Vascular remodeling after AVF creation as angioaccess for hemodialysis : the predictive value of a patient-specific computer model

technische universiteit eindhoven

Vascular remodeling after AVF creation as angioaccess for hemodialysis: the predictive value of a patient-specific computer model

Huberts W.[1], Planken R.N.[2], Bosboom E.H.M.[1], Tordoir J.H.M.[2], van de Vosse F.N.[1]
[1]Eindhoven University of Technology, dept of Biomedical Engineering,
[2]University Hospital Maastricht, dept of Surgery

Introduction

Functioning of hemodialysis arteriovenous fistula (AVF) immediately after surgical creation is mainly hampered by non-maturation, which is characterized by insufficient flow increase and insufficient vessel remodeling. Despite available preoperative diagnostics 20-50% of all newly created AVFs fail[1,2]. The initial postoperative flow (pFV) increase is generally accepted to be indicative for proper maturation[2].

Aim of the study

The development of a patient-specific computer model that is able to predict the pFV increase after AVF creation as angioaccess for hemodialysis. Eventually, the model will be used for surgical AVF planning.

Research approach

Vascular hemodynamics is simulated by either one of two different modeling approaches, lumped parameter modeling[3] or 1D-wave propagation modeling[4]. For both models the human vascular tree is divided into segments representing local blood and vessel wall properties (fig. 1). All models are adapted to patient-specific conditions and results are compared with clinical measurements.

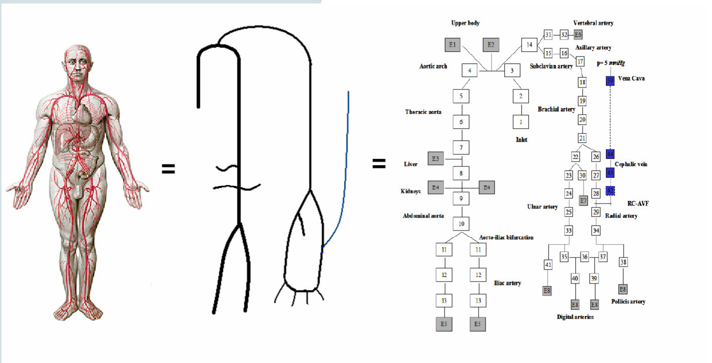

Figure 1: The vascular tree divided in segments.

Lumped parameter model[3] (0D): Pressure is represented by electrical potential and flow by electrical current. A resistor and an inductor are used to model the viscous and inertial blood properties. Vessel compliance is modeled with a condensator.

Wave propagation model[4] (1D): Flow in a vessel is divided in an inertia dominated core and a friction dominated boundary layer. By assuming equilibrium between inertia and viscous forces at the transition from core to boundary layer, a velocity profile as function of the flow and the pressure gradient is derived that is used to solve the 1D momentum equation.

Patient-specific model input

- CE-MRA[5]: Geometry and diameters (fig. 2)
- Ultrasound: Diameters, blood flow and wall distensibility (fig 3)
- PC-MRI: Arterial blood flow and cardiac output
- Tonometry and Penaz method: Radial and finger pressure

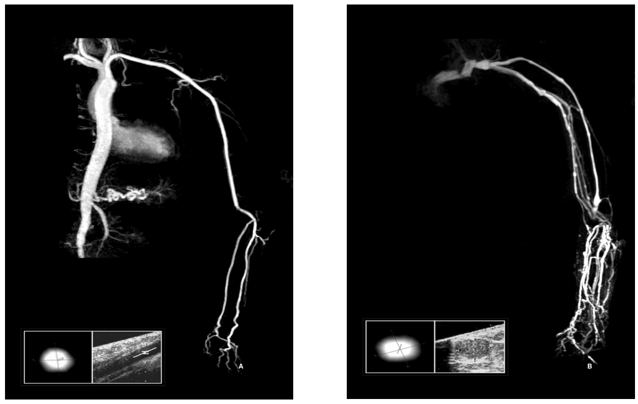

Figure 2: Anterio-posterior maximum intensity projections of a CE-MRA image of the left arm arteries (A) and vein[5] (B).

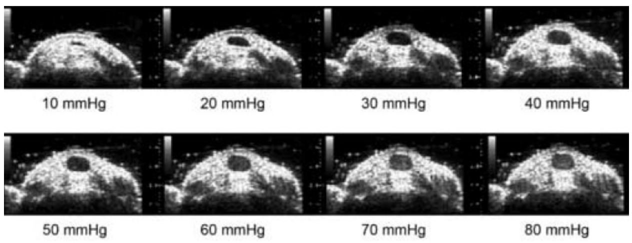

Figure 3: A transversal B-mode image of the cephalic vein for different congestion pressures[5].

Future work

- Test the feasibility of the 1D-model and extend the model with heart and veins
- Incorporate nonlinear pressure-flow relationships for veins and anastomosis
- Introduce visco-elastic behavior of the vessel wall
- Collect patient-specific data for 60 patients
- Perform simulations for 60 patients
- Determine the model's predictive value

References

1 Allon M, Kidney Int, 62(4): 1109-1124, 2002
2 Tordoir JHM, Nephrol Dial Transplant 18: 378-383, 2003
3 Westerhof N, J Biomech 2:121-143, 1969
4 Bessems D, J Fluid Mech 580:145-168, 2007
5 Planken RN, PhD thesis, Maastricht, 2006