BIOMECHANICAL ADAPTATION OF THE CAROTID ARTERY TO FLOW OVERLOAD IN A PORCINE ANASTOMOSIS MODEL

***E. P. Kritharis*[1,2]*, J. D. Kakisis*[3]*, N. Stergiopulos*[4]*, S. Tsangaris*[2]*, D. P. Sokolis*[1]**

[1]*Laboratory of Biomechanics, Foundation of Biomedical Research, Athens, Greece*

[2]*Laboratory of Biofluid Mechanics and Biomedical Engineering, School of Mechanical Engineering, National Technical University, Athens, Greece*

[3]*Vascular Unit, 3rd Department of Surgery, University Hospital 'Atticon', Athens University Medical School, Athens, Greece*

[4]*Laboratory of Hemodynamics and Cardiovascular Technologies, Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland*

6 Soranou Ephesiou, 115 27 Athens, Greece, dsokolis@bioacademy.gr

1. Introduction

The creation of an arteriovenous shunt (AVS) by use of synthetic grafts is a common practice in hemodialysis patients. However, the hemodynamic conditions in the anastomosed vessels are altered, and we hypothesized that the vessels' morphology and biomechanical properties may adapt in response to these hemodynamic alterations. This study was designed to test this hypothesis by examining the long-term biomechanical adaptation of the arterial wall to flow overload in a porcine AVS model.

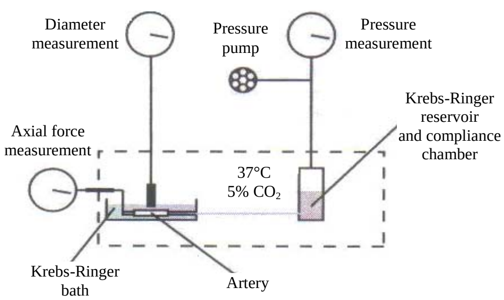

Fig. 1: Schematic representation of the apparatus used for biomechanical testing

2. Materials and Methods

6 Landrace pigs, weighing 64±2 kg, received an e-PTFE graft between the common carotid artery and the internal jugular vein. Blood flow in the proximal carotid artery was measured prior to and after graft implantation using a perivascular flowmeter (Transonic). One month post-implantation, intraluminal pressure was recorded in the anastomosed (AC) and contralateral carotids (CC) by high-fidelity catheters (Millar); blood flow was measured in AC. Post-euthanasia, the proximal carotids were excised and subjected to inflation-extension testing (Fig. 1). The vessels were mounted on the apparatus and elongated to their individual in situ length. Subsequent to mechanical preparation, pressure-radius-force data from one inflation cycle (0-200 mmHg) were recorded under passive conditions (by administration of 0.1 mM papaverine in the Krebs-Ringer bath) for biomechanical analysis. From the experimental data, area compliance was calculated as $C=dA/dP$ and distensibility as $D=C/A$, in which A and P denoted lumen area and pressure. Circumferential wall stress was calculated as $\sigma_\theta=PR/T$ (Laplace equation) and shear stress assuming Poiseuille flow as $\tau=kQ/R^3$, with R, T and Q being lumen radius, wall thickness and mean blood flow; and k depending on blood viscosity. Mean±SEM of all parameters were calculated. Statistical comparisons were performed with the paired t- test, with $P<0.05$ denoting significance.

3. Results

Blood flow in the AC increased significantly post-AVS (267.1±44.4 vs. 551.0±103.0 ml/min; Fig. 2a) and did not alter until euthanasia (414.9±86.4 ml/min), while there was no difference in pressure between AC and CC (65.2±4.4 vs. 60.7±3.2 mmHg; Fig. 2b). A displacement of the diameter-pressure curves towards higher diameter values was observed in AC compared to CC at all pressures (Fig. 3a). The compliance-pressure (Fig. 3b) and distensibility-pressure curves (Fig. 3c) of CC were shifted upwards compared to AC at low pressures (0-30 mmHg), but the opposite occurred

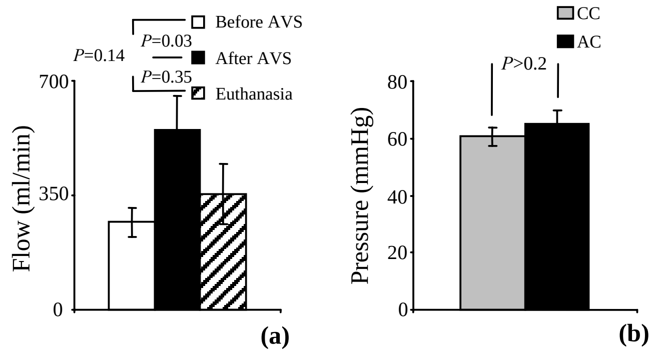

Fig. 2: Mean flow in AC at different phases (a) and mean pressure in AC and CC (b).

at higher pressures (30-200 mmHg). Circumferential stress, evaluated at the mean *in vivo* arterial pressure, was not significantly different in AC than CC (9.8±2.0 vs. 6.9±0.4 kPa; Fig. 4a) and similarly for shear stress (0.6±0.1 vs. 0.4±0.1 Pa; Fig. 4b). Both cross-sectional area compliance (0.361± 0.058 vs. 0.077±0.012 $mm^2/mmHg$; Fig. 4c) and distensibility ($0.009\pm6\times10^{-4}$ vs. $0.003\pm4\times10^{-4}$ $mmHg^{-1}$; Fig. 4d) were higher in AC at the *in vivo* pressure.

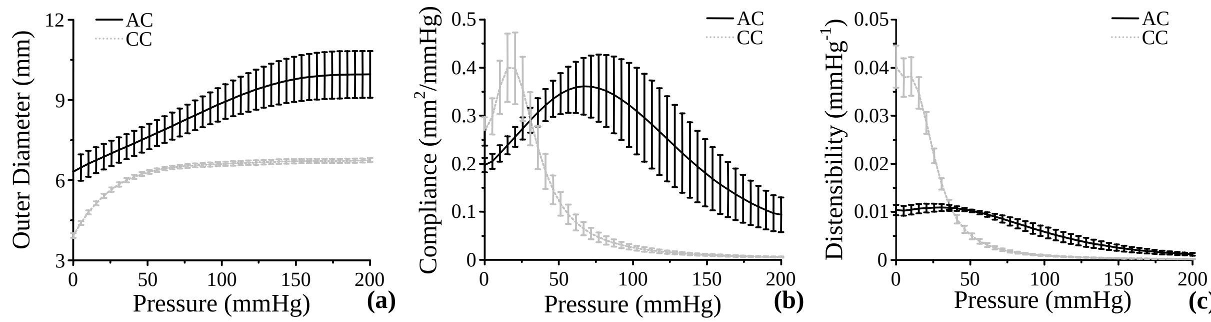

Fig. 3: Diameter-pressure (a), compliance-pressure (b) and distensibility-pressure (c) curves for AC and CC.

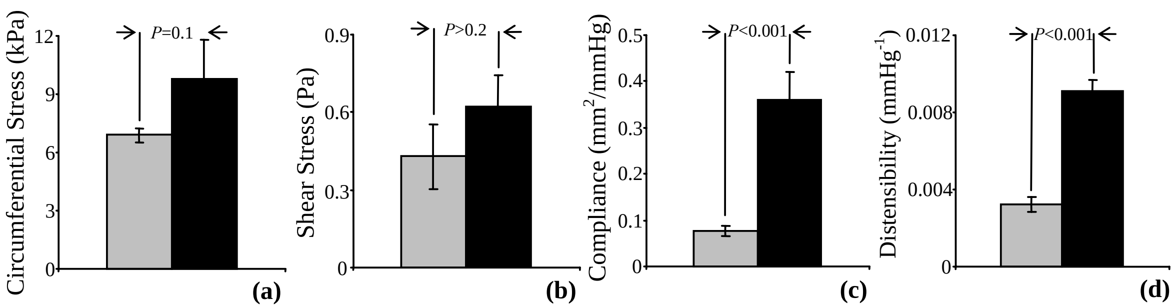

Fig. 4: Circumferential stress (a), shear stress (b), compliance (c) and distensibility (d) at the in vivo mean pressure for AC (■) and CC (▨).

4. Conclusions

AVS led to a sustained blood flow overload in the AC, in response to which the diameter of the AC chronically increased, and both circumferential and shear stresses were normalized to their homeostatic values. Concurrently, the wall biomechanical properties of AC changed significantly at all pressure levels compared to CC, similarly to a previous study [1] on a small-caliber vessel, but unlike another investigation [2] that reported carotid artery diameter enlargement without alteration in distensibility throughout the pressure range tested. The present study provides evidence of arterial biomechanical adaptation as a result of chronic flow overload in a porcine AVS model.

5. References

[1] J.G.R. De May and F. Pourageaud (1997). *Am J. Physiol.*, **273**, H1699-H1706.

[2] A. Kamiya and T. Togawa (1980). *Am. J. Physiol.*, **239**, H14-H21.

6. Sources of Funding

This paper (thesis etc) is part of the 03ED262 research project, implemented within the framework of the “Reinforcement Programme of Human Research Manpower” (PENED) and co-financed by National and Community Funds (25% from the Greek Ministry of Development-General Secretariat of Research and Technology and 75% from E.U.-European Social Fund).