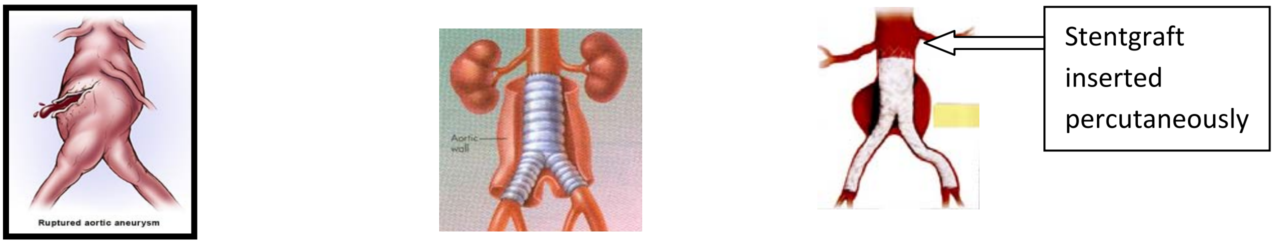
Fluid-structure interaction in stent-grafts after repair of abdominal aortic aneurysms

Ragnar Larsson, Håkan Nilsson, Applied Mechanics, Chalmers
Håkan Roos, Mårten Falkenberg, Div. for vascular and thoracic surgery, Sahlgrenska Academy,

Background

Abdominal aortic aneurysms (or aortic rupture) is a disease common for males >65 years of age. The aneurysm (or dilatation of the aortic vessel) increases the tension of the vessel wall according to the law of Laplace (yields a weakening zone of the vessel wall) leading to a significant increase of the risk of rupture which, untreated, is lethal, cf. Figure 1a. The classical treatment consists of a major open operation, where aim is to replace the affected vessel wall with a prosthesis, i.e. a tube consisting of Dacron or e-PTFE (gore-tex) as shown in Figure 1b. The alternative treatment, which is well established and used in practice worldwide, is to adopt reinforcement of the aneurysm using so-called stentgrafts. The stentgrafts are inserted percutaneously using x-ray technique, and consists of a special fabric supported by a metallic mesh covered by a skin, cf. Figure 1c and Figure 2. This treatment is named EndoVaskular Aortic Repair (EVAR).



(a) (b) (c)

Fig. 1 a) Aortic aneurysm rupture formation, b) Open surgery, c) EVAR

Hypothesis

The idea is to study the flow in the grafts vessel system considered as a Fluid-Structure Interaction (FSI) problem. The flow within the flexible vessel (represented by the stent graft) yields a distributed force transmitted to the aortic walls of the graft and, in particular, to the attachments, cf. Figure 2.

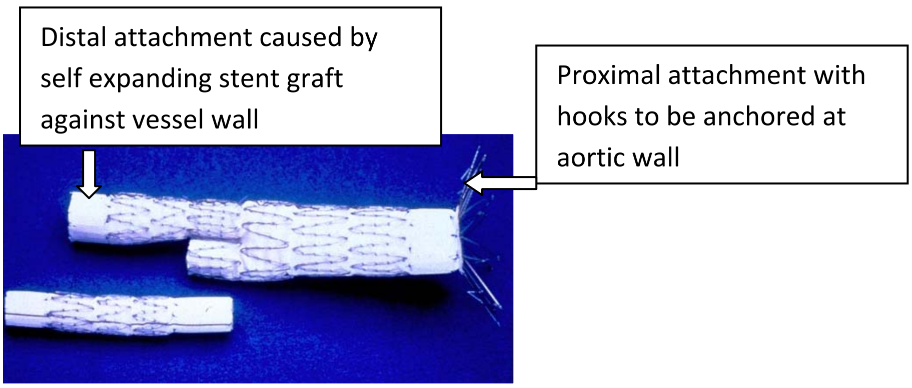


Fig. 2 Example of a stentgraft used in EVAR

Research tasks

The project will be carried out as a collaborative work between Sahlgrenska Academy, div for vascular and thoracic surgery and Chalmers, department of Applied Mechanics. Research tasks concerning physical testing will be carried out at by the research group at Sahlgrenska, whereas the modeling and computational work is carried out as a master thesis work within the Solid and Fluid Mechanics master program at Chalmers.

Fluid-structure interaction modeling and computation

The aim of the modeling and computational work is to support and establish the findings of the physical testing activity. Therefore, a simplified one-way-coupled study is carried out. The hypothesis is also that the problem requires demanding and challenging FSI modeling. In order to assess the significance of the FSI coupling pertinent to the present problem, a related simplified planar FSI model is developed. The research tasks are formulated as follows:

- Initial one-way-coupled analysis of the 3D problem. In order to obtain an idea of the actual flow and fluid pressure conditions standard CFD analysis will be carried out with respect to a typical *fixed* configuration of a stent graft dividing the flow into two channels, such as the stent shown in Figure 2. This investigation focus on the fluid flow and the possible occurrence of turbulence due to observed Reynolds numbers in the flow domain. In addition, the forces acting on the stent walls are identified and invoked into a stress analysis as a one-way-coupling.

- A fundamental investigation of the state of the art concerning of FSI modeling, cf. Fig 3, pertinent to lightweight, flexible thin-walled structures coupled to fluid flow in an incompressible regime is considered. A simplified planar approximation of the 3D problem stated above is taken as the basis for the analysis. A Finite element based approach to both the solid the fluid phases is considered as the primary paradigm in this part of the work. Attention is focused on the implication of the flexibility of the stent graft with respect to the obtained fluid flow and pressure distributions.

Collaboration

The proposed research has high relevance to biomechanics, with research issues established in collaboration with Sahlgrenska Academy, Dr. Håkan Roos and Dr. Mårten Falkenberg. The project also represents research scientific issues related to computational fluid as well as solid mechanics; In particular, represented by the fluid structure interaction problem. The preliminary one-way-coupled analysis will be carried out in common between two M.Sci. candidates, whereas in a second phase of the project one student will focus on flow modeling/simulation including the possibilities to exploit Openfoam for FSI computations. The second student will focus on the fundamental computational formulation of the present FSI-problem on the basis of a finite element based approach. The work involves exchange of ideas and experience from the common physical problem. For example, a common benchmark problem will be established and the results of the different approaches can and will be compared. Pros and cons of the different approaches to the FSI problem will be investigated and presented in one common M.Sci. thesis between two students.