Numerical Simulation of A Realistic Aortic Flow with MRA on Parallel Computers

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Abstract A prototype, multi-scale, computational hemodynamic model is developed to predict blood flow patterns and wall stresses in a realistic human aorta. The three-dimensional model is utilized for blood flow simulation, which is based on Roe and HLLC type incompressible full Navier-Stokes equations and one-dimensional systematic arteries network models will be embedded into the future work. In this study, two- and three-dimensional secondary flows and vessel wall shear stress distributions in a human aortic arch have been predicted numerically for a Reynolds number of 5000 at entrance based on the techniques of CFD and MRA. The simulated geometry was derived from the three-dimensional reconstruction of a series of two-dimensional slices and several flow rates at different cross sections of aorta with the tree branches obtained from MRI. Numerical results demonstrate wall shear stresses were high along the outer wall in the vicinity of the branches and low along the inner wall, particularly in the descending thoracic aorta. The maximum wall stress distribution is presented on the aortic arch in the systole. Extensive secondary flow motion was observed in the aorta, and the structure of these secondary flows was influenced considerably by the presence of the branches. Within the aorta, both numerical results and MRI data observed that clockwise secondary flow recirculation appears in the upstream of aortic arch in the late systolic and turn out to be a pair of counter-clockwise vortex in the downstream of the arch in the early diastole. In addition, three-dimensional particle trace plots observe the secondary flows in middle and right branches and violent rotation in left branch.The original FORTRAN code is converted to the MPI code and tested on 32-CPU IBM SP2 Power 3 and Power 4 parallel computers and two 32-node PC Clusters.

Keywords; Aortic Flow Model, Riemann Solvers, Blood flow, MRI

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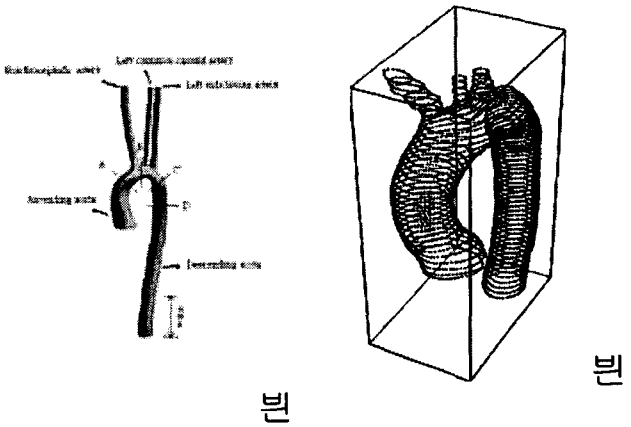

Figure 1 Schematic diagram of a normal aorta with a branch (Left), aorta outline scan by MRA (Right)

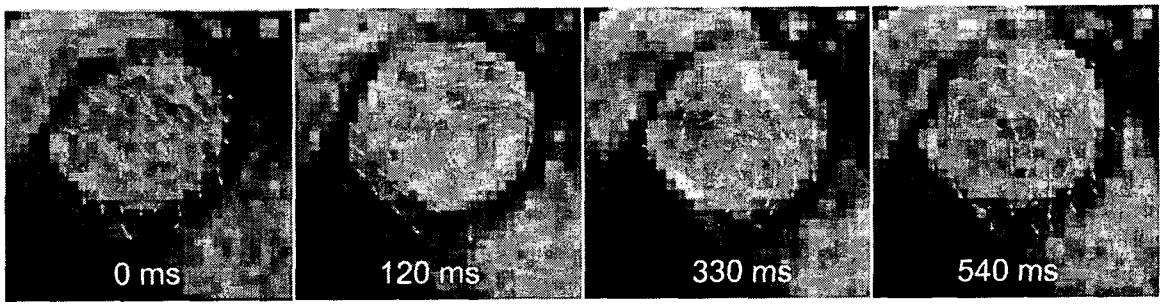

Figure 2 Velocity vector images scan by MRI

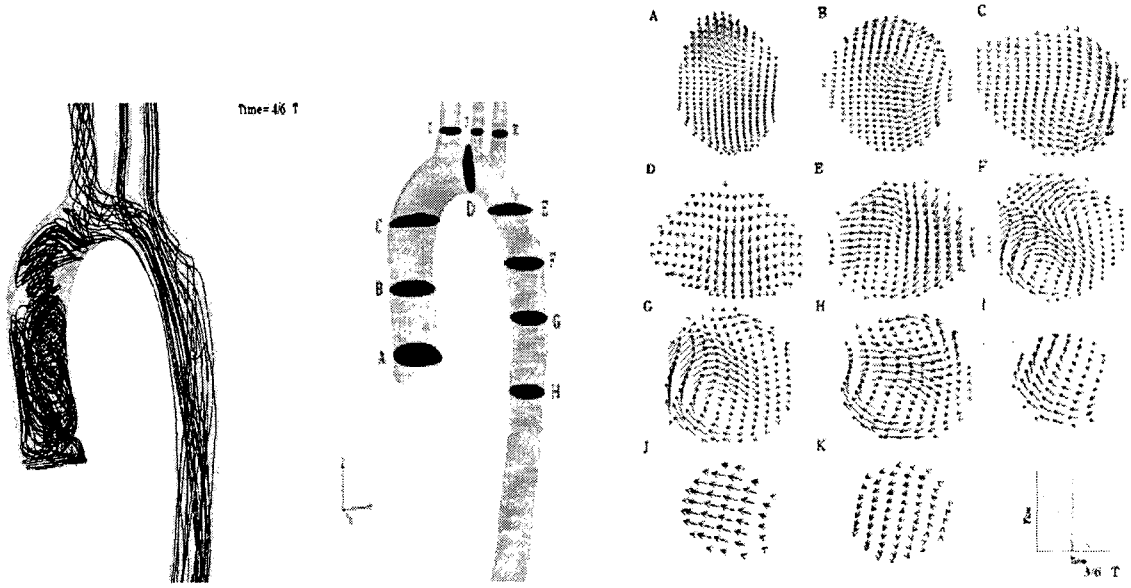

Figure 3 Particle traces in aorta and velocity vectors on cross sections in a diastolic cycle