Endovascular treatment of AAAs using geometry-matched stent-grafts

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Introduction
An abdominal aortic aneurysm (AAA, Figure 1a) is a local dilation in the infrarenal aorta. To prevent an AAA to rupture, which is fatal in 80-90% of the cases, a prosthesis is placed in the AAA. An alternative for the conventional open surgical repair is the less invasive endovascular repair, in which a stent-graft is inserted in the AAA via the femoral arteries (Figure 1b). This repair procedure has major perioperative advantages, such as reduced blood loss and faster recovery, but major complications, like migration and endoleaks, are often seen in endovascular repair.

Hypothesis
In this study, it is hypothesized that migration and endoleaks can be prevented using a geometry-matched stent-graft (Figure 1c).

Objectives
- Develop methods for manufacturing and implanting geometry-matched stent-grafts
- Evaluate the geometry-matched stent-grafting principle

Methods
Manufacturing
Using Rapid Prototyping, a patient-specific mould is made to create different designs of Nitinol stents. The stents are embedded in a graft to prevent corrosion. A poly-urethane graft can be created on-demand with the desired geometry.

There are two conflicting requirements in the design:
- Sufficient radial stiffness to keep the lumen open
- Possibility of inserting the stent-graft in a delivery system (diameter < 7mm)

Implantation
For an optimal positioning of the stent-graft, a 3D high-resolution reconstruction of the AAA during the intervention is necessary. For this, a combination of 3D rotational angiography (3DRA, Figure 2) and intravascular ultrasound (IVUS, Figure 3) will be used.

Evaluation
The geometry-matched stent-grafts will be compared with the conventional stent-grafts using finite element simulations and in-vitro experiments. Thrombus formation likely will occur in geometry-matched stent-grafts due to reversed flow. A hybrid stent-graft (Figure 1d) can be the solution to this problem.

- Finite element simulations
  - Prediction of short-term results (pressure, stress, flow)
  - Optimization of the stent-graft design.
- In-vitro experiments
  - Validation of the computational model
  - Development of image-guided implantation procedures.

Figure 1 a) AAA b) Conventional stent-graft c) Geometry-matched stent-graft d) Hybrid stent-graft

Figure 2 3DRA of AAA stent-graft (Philips Medical Systems)

Figure 3 IVUS image of the aorta (Volcano, IVG3–system)

Future work
- Optimize stent-graft design
- Model the stent-grafts in finite element simulations
- Test stent-graft prototypes in in-vitro set-up
- Develop tools for 3D reconstruction from 3DRA and IVUS
- Registration of 3DRA/IVUS with pre-operative CT
- Optimize implantation procedures

References: