Predicting the initial postoperative flow after AVF creation for hemodialysis : two modeling approaches

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Introduction

Functioning of hemodialysis arteriovenous fistula (AVF) immediately after surgical creation is mainly hampered by nonmaturation, which is characterized by insufficient flow increase and insufficient vessel remodeling. Despite available preoperative diagnostics 20-50 of all newly created AVFs fail [1, 4]. The initial postoperative flow (pFV) increase is generally accepted to be indicative for proper maturation [4].

Objective

The aim of this study is to compare a lumped parameter model with a 1D-wave propagation model in their ability to predict the postoperative flow increase after AVF creation.

Methods

Vascular hemodynamics is simulated with two different modeling approaches, lumped parameter modeling [3, 5] and 1D-wave propagation modeling [2]. 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.

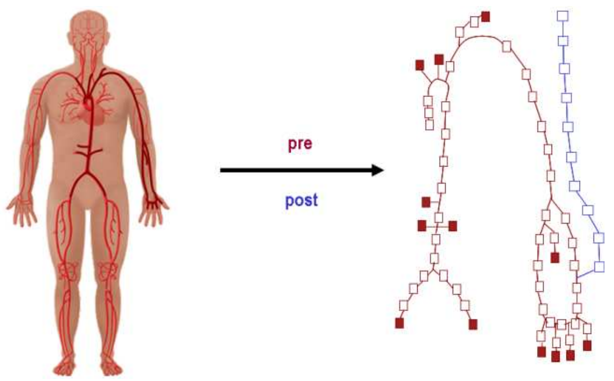

Fig. 1 *The vascular tree divided in segments.*

0D-lumped parameter model [3, 5]: 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.

1D-wave propagation model [2]: 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.

Results and discussion

Both modeling approaches were able to describe the acute hemodynamical effects associated with AVF creation and give similar results (Fig. 2,3). In both models the flow increases dramatically after RCAVF creation in accordance with duplex measurements.

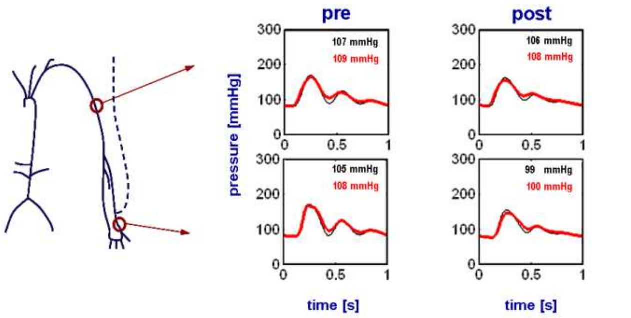

Fig. 2 *Example of the pressure contours before and after RCAVF*

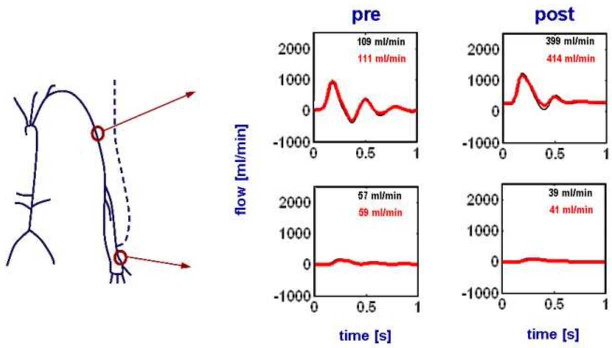

Fig. 3 *Example of the flow contours before and after RCAVF creation for the 0D- (black) and the 1D-model (red).*

The 0D-model is easier to adapt to patientspecific conditions, while it is more difficult to incorporate nonlinear terms (e.g. viscoelasticity). In addition, vessel tapering within a segment is neglected in the 0D-model. Model improvements are necessary to improve the patient-specific predictions.

Future work

- Improve the modeling of the veins and anastomosis
- Perform a parameter study
- Obtain more accurate input data: MR and US (n=60)
- Determine the models predictive value

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