The effects of anastomosis angle on blood flow in bypassed blood vessel

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Introduction

- ❖ Severe atherosclerosis have been treated with vascular bypass surgery.
- ❖ It is known that wall shear stress effects on the patency of surgery.
- ❖ Aim of this study: to understand the correlation between anastomosis angle and wall shear stress distributions in a totally occluded vessel.

Figure 1. Development of Atherosclerosis
Image source : UR Medicine

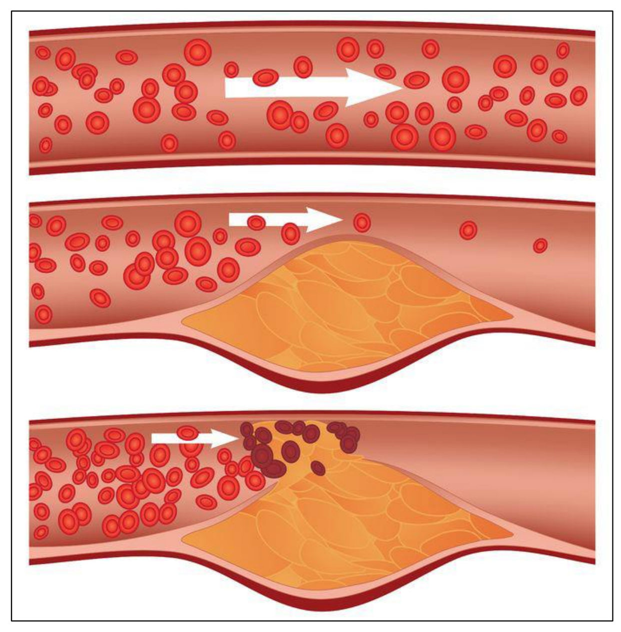
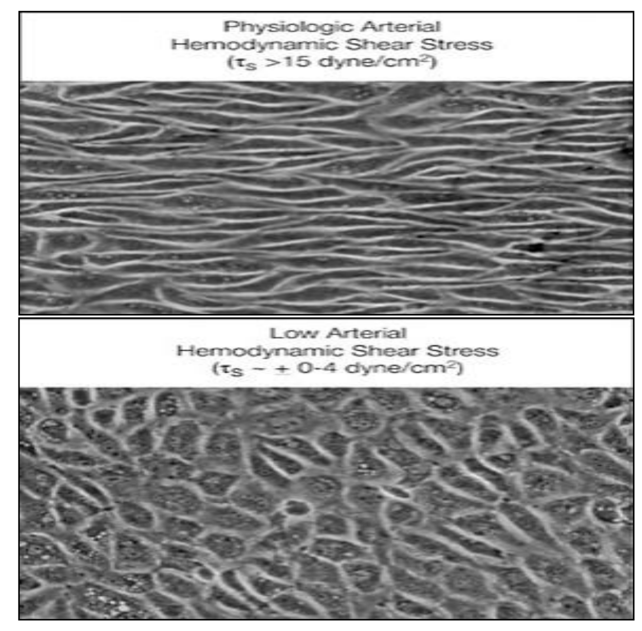
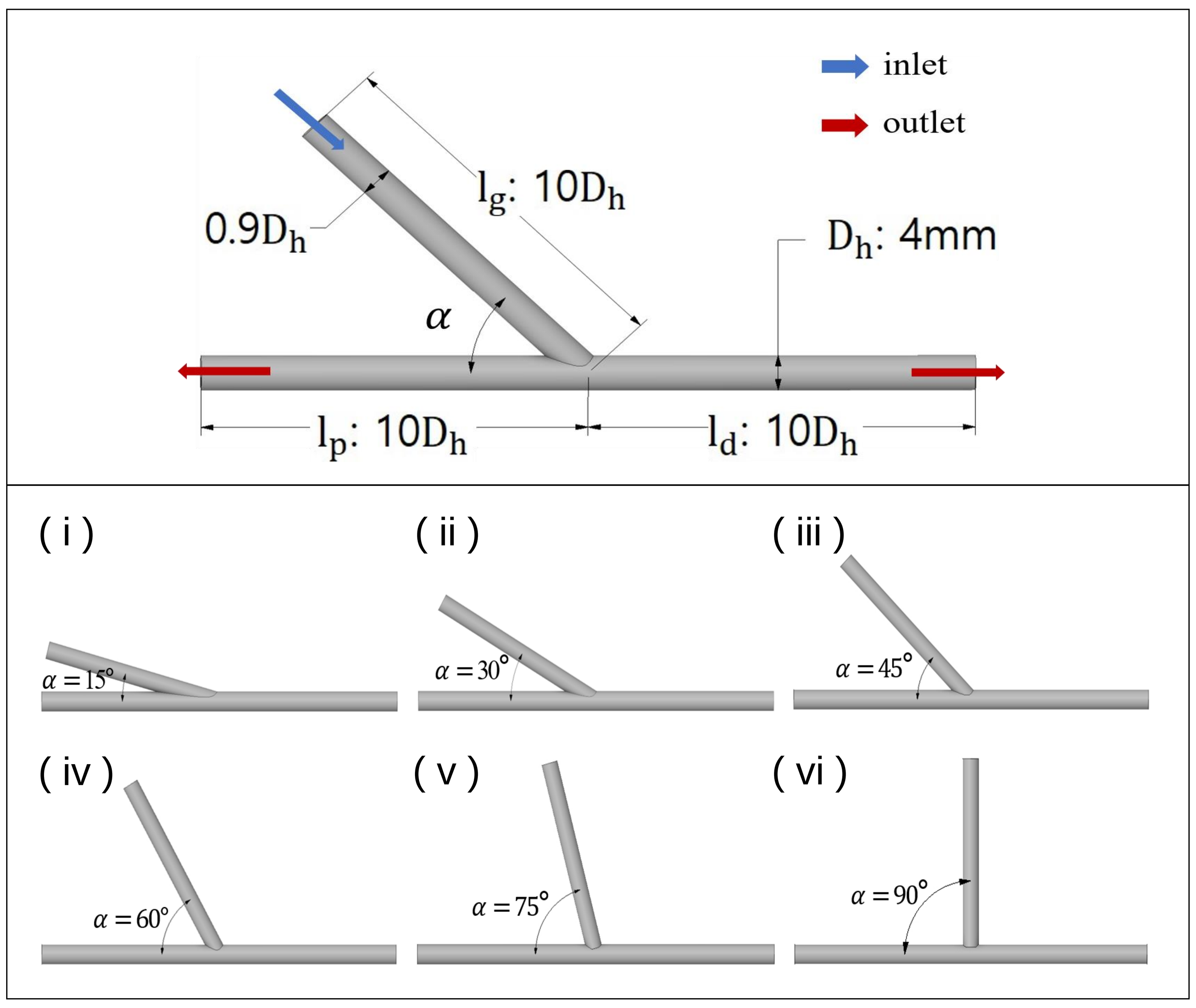


Figure 2. Endothelial Cell Morphology according to Shear Stress level
Image source : Malek et al, "Hemodynamic Shear Stress and its Role in Atherosclerosis"



Modeling

Figure 3. Dimensions of model i ~ vi : anastomosis angle (α) 15° ~ 90° with 15° interval



❖ Governing Equations

- Continuity Equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

- Navier-Stokes Equation of Incompressible Newtonian Fluid

$$\rho g_x-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)=\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)$$

$$\rho g_y-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)=\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)$$

$$\rho g_z-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)=\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)$$

❖ Numerical Analysis Method

- Finite Volume Method (Ansys Fluent 2021 R1)

❖ Mesh

- Tetrahedral Mesh

Number of Mesh
Model i : 558,678 , Model ii : 326,014, Model iii : 331,453
Model iv : 581,301, Model v : 649,433 , Model vi : 662,149

❖ Assumptions

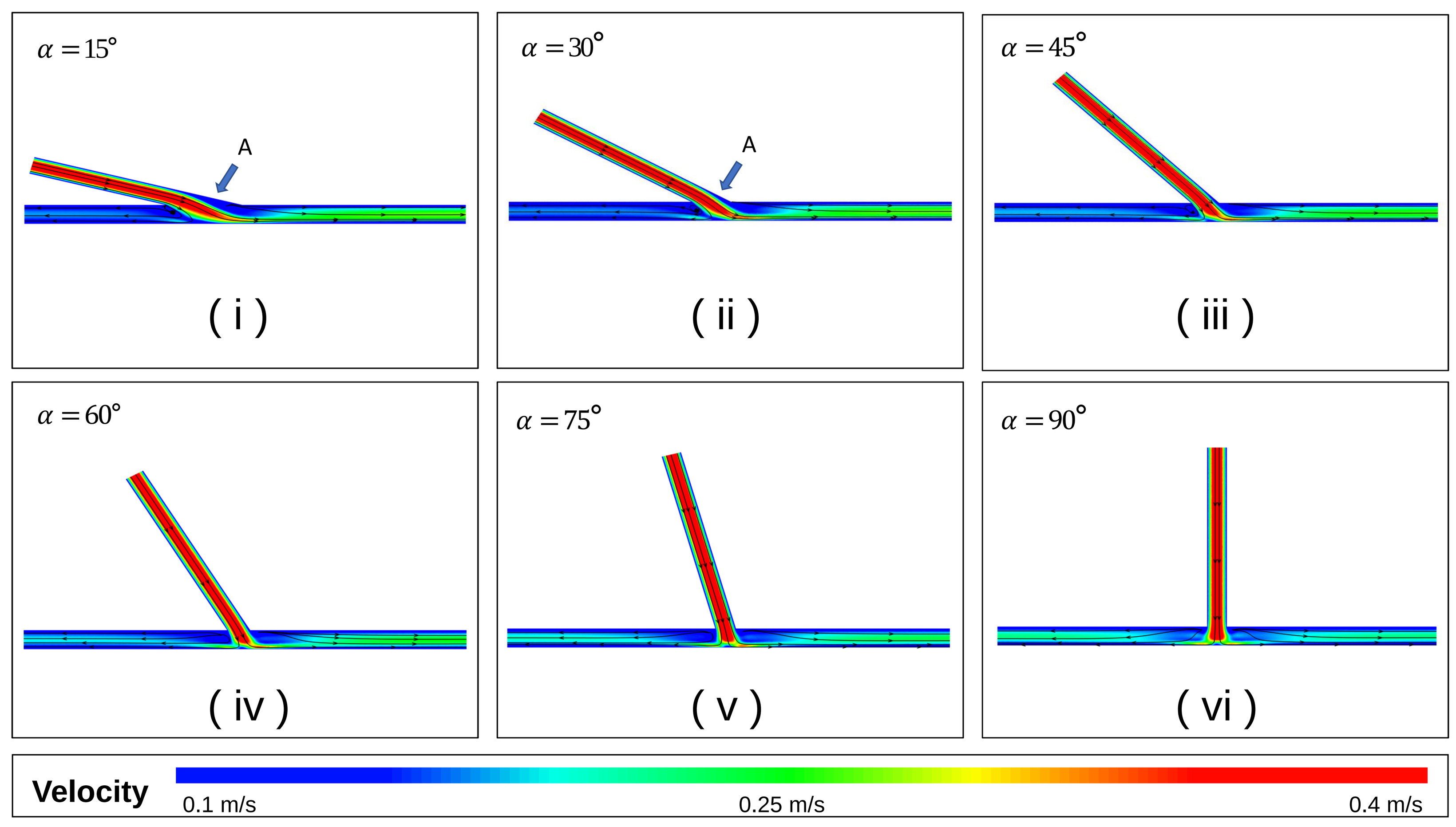
- Steady Flow, Incompressible Newtonian Fluid, Rigid Wall, No Gravitational Effect

❖ Boundary Condition

- Inlet : Re = 250, V_{avg} = 0.26984 m/s , Fully Developed Laminar Flow
- Outlet : Neumann Boundary, Zero Traction

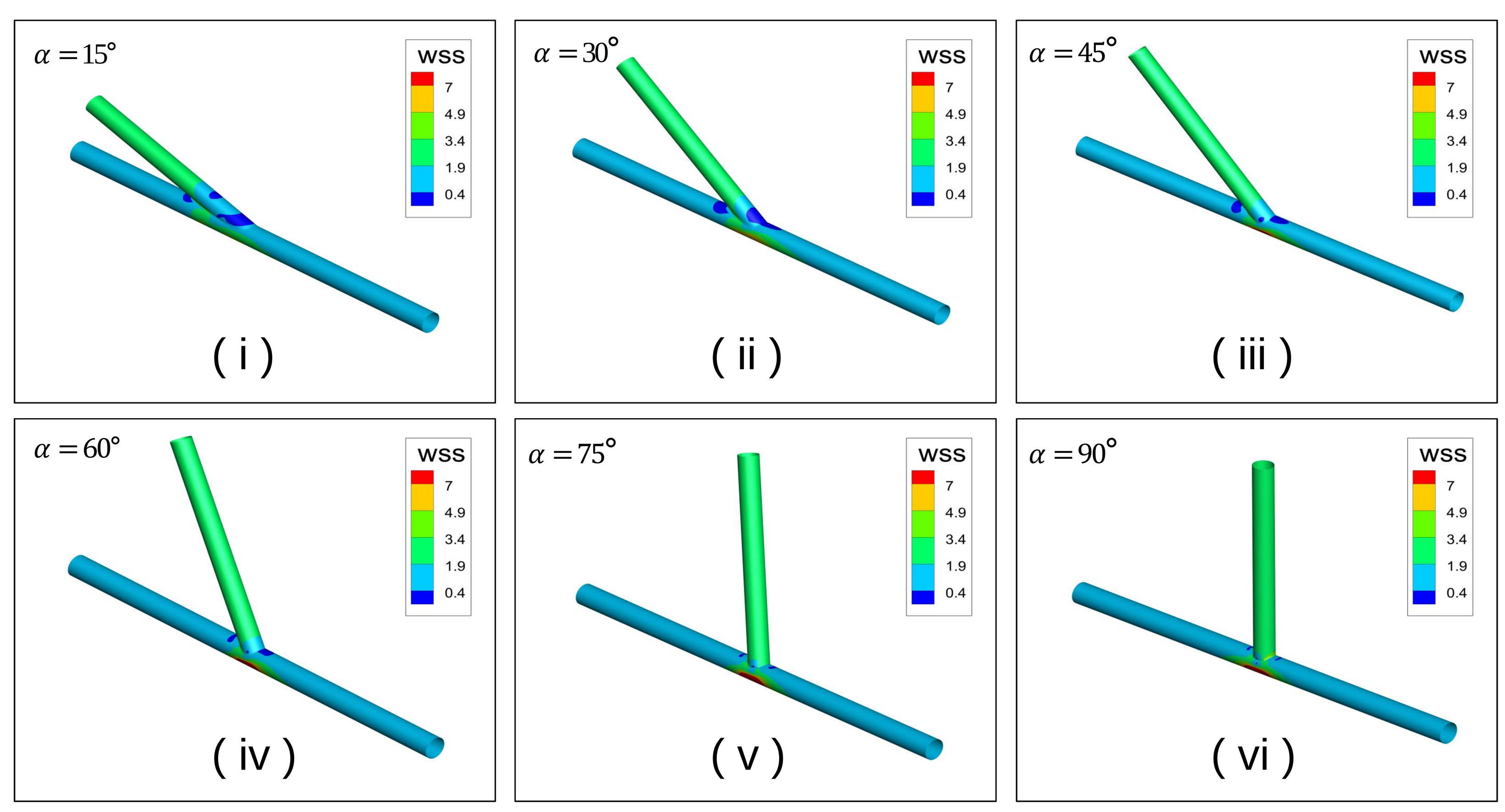
Result

Figure 4. Velocity Contour in Axial Section



- Flows with high velocity(above 0.3m/s) were not affected by anastomosis angle.
- Slow moving flows were observed in graft anastomosis(area A) in model i and ii (15° and 30°)
- Velocity in proximal area was faster in models with anastomosis angle above 45°, compared to models below 45 °.
- Recirculating flow was formed in proximal anastomosis area in models with anastomosis angle below 45°.

Figure 5. Wall Shear Stress Distributions



- Low wall shear stress regions were observed near anastomosis in all models.
- The increase of anastomosis angle decreased the size of low wall shear stress region.

Conclusion

❖ As the size of low wall shear stress region decreases near anastomosis, increasing anastomosis angle may reduce the risk of restenosis near anastomosis.

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