DISTRIBUTION OF WALL SHEAR STRESS WITH INITIATION AND PROGRESS OF ANEURYSM AROUND ANTERIOR COMMUNICATING ARTERY

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INTRODUCTION

The aneurysm in the cerebral artery is apt to initiate around the "Circle of Willis". The anterior communicating artery (ACoA), which composes one of major part of the circle of Willis, is the most predilection artery of the aneurysm[1]. This artery is characterized by a singular geometry. At this artery, two proximal anterior cerebral arteries (A1, confluence) join facing each other. Just at this artery, the flow bifurcates two distal anterior cerebral arteries (A2, bifurcation). Namely, this artery has a function as a bypass channel. Therefore, the flow around the anterior communicating artery would be very unstable. The aneurysm arises around the apex of this artery where the confluent flow collides.

The flow field around the anterior communicating artery is simulated by two confluent tubes, two bifurcating tubes, and the junctional tube connecting four anterior cerebral arteries[2]. In the present paper, the change of flow structure such as the wall shear stress at the apex of ACoA with the initiation and progress of aneurysm is described in steady flow. In experiment, the velocity profile is measured by LDV and the wall shear stress is estimated from the velocity near the tube wall. Particularly, the change of wall shear stress around the apex, where the main flow collides, is clarified experimentally.

EXPERIMENT

Anterior Communicating Artery Model

The model geometry simulating the anterior communicating artery at normal, initial, and progressive condition of aneurysm is shown in Fig.1. Two confluent tubes of $2R_0$=24mm in diameter join at 60 degrees. After joining at the anterior communicating artery of δ=6mm in diameter, the flow bifurcates at two bifurcating tubes of $2R_1$=18mm in diameter. In this arterial model, the radius of curvature of tube wall connecting these tubes is 9mm. The aneurysm is apt to initiate at the apex in the medial corner in one confluent tube with much flow rate. The initial and progressive aneurysm is simulated by the concave radius λ=2 and 3mm, respectively. The coordinate system and the measurement section are also shown in Fig.1. The axes x and y

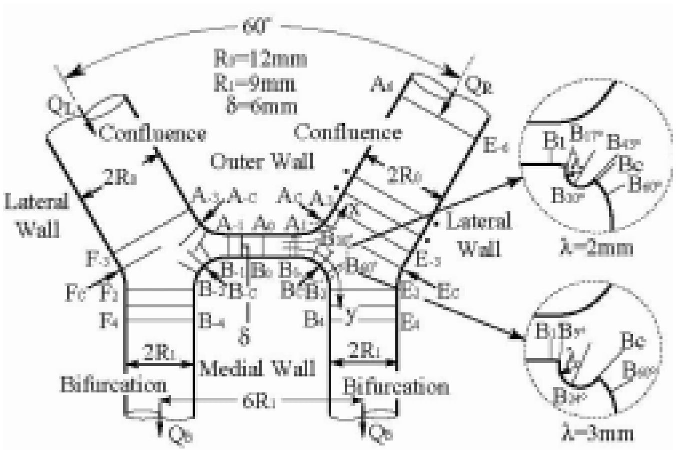

Fig.1 Test Model and Measurement Section

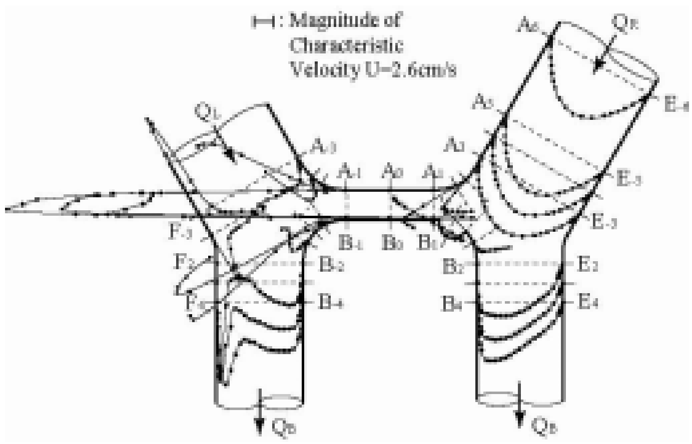

Fig.2 Axial Velocity Profile (Re=400, Q_R/Q_L=2.2, λ=3mm)

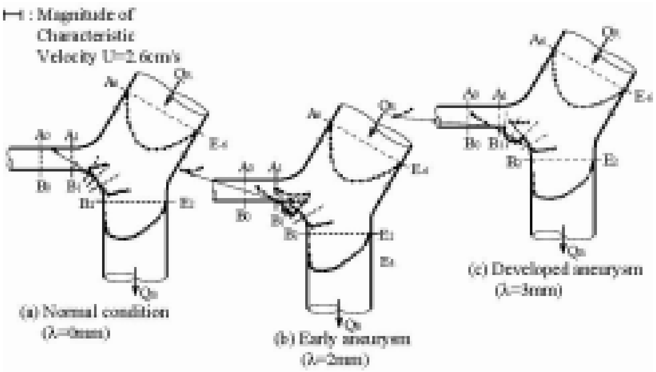

Fig.3 Effect of Radius λ on Velocity Profile (Re=400)

are along the outer and the medial walls, respectively. Q_R and Q_L denote the flow rate through the right and the left confluent tubes, respectively.

Measurement

The dot line across the tube diameter denotes the measurement section for the velocity profile, and the solid line at the sections A_6-E_{-6}, B_1, $B_{30°}$, B_C, $B_{60°}$, and B_2 denotes the measurement section for the velocity profile around the right medial corner. The saturated sodium iodide (NaI) solution with the same refractive index as the channel material, acrylic plate, is employed as the working fluid. The velocity profile is measured by the laser Doppler velocimetry. The velocity measurement near the tube wall is carried out every 0.2mm from the tube wall, and the wall shear stress is estimated from the velocity difference between the tube wall and the position at 0.6mm from the tube wall.

RESULTS AND DISCUSSION

The measurement has been carried out at the Reynolds number of $Re=2R_0U/\nu=250$, 400, and 550, the confluent flow ratio of $Q_R/Q_L=1.5$, 2.2, and ∞. U is the mean velocity based on the average flow rate of $Q_m=(Q_R+Q_L)/2$, and ν is the kinematic viscosity.

Velocity Profile

The measurement has been primarily carried out at the Reynolds number of Re=400 and the confluent ratio of $Q_R/Q_L= 2.2$.

The velocity profile around ACoA with the progressive aneurysm is shown in Fig.2 (λ=3mm). Except for the flow field around the progressive aneurysm, the velocity profile around ACoA as a whole is similar to that without the aneurysm at normal condition. The velocity through ACoA is several times as large as the maximum velocity in the right confluent tube. The core flow in the right confluent tube impinges at the right apex, right medial corner. The velocity profile around the apex with aneurysm of the concave radius λ=0, 2, and 3mm is shown in Fig.3(a), (b) and (c), respectively. There is a small recirculating flow in the concave, aneurysm.

Wall Shear Stress

The wall shear stress is normalized by that of Poiseuille flow with the mean velocity U through the upstream confluent tube. Except for the flow field around the progressive aneurysm, the distribution of wall shear stress around the ACoA as a whole is also similar to that without the aneurysm at normal condition. The wall shear stress changes around the right apex. Particularly, this change is extremely large around the concave as shown in Fig.4. Therefore, this abrupt change of wall shear stress may induce the progressive development of aneurysm.

Effect of Confluent Flow Ratio

The effect of confluent flow ratio on the velocity profile and the

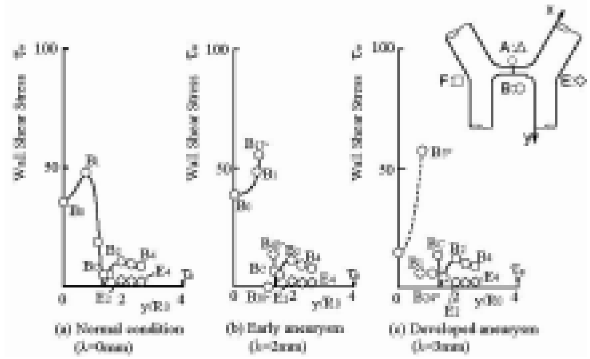

Fig.4 Effect of Radius λ on Wall Shear Stress (Re=400)

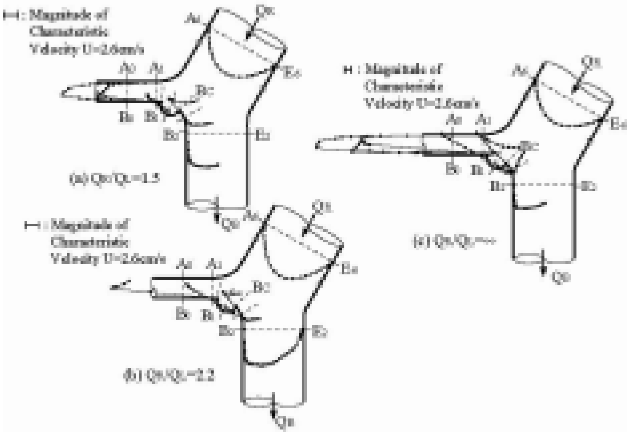

Fig.5 Effect of Flow Ratio on Shear Stress (Re=400)

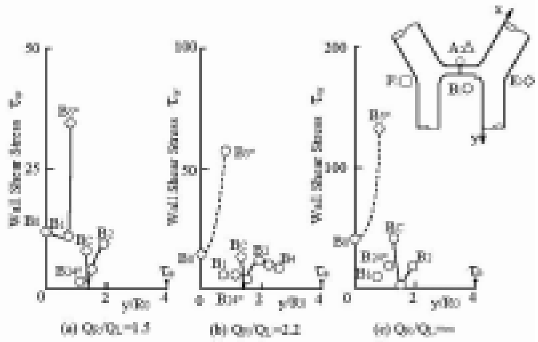

Fig.6 Effect of Flow Ratio on Shear Stress (Re=400)

wall shear stress of λ=3mm is shown in Figs.5 and 6, respectively. The increase of confluent flow ratio is associated with the large change of wall shear stress. The imbalance of confluent flow induces the high recirculating velocity within concave, and the high wall shear stress arises at bottom in the concave. Therefore, the large change of wall shear stress is physiologically related the progressive development of aneurysm.

REFERENCES

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