INTRODUCTION

Hemodynamics in large arteries plays an influential role in the generation and development of the atherosclerosis disease [1,2,3]. These study focus on the influence of posture change on the geometry and hemodynamics of the carotid bifurcation. Head positioning changes may alter the hemodynamic variables that are generally associated with the development of atherosclerosis, such as low oscillating wall shear stress (WSS) and particle residence times. Glor et al. [4] had reported changes in the right carotid bifurcation geometry with leftward rotation of the head. An earlier study in premature infants showed that blood velocity profiles changed in the internal carotid artery (ICA) [5]. We have previously reported that geometric differences in the right and left carotid bifurcation occur with a rightward rotation of the head [6]. To investigate the geometric changes in the carotid geometry that occur in the prone sleeping position with rightward and leftward head rotation, we have performed studies in two healthy young volunteers. We defined specific geometric parameters of the carotid bifurcation, such as bifurcation angle, asymmetry angle, planarity angle, tortuosity and mean curvature, and compared their corresponding values in three head postures: 1) the supine neutral position, 2) the prone sleeping position with head rotation to the right (~80 degrees), and 3) the prone sleeping position with head rotation to the left (~80 degrees).

MATERIALS AND METHODS

The volunteers were two healthy men of 30 and 33 years old respectively. The study was approved by the Cyprus Bioethics committee (2006).

Magnetic resonance (MR) images were acquired using a 3T MRI instrument (Philips Medical Systems, the Netherlands). The imaging protocol we followed and MRI acquisition settings in more details were described previously [6,7]. Each subject was imaged in three different scanning sessions. The two sessions were performed in the same day, corresponding to the supine neutral position and the prone sleeping position with rightward head rotation. The session with the leftwards head rotation was done a year later.

Virtual Model Development

The solid surface models were constructed by slice-by-slice manual segmentation (ITK-Snap, Paul Yushkevich, Penn Image Computing and Science Laboratory (PICSL), USA) [8] and using various features of the vascular modeling toolkit (VMTK) [9]. Specific important geometric parameters, such as bifurcation angle, internal carotid artery (ICA) angle, ICA planarity angle, in-plane asymmetry angle, curvature and tortuosity, were identified and determined according to relevant published definitions [6,7,10].

RESULTS

Figure 1 shows the virtual reconstructed models of the two volunteers for the three examined head postures indicating the qualitative changes in geometry due to head rotations. Figure 2 shows the absolute difference values for the supine head position. Measurement Accuracy Studies

To assess the accuracy of the qualitatively results for all ten volunteers and both carotids a comparison study includes the median value from all geometric features done with the results from other researchers and both carotids a comparison study includes the median value from other researchers and both carotids a comparison study includes the median value from the results of other researchers and found similar results (error < 5%) [10,11]. Also the relationship between the radius of parent and daughter branches obey strongly the Murray’s law [12].
Discussion

There are significant quantitative changes in geometric parameters with posture change in individual volunteers. Zhang et al. (2009) [13] and others, have reported that ICA and CCA tortuosity, curvature and area ratio of ICA to ECA are important parameters in the disturbance level and formation of low/oscillating WSS regions at the carotid bulb. Our earlier studies [14], also indicate that small changes in geometric parameters with head rotation can cause significant changes in the hemodynamic parameters important in the development of arterial disease.

Therefore our present results on a greater number of volunteers, indicated that there are random and frequently significant changes in geometric parameters at the prone position which is a frequent sleeping posture for many subjects and patients. The effects of such changes to the flow field in the carotid bulb and the development of carotid disease are unknown. The effects of such geometric changes on the structural integrity of carotid stents and the stress distribution on unstable plaque are also unknown and need to further be investigated. Hemodynamic studies and comparisons between geometries are currently in progress.

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REFERENCES