COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Influence of vertebrae and intervertebral disc on stresses in abdominal aortic aneurysms

O. Lisický [a], S. Polzer [b], J. Burša [a]

[a] Institute of Solid Mechanics, Mechatronics and Biomechanics, Brno University of Technology, Czech Republic
[b] Department of Applied Mechanics, VSB Technical University of Ostrava, Ostrava, Czech Republic

Computational modelling of stress-strain states in Abdominal Aortic Aneurysms (AAAs) has become an important tool in assessment of their rupture risk in the last decades. As its application potential in clinical practice is increasing with every additional influencing factor considered in the model, many factors have been analysed already. Up-to-date models are based on patient-specific AAA geometry obtained typically from CT-A imaging under a known level of blood pressure. Mean arterial pressure (MAP) is used to create their unloaded geometry [1] which (with other additional features such as residual stresses) may increase the credibility of the results. Material behaviour is also a very important feature to be described correctly. Large deformations of the arterial wall and intraluminal thrombus (ILT) are mostly described using constitutive models based on mean population data gathered from mechanical testing of patient-specific specimens [3]. ILT can be taken into consideration not only for his poroelastic structure reducing the blood pressure on the AAA wall but also for its significant load-bearing contribution. Different mechanical properties across the ILT thickness. Can be considered as a significant feature too. ILT with large thickness also reduces oxygen supply into the AAA wall underneath and consequently changes its mechanical properties (strength).

Nevertheless, very little attention has been devoted to the impact of the surrounding organs on the stresses in the AAA wall. Most computational models are just fixed on both ends of the AAA (boundary condition constraining all degrees of freedom). However, AAA is surrounded by less or more compliant connective tissues attached to other organs along its length which could lead to reduction of movements. Among lots of organs and tissues around the aorta, vertebrae along with intervertebral discs represent the stiffest ones and may have several contacts with the AAA, see Fig. 1. In these regions the AAA may be bent over the backbone which induces additional bending stresses in it and the contact regions may also change due to the movement of the AAA.

Taking most of the above features into consideration, the impact of backbone has been investigated in this preliminary study using a static stress-strain analysis of AAAs. The FE analysis of the idealized geometry shows a negligible impact on stresses in various vertebrae models (cylinder, vertebrae based on mean dimensions …). In contrast, significant differences in stresses have been found in case of patient-specific models. As expected, the impact of backbone does not occur under MAP because the deformed shape corresponds to that recorded from the CT-A imaging where the geometry and contacts were detected. However, when the elevated systolic pressure (assumed as 1.5 MAP in this study) was used to load the AAA wall, some patient-specific geometries showed significant differences in displacements and PWS, see Table 1. The relative increase of PWS due to the presence of backbone ranged from -2 to 81 %. Node-to-node comparison of the stresses between all the pairs of patient-specific models confirmed a global increase of stresses with consideration of backbone.

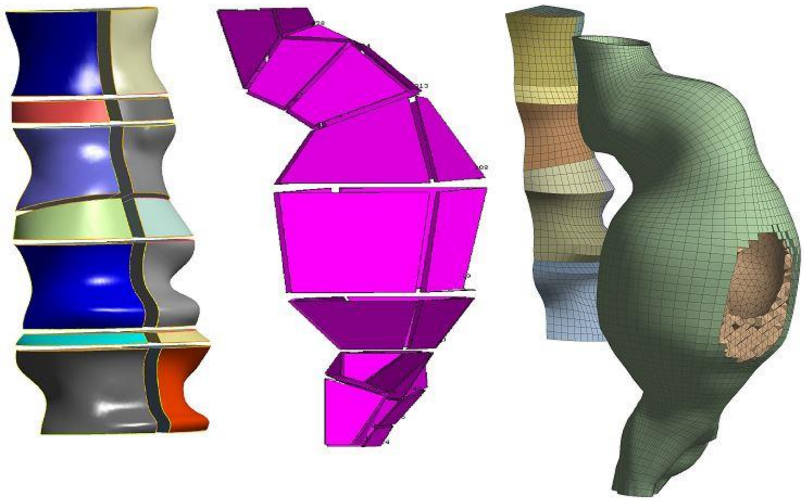

Fig. 1. Discretized model of vertebrae, intravertebral discs and AAA with pure hexahedral mesh using linear SOLID 185

Table 1. Comparison of PWS [MPa] in the patient-specific models with and without backbone

Patient [-]	1	2	3	4	5	6	7	8	9	10
WITHOUT backbone [kPa]	1450	783	3368	2089	1132	2468	3000	1136	882	1843
WITH backbone [kPa]	2630	783	3389	2630	1280	2530	3016	1420	921	1800
Difference [%]	81	0	1	26	13	3	1	25	4	-2

The results of FE analysis show NO significant increase or decrease in case of idealized models but significant variations in PWS (p = 0.034) have been found within the patient-specific models. As no indicator can be specified in what cases the backbone should be included, we recommend to include it in all FE models of AAA rupture.

Acknowledgements

This work was supported by project NETME CENTRE PLUS (LO1202), created with financial support from the Ministry of Education, Youth and Sports under the National Sustainability Programme I.

References

[1] De Putter, S., et al., Patient-specific initial wall stress in abdominal aortic aneurysms with a backward incremental method, Journal of biomechanics 40 (5) (2007) 1081-1090.

[2] Gasser, T., et al., Failure properties of intraluminal thrombus in abdominal aortic aneurysm under static and pulsating mechanical loads, Journal of Vascular Surgery 48 (1) (2008) 179-188.

[3] Polzer, S., et al., Importance of material model in wall stress prediction in abdominal aortic aneurysms, Medical Engineering and Physics 35 (9) (2013) 1282-1289.