KTH ROYAL INSTITUTE
OF TECHNOLOGY

Biomechanical rupture risk assessment of Abdominal Aortic Aneurysms (AAA)

BIOMECHANICS, HEALTH AND BIOTECHNOLOGY

Introduction and problem definition

The rupture of an Abdominal Aortic Aneurysm (AAA), the local enlargement of the infrarenal aorta as shown in Fig. 1, is a serious condition and causes many deaths, especially in men exceeding 65 years of age. Over the past quarter of a century, computational biomechanical models have been developed towards the assessment of AAA risk of rupture, technology that is now on the verge of being integrated within the clinical decision-making process [1-3]. Whilst most of the aspects concerning computational mechanics have already been settled, it is the exploration of the failure properties of the AAA wall, the Machine Learning-based (ML-based) integration of heterogenous input information [4] and a probabilistic rupture risk prediction [5], that has a great potential for the further improvement of this technology.

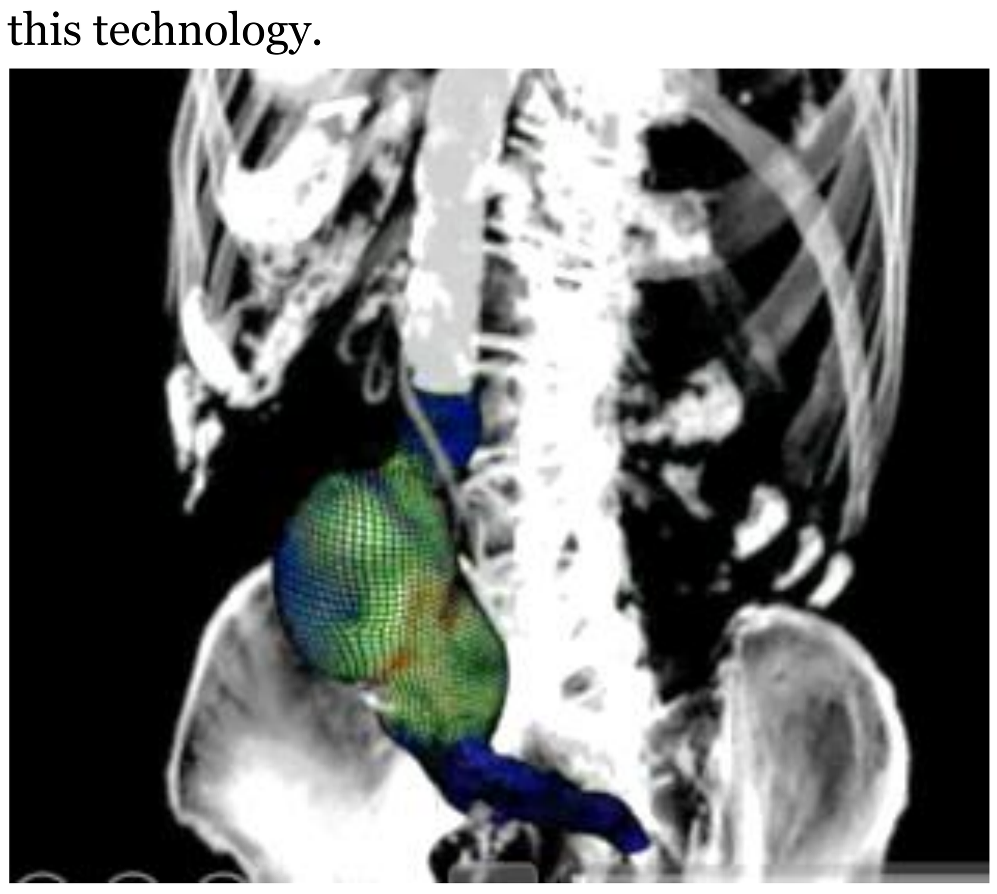

Fig.1: AAA reconstructed from clinical Computed Tomography-Angiography images

Characterization of vessel wall properties

AAA is the end-result of the irreversible pathological remodeling of the vessel wall. It is characterized by the significant degradation of medial elastin and cell death. Collagen is then the remaining structural protein that supports the load-carrying of the aneurismatic vessel wall. With increasing size, the blood-pressure-induced tensile stress in the vessel wall increases proportionally, until it eventually ruptures the aneurysmatic aorta. The fracture of vascular tissue is poorly explored, and our group uses modified Compact Tension (CT) testing, as shown in Fig.2, to study fracture mechanism and threshold levels. This information helps us then to design new multi-scale constitutive models [6] of the vessel wall towards the better assessment of AAA rupture in individual patients.

Conclusions and further direction

The vessel ruptures at the location where wall stress exceeds wall strength. Structural biomechanical simulations are therefore well-suited to study the risk of AAA rupture in individual patients. Regardless fundamental aspects of vessel wall fracture are unknown, already today the biomechanical rupture risk assessment is able to complement the clinical decision making. AAA rupture is influenced by biomechanical, biochemical and clinical factors, all together determines of how an aneurysm grows in time. In addition to the rupture risk assessment, the prediction of AAA growth in an individual patient [7], as shown in Fig.3, is important for the surveillance of AAA patients. Modern data processing approaches, such a ML could also play here an important role in the integration of heterogenous input information [8].

Fig. 2: Vessel wall fracture experiment

Literature

[1] Gasser. Aorta 2016; 4(2):1–25.

[2] Singh, et al. British Journal of Surgery 2020; DOI: 10.1002/bjs.11995.

[3] Polzer, et al. Journal of Vascular Surgery 2020; 71(2):617-626.e6.

[4] Alloisio, et al. ESVS 35th Annual meeting, Rotterdam; 2021.

[5] Polzer, Gasser. Journal of the Royal Society Interface 2015; 12(113).

[6] Miller, Gasser. Journal of the Mechanics and Physics of Solids 2021; 154:104500.

[7] Martufi, Gasser. Journal of The Royal Society Interface 2012; 9(77):3366–3377.

[8] Lindquist Liljeqvist, et al. Scientific Reports 2021; 11, 18040.

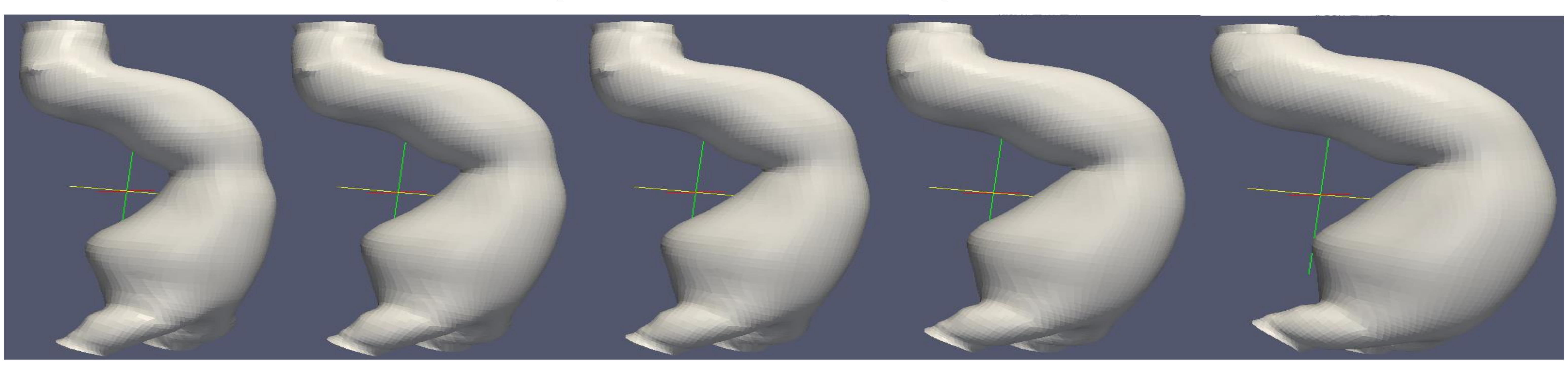

Fig. 3: Simulation of AAA growth through the description of collagen turn over