Author’s response to reviews

Title: The combined impact of mechanical factors on the wall stress of the human ascending aorta - a finite elements study

Authors:

Tomasz Plonek (tomaszplonek@gmail.com)
Malgorzata Zak (malgorzata.a.zak@pwr.wroc.pl)
Karolina Burzynska (karolina.burzynska@pwr.wroc.pl)
Bartosz Rylski (bartosz.rylski@universitaets-herzzentrum.de)
Anna Gozdzik (anna.gozdzik@umed.wroc.pl)
Wojciech Kustrzycki (wojciech.kustrzycki@umed.wroc.pl)
Friedhelm Beyersdorf (friedhelm.beyersdorf@universitaets-herzzentrum.de)
Marek Jasinski (marek.jasinski@umed.wroc.pl)
Jaroslaw Filipiak (jaroslaw.filipiak@pwr.wroc.pl)

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Author’s response to reviews:

Reviewer 1

Efrem Civilini (Reviewer 1): This study by Tomasz Plonek and collaborators analyzes aortic wall stress including pathological geometries subjected to different grades of aortic root motions and blood pressures.

The good of the computational model is enforced by the correlation between the predicted results and the most commonly found entry sites in real case-scenario aortic dissections.

From my point of view, however, while SAS has been evaluated well beyond the physiologic stretching (i.e. 15 mm), systolic pressure of 200 mmHg, commonly found in the acute setting of acute dissection, has not been included in the analysis. Can the Authors explain why this element has not be assessed?
Dear prof. Civilini,

Thank you for your review. Your remark that the 200 mmHg may be a good parameter to assess is very important. Indeed, in the acute setting some patients do have extremely high systolic blood pressure. Two of our patients developed dissection while doing weight lifting and their pressures were at that moment certainly even higher than 200mmHg. Some researchers claim that the systolic blood pressure can reach in such situations (isometric push above the level of the head) up to 300 mmHg.

We are carrying out an extensive research on longitudinal stretching of the aorta using various radiological methods: aortography, echocardiography and cine sequences in magnetic resonance imaging. In our series, this stretching was on average 9-13mm, what is consistent with research done by Beller et al. who reported it to be around 11mm. The maximum stretching value in our patients was 23mm. We excluded the maximum values (above two SD over the mean value). The upper normal limit was roughly 16mm. To make it more clear we chose 5mm intervals (0, 5, 10 and 15mm).

We did not aim at simulating the acute setting and we decided to compare the impact on the stress in everyday situations. Therefore, we did not simulate very high values of blood pressure, longitudinal stretching of the aorta and extremely stiff and fragile aorta.

Your suggestion, however, is very valuable and we will definitely carry out an additional research simulating the acute setting with higher values of blood pressure, stretching of the aorta and more fragile aortic wall.

Sincerely Yours,

Tomasz Plonek
Giulia Luraghi (Reviewer 2): The authors present a structural finite element analysis to study how different factors, such as material properties and loading conditions, influence the stress filed in the wall of a non-dilated aorta, an aorta with aneurysm of the ascending part and an aorta with an aneurysm in the aortic root. They built three different simplified geometries to model physiological and pathological cases. They modelled the material of the aorta with a linear elastic law and, in case of an aneurysm, they investigated the consequence of increasing the elastic modulus in the aneurysm site. Two different type of loading conditions were explored: a blood pressure of 120 mmHg or 160 mmHg and different values of longitudinal up-and down movement of the aortic root (0, 5, 10 and 15 mm).

They identified the areas of the maximal stress in all the models. They observed the influence of each factor and they conclude that:

- The models with higher elastic modulus had higher stress values;
- An increment in blood pressure caused an increment in the peak wall stress;
- Systolic aortic stretching caused a significant increase in the peak wall stress.
- The highest wall stress was observed in the model representing the aneurysm in the ascending aorta.

Reviewer 2.

Dear prof. Luraghi,

Thank you for your review. We are grateful for all your suggestions. We would like to address all your comments.

1) The results on the comparison with different elastic modulus and loading conditions are obvious and the simulations do not provide further information.
We agree the results of this comparison are already known and consistent with what we already know. However, the aim of the study was to compare an impact of various elements in one model and, therefore, we had to implement different elastic modulus in our models.

2) The only relevant result is the comparison between different location of the aneurysm, but the idealized and simplified geometry makes unsatisfactory the conclusion. In fact, the effect of the geometry should be investigated in a reconstructed patient-specific model.

Thank you for this comment. We agree that patient-specific models reflect better the localization and values of the peak wall stress than “idealized” or rather “simplified” models. We also performed many simulations on patient-specific models with three-layered aortic wall, which mimicked more the real-life aortas. However, we aimed at assessing which of the parameters (dilatation, luminal pressure, elastic modulus, longitudinal stretching of the aorta) had the biggest impact on aortic wall stress. We wanted to assess more a trend rather than a specific value of stress in a given patient. However, your suggestion to perform the analyses on patient-specific models is very valuable, and we will definitely perform a research comparing the patient-specific models. It will be interesting to evaluate to which extent those results would differ from the simplified models.

3) The assumption of rigid wall makes this study too simple. A Fluid-Structure interaction approach should be encouraged, to bring some novelty in this field.

Without a verification/validation using patients’ data, this work remains as a theoretical view. The clinical inference of such a study should be reported and discussed with real life cases.

At the beginning, we decided to implement a fluid-structure interaction. However, we were not able to implement an important factor (longitudinal stretching of the aorta). We are not able to implement the movement of the aortic annulus to mimic the stretching of the aorta in the simulations. As far as we know, this problem has not been solved by other research groups. We could use the Fluid-Structure interaction approach but we would have to omit the aortic stretching which is regarded as one of the most important biomechanical factor that has an impact on the stress of thoracic aorta. We are currently working on this problem, and would more than happy to cooperate with you to solve it.

We agree that this is a theoretical view. It is rather an indication that longitudinal stretching of the aorta should be implemented in the simulations of the thoracic aorta.
Minor comments:

Line14: instead of "the aortic wall elasticity was decreased", please use "Young Modulus was increased".

The text was changed accordingly.

Line17: allows

The text was changed accordingly.

Once again thank you for your comments. We find them very valuable, and we are looking forward to cooperating with you and solving the problems of the biomechanics of the aorta.

Yours sincerely,

Tomasz Plonek