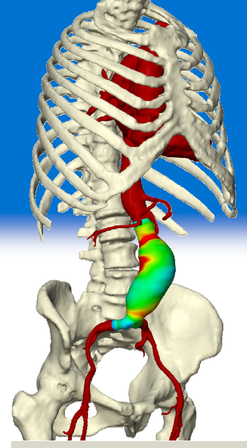


Glucose Metabolism in the Wall of Abdominal Aortic Aneurysms Correlates with Increased Mechanical Stresses

Andreas Maier[1], Michael W. Gee[1], Christian Reeps[2], Maximilian Baust[3] and Wolfgang A. Wall[1]

[1] *Institute for Computational Mechanics, Technische Universität München, Germany*
[2] *Clinic for Vascular Surgery, University Hospital Rechts-der-Isar of the Technische Universität München, Germany*
[3] *Chair for Computer Aided Medical Procedures, Technische Universität München, Germany*

Introduction

Stress-tissue interactions are the central postulate of abdominal aortic aneurysm (AAA) pathogenesis and rupture, but have thus far never been quantified on the organ level. For the present study, we calculated different mechanical AAA quantities using computational finite element (FE) simulation [1] and correlated them to ^{18}F-fluorodeoxyglucose (FDG) metabolism in the AAA wall detected by PET/CT [2,3].

Methods

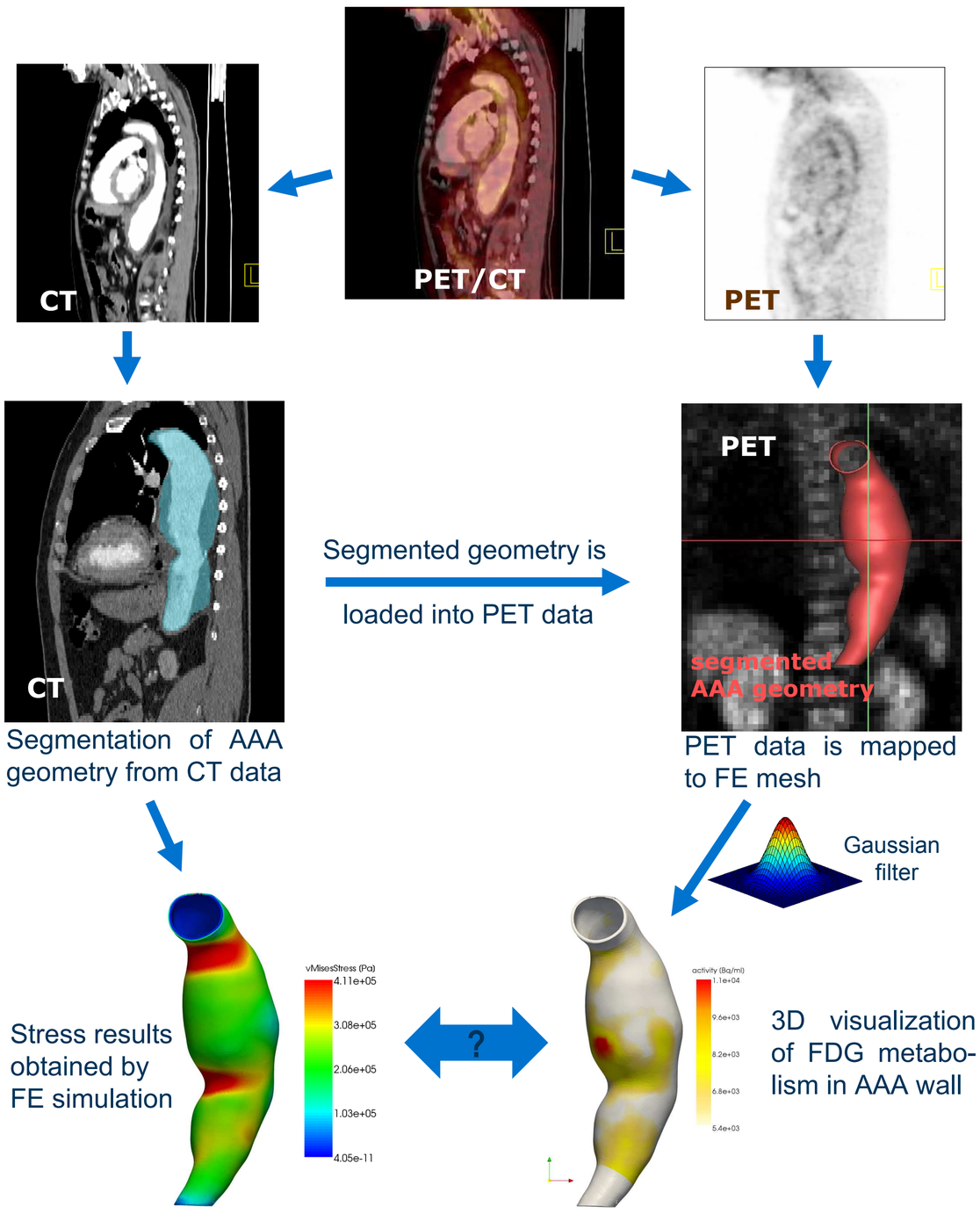
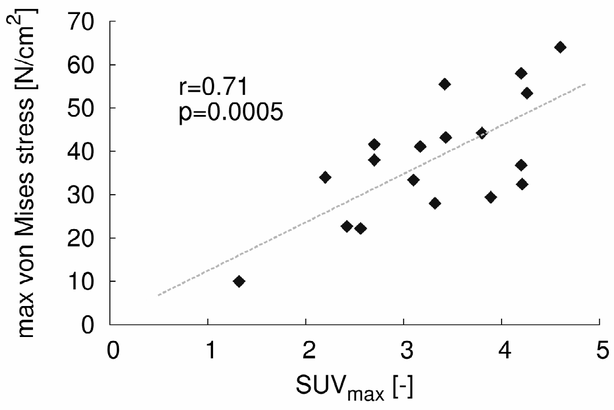


Figure 1. Process chart for FE simulation of AAAs and 3D visualization of FDG-uptake in the AAA wall.

Results

The study cohort comprised 18 AAAs. We compared maximum values of mechanical quantities and FDG-uptake (Figure 2) as well as their spatial, element-wise correlation (Figures 3 and 4).



Correlation of SUV_{max} to …	r-value [-]	p-value [-]
max displacements	0.62	0.0026
max strains	0.66	0.0013
max v Mises stress	0.71	0.0005
min strength $^{-1}$	0.10	0.3501
rupture potential index (RPI)	0.63	0.0026

Figure 2. Correlation of maximum FDG-uptake (SUV_{max}: max Standardized Uptake Value) to maximum wall displacements, strain, stress, strength and RPI [4]. The strongest and most significant correlation was obtained between SUV_{max} and max wall stress (as shown in the graph).

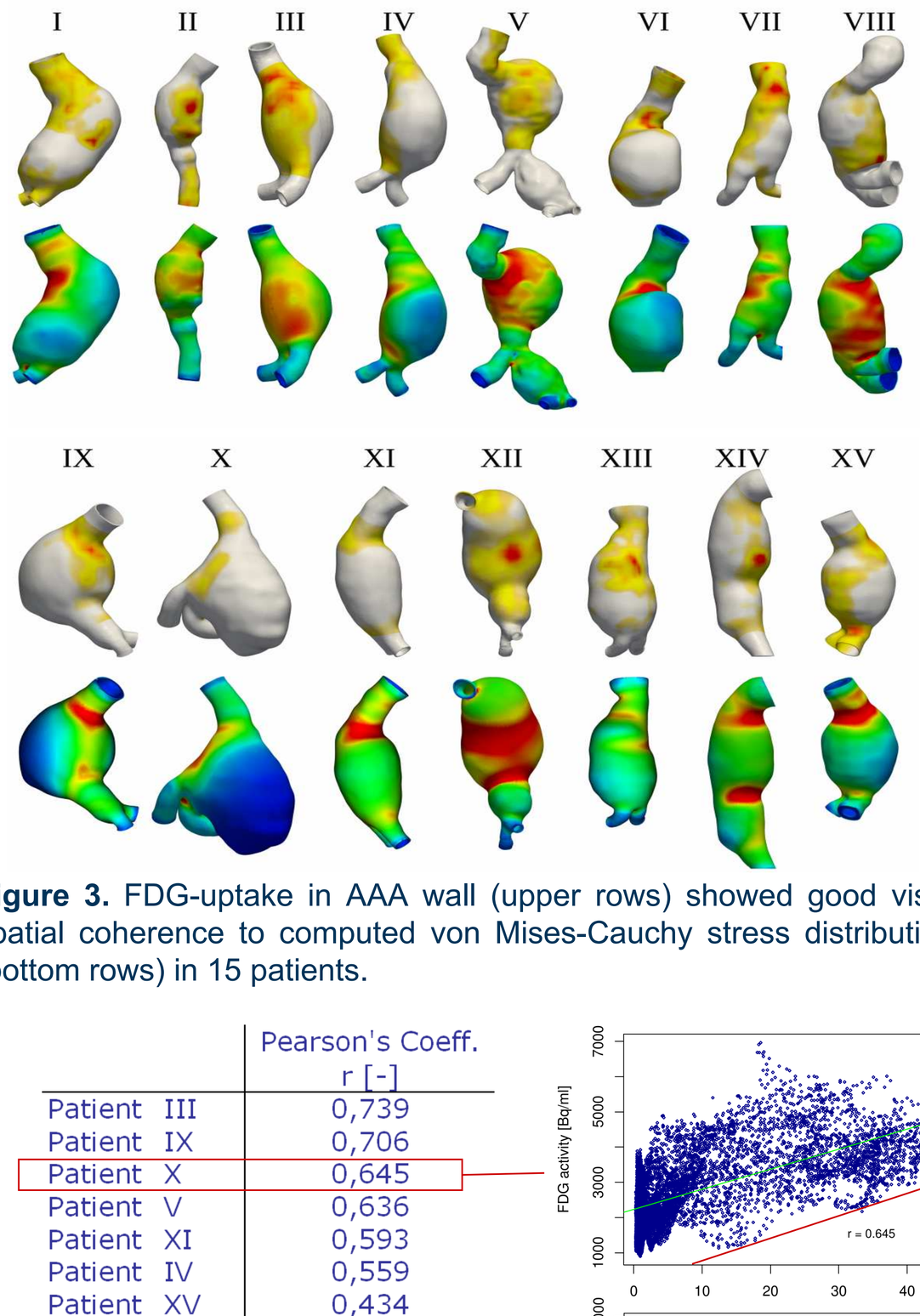


Figure 3. FDG-uptake in AAA wall (upper rows) showed good visual spatial coherence to computed von Mises-Cauchy stress distributions (bottom rows) in 15 patients.

	Pearson's Coeff. r [-]
Patient III	0,739
Patient IX	0,706
Patient X	0,645
Patient V	0,636
Patient XI	0,593
Patient IV	0,559
Patient XV	0,434
Patient XIV	0,431
Patient XIII	0,427
Patient VII	0,401
Patient VI	0,321
Patient β	0,317
Patient XII	0,293
Patient VIII	0,233
Patient I	0,144
Patient II	0,109
Patient α	-0,125
Patient γ	-0,169

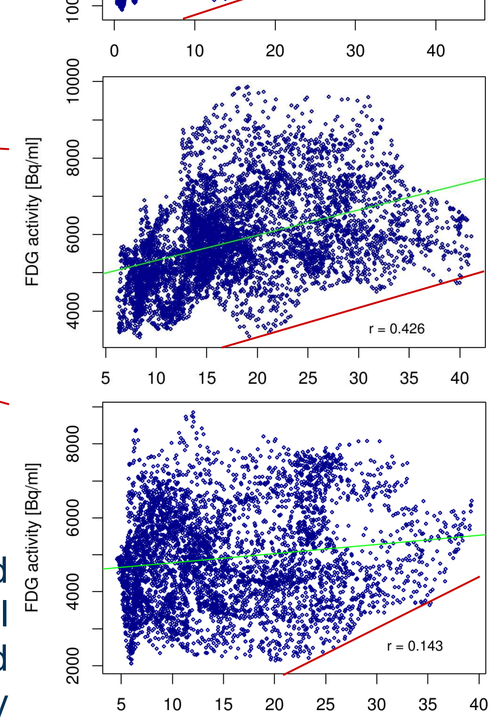


Figure 4. Element-wise correlation and scatter plots of FDG-uptake versus wall stress. Positive correlation was obtained for 16 out of 18 patients. It is noteworthy that minimum FDG-uptake was increased if the stresses acting in the aortic wall exceeded the physiological stress range (as indicated by red lines in the scatter plots on the right).

Conclusion

The findings demonstrate and quantify the complex interactions between biomechanics and tissue reactions in vivo. Our results indicate that biomechanical forces may be causative for regionally increased FDG-uptake and therefore metabolic activity in AAA wall, often linked to inflammatory processes. Thereby, FDG-uptake is correlated quantitatively and spatially to levels of max wall stress. We also found stress independent FDG-uptake, indicating additional autochthon inflammatory processes. Larger studies will be performed to confirm these results.

References

[1] Reeps C, Gee MW, Maier A, Eckstein HH, Wall WA, The impact of model assumptions on results of computational mechanics in abdominal aortic aneurysm, Journal of Vascular Surgery, 2010, 51, 679-688.
[2] Sakalihasan N, Hustinx R, Limet R. Contribution of PET scanning to the evaluation of abdominal aortic aneurysm, Seminars in Vascular Surgery, 2004, 17, 144-153.
[3] Reeps C, Gee MW, Maier A, Pelisek J, Gurdan M, Wall WA, Mariss J, Eckstein HH, Essler M. Glucose Metabolism in the Vessel Wall Correlates With Mechanical Instability and Inflammatory Changes in a Patient With a Growing Aneurysm of the Abdominal Aorta, Circulation: Cardiovascular Imaging, 2009, 2, 507-509.
[4] Vande Geest JP, Wang D, Wisniewski S, Makaroun M, Vorp D. Towards A Noninvasive Method for Determination of Patient-Specific Wall Strength Distribution in Abdominal Aortic Aneurysms, Annals of Biomedical Engineering, 2006, 34, 1098–1106.

6th World Congress on Biomechanics, 1 – 6 August 2010, Singapore

Institute for Computational Mechanics – Prof. W. A. Wall – http://www.lnm.mw.tum.de