THE EFFECT OF ANTI-HYPTERTENSIVE DRUGS ON CAROTID HAEMODYNAMICS

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INTRODUCTION

Recent studies (Stanton et al., 2001) have illustrated that the effect of sustained anti-hypertensive treatments using a particular calcium-blocker (CB) or ACE-inhibitor (AI) have a different impact on carotid morphology despite the same pressure drop. Patients on AI treatment show a decrease in lumen diameter (LD) and intima-media thickness (IMT), whereas CB maintains LD and lowers IMT even more.

The reason for these morphological changes is unknown. A pressure drop is typically followed by a drop in LD, in analogy with the deflation of a balloon. Furthermore, the smaller pressures and anti-hypertrophic effects of the drug induce a decrease in IMT. This explains the long-term effects of AI. For the CB treatment, it was hypothesised that the changes could be mediated by the local shear stresses. In this hypothesis, the AI treatment would show elevated shear stresses, which would increase LD (Powell, 2003) and stretch the IMT in the circumferential direction.

The aim of this study was therefore to investigate the acute effects of the administration of CB or AI on the carotid shear stresses. This was done using image-based computational fluid dynamics (CFD).

METHODS

Ten subjects were submitted to a double-blind, placebo controlled, randomised, 3 way cross over clinical trial. The protocol involved one week of treatment with CB, AI or placebo, followed by a wash-out period. Pressure, geometry, flow and vessel wall parameters were assessed after every treatment. Of the 10 subjects, 8 subjects were scanned using magnetic resonance imaging (MRI) and 2 claustrophobic subjects were assessed with 3D ultrasound (3DUS).

Time-Of-Flight MR images acquired on a Siemens Magnetom Sonata 1.5T scanner were segmented semi-automatically using the region growing method described by Long et al. (1998) followed by the Snake Method which deforms and smoothes the contour of the preliminary region.

An ultrasound scanner (ATL-Philips Medical Systems, WA) equipped with a conventional 5 to 12 MHz broadband linear array transducer (HDI 5000, ATL-Philips Medical Systems) was used to image ECG gated 2D transverse cross-sections of the carotid bifurcation. Simultaneously, an electromagnetic position and orientation measurement (EPOM) device (Ascension Technology Inc, Vermont) mounted on the probe recorded the position and orientation
of the probe in 3D space. Acquired images were segmented using purpose-built software. In combination with the information from the EPOM device, the data allowed reconstruction of a smooth 3D geometry of the carotid bifurcation. The US device and reconstruction of the carotid artery bifurcation from 3DUS images have been described in detail by Barratt (2002).

Computational meshes were fitted using an enhanced in-house purpose-built mesh generator. The partial differential equations describing the movement of the fluid were solved numerically using the Quadratic Upwind Interpolation for Convective Kinematics differencing scheme implemented in CFX-4.4 (AEATechnology, 1999). Two cardiac cycles of 80 equally spaced time-steps were simulated. Blood density was 1176 $\text{kg}/\text{m}^3$ and the Quemada-model was used to model blood viscosity.

RESULTS AND DISCUSSION

Figure 1 shows the time-averaged wall shear stress (WSS) distribution for three subjects. WSS was higher after the CB- than after the AI-intake on all segments of the carotid wall ($p<0.1$). This increase was mainly due to an increased flow and heart rate with the CB treatment, rather than to changes in carotid geometry. This result confirms the hypothesis made at the start: the increased LD and decreased IMT for patients on CB treatment are due to a raise in local WSS.

CONCLUSION

In the present work, image-based CFD has been applied successfully in a clinical study. It showed that the studied calcium-blocker (CB) raised the shear stresses in the carotid artery in comparison with the ACE-inhibitor (AI). This explained the long-term effects of CB or AI intake.

REFERENCES


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