greater number of category B (25% increased risk) and a smaller amount of category D (100% increased risk) and category E (200% increased risk) in the Netherlands. The US still leads in the extent and severity of Subclinical Carotid Atherosclerosis but the Netherlands is rapidly catching up. Carotid IMTplus® remains a reliable surrogate to assess atherosclerosis development.

## P2.4

### FEASIBILITY OF AORTIC ARCH MECHANICS - A STUDY IN NORMAL SUBJECTS

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There are no data in the literature regarding aortic arch mechanics assessed with 2D speckle tracking (2D-ST) echocardiography.

**Purpose:** To study the feasibility of measuring vascular mechanics in the aortic arch with 2D-ST echocardiography and to define normal values.

**Methods:** We recruited 54 healthy volunteers and performed a complete echocardiographic exam. We included in the analysis a short axis view of the aortic arch, after the emergence of the brachiocephalic artery. The 2D-ST methodology was used to off-line calculate aortic arch mechanics (EchoPAQ, GE Healthcare®). The analysis was performed for circumferential aortic strain (CAS) and for early circumferential aortic strain rate (eCASR). We assessed the aortic pulse wave velocity (PWV) with the Complior®. Kolmogorov-Smirnov test was used for normality assessment.

**Results:** We included 50 controls with a gender balance and a mean age of 33±9 years. Of the total 300 aortic wall segments, 278 had adequate waveforms for analysis. Global CAS had a normal distribution ( $p=0.20$ ); the mean and median CAS were 11.3±3.2% and 11.5% (8.4 - 13.7) respectively. Global eCASR also had a normal distribution ( $p=0.10$ ); the mean and median eCASR were 1.5±0.4 s<sup>-1</sup> and 1.6 s<sup>-1</sup> (1.3 - 1.7), respectively. There was a significant negative correlation between CAS, age ( $r=-0.46$ ,  $p<0.01$ ), pulse pressure ( $r=-0.40$ ,  $p<0.01$ ), PWV ( $r=-0.52$ ,  $p=0.03$ ) and the vascular augmentation index ( $r=-0.60$ ,  $p=0.01$ ). A similar association was identified for eCASR.

**Conclusion:** 2D-ST is a feasible methodology for the analysis of the aortic arch mechanics; in this study, we obtained reference values and normal distributions.

## P2.5

### WITHDRAWN

## P2.6

### ARTERY DISTENSION MEASURED WITH STANDARD B-MODE IMAGE ECHO-TRACKING HAS SIMILAR ABSOLUTE VALUES AND PRECISION AS MEASURED WITH RADIO-FREQUENCY PHASE-TRACKING

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**Objectives:** Artery distension, the difference between diastolic and systolic diameter, is an important measure in stiffness evaluation. Distension can be extracted with high precision and accuracy from radio-frequency ultrasound (US) measurements at a high frame-rate using phase-tracking. However, in daily practice processed B-mode images are collected with a lower frame-rate, but higher line density, and distension may only be assessed using echo-tracking. Therefore, the aim of this study is to evaluate the accuracy and precision of echo-tracking distension as compared to that of phase-tracking distension.

**Methods:** Longitudinal B-mode (40mm, 37fps) US-measurements (video clips 3-6 heartbeats) of the left common carotid artery were performed with a Philips IU22 scanner on 21 patients (age 45-88y) with a recent cerebrovascular accident. In addition, unprocessed radio-frequency US-measurements were performed with a Mylab70 scanner operating in Fast B-mode (31 lines covering 29mm, 300fps, 3-6 heartbeats). To extract the diameter waveform, semi-automatic wall echo-tracking and phase-tracking methods were applied to B-mode and Fast B-mode measurements respectively.

**Results:** One patient was excluded due to large out of plane motion. Although phase-tracking diameter waveforms showed more detail, both methods exhibit similar intra-subject precision (SD=34µm and SD=33µm, F-test:  $p$ -value=0.4). Echo-tracking and phase-tracking systolic-diastolic distension were similar (bias is 25±90µm, paired t-test:  $p$ -value=0.18).

**Conclusion:** Clinical scanners operating in B-mode can be used to measure distension with reasonable precision and accuracy in a relevant stroke population, although waveform details may be masked at lower frame-rates. This research was supported by the Center for Translational Molecular Medicine and the Dutch Heart Foundation.

## P2.7

### VALIDATION OF THE COMPLIOR® ANALYSE IN THE ASSESSMENT OF CENTRAL ARTERY PRESSURE CURVES AND AORTIC PULSE WAVE VELOCITY

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**Introduction:** The purpose of this study was to evaluate the accuracy of carotid pulse wave analysis (PWA) and aortic pulse wave velocity (PWV) with the new version of the Complior device - the Complior Analyse.

**Methods:** Two cross-sectional studies were implemented to address the reproducibility of the device (87 participants, 60% men, with a mean age of 34.26±16.58 years), and its accuracy comparing it with invasive hemodynamic parameters (15 patients, 7 female gender, mean age 62.07±10.59 years, referenced for cardiac catheterization).

**Results:** The analysis of concordance revealed a very good agreement for paired PWA and PWV values, regarding both the intra- and inter-observer variability. The intra-observer's intra-class correlation coefficients (ICC) were 0.99 (IC:0.95-1.00,  $p<0.0001$ ), 0.97 (IC:0.96-0.98,  $p<0.0001$ ), 0.98 (IC:0.97-0.99,  $p<0.0001$ ) and 0.86 (IC:0.77-0.90,  $p<0.0001$ ), respectively for PWV, central systolic (cSBP), pulse pressure (cPP) and augmentation index (AIx). For inter-observer analysis, the ICCs were 0.98 (IC:0.93-0.99,  $p<0.0001$ ), 0.98 (IC:0.97-0.99,  $p<0.0001$ ), 0.98 (IC:0.97-0.99,  $p<0.0001$ ) and 0.85 (IC:0.77-0.89,  $p<0.0001$ ).

A good concordance between Complior and invasive hemodynamic data was also obtained for all the measured parameters, with intraclass correlation (ICC) coefficients above 0.9. Bland-Altman's analysis also denoted a good accuracy profile of the Complior device, with small mean differences observed for all parameters and most values confined within 2 standard deviations of the mean difference.

**Conclusion:** The presented results and available research clearly indicate that the Complior Analyse device measures accurately carotid pressure waves, and has an excellent reproducibility when used in ideal conditions and by experienced observers.

## P2.8

### IS THE GOLD-STANDARD FOOT-TO-FOOT PULSE WAVE VELOCITY A GOOD ESTIMATE FOR AORTIC STIFFNESS? A NUMERICAL ASSESSMENT

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Arterial stiffness is an important predictor of cardiovascular events. In clinical practice, it is commonly evaluated non-invasively by central (carotid-femoral) or peripheral (femoral-ankle or brachial-ankle) foot-to-foot pulse wave velocities (PWV). Though, the efficiency of these indices as predictors of aortic stiffness in normal and pathological conditions has not been theoretically validated.

This study investigates the relation between aortic stiffness and central and peripheral PWV in normal and pathological conditions using a validated one-dimensional model of blood flow in the arterial network. The model allows us to (i) calculate the theoretical value of aortic stiffness from model parameters and (ii) investigate the effect of specific pathological changes in parameters on PWV estimates.

Our results show that in normal conditions, the central PWV over-estimates aortic stiffness by 8%. This error ( $e$ ) tends to decrease with increased aortic ( $e=-0.5\%$ ) and global ( $e=2,3\%$ ) arterial stiffening (200% increase from baseline). However, in the presence of isolated lower-limb arterial stiffening, the central PWV over-estimates the aortic stiffness by up to 20%.

In normal conditions, peripheral PWV largely over-estimate aortic stiffness (42% <  $e$  < 67%). Though, these errors drop to less than 3% with aortic stiffening.

Increased global arterial stiffening induces significant increases in all PWV. However, progressive increases in aortic stiffness are only detected by central PWV. Interestingly, increased peripheral vascular resistance and compliance only induce small changes in all PWV.

Our study suggests that central PWV is a good estimate of aortic stiffness, and that peripheral PWV can augment diagnosis by detecting the origin of vascular stiffening.

## P2.9

### ASSESSMENT OF CENTRAL AORTIC PRESSURE AND ITS ASSOCIATION TO ALL CAUSE MORTALITY CRITICALLY DEPENDS ON WAVE FORM CALIBRATION

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**Background:** The impact of different calibration methods on the prognostic power of aortic systolic pressure (aSBP) is only rarely reported in literature.

**Objective:** The aim of this work was therefore the prospective investigation of the association of brachial (bSBP) and aortic systolic blood pressures to all cause mortality with special emphasis on different calibration methods for central pressure estimates, in particular brachial systolic and diastolic as well as brachial mean and diastolic pressures.