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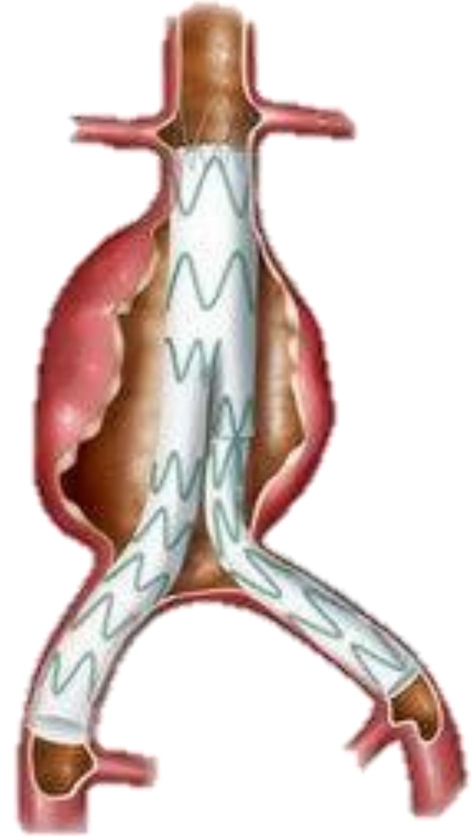

The Methodology of Endovascular Aneurysm Repair Simulation

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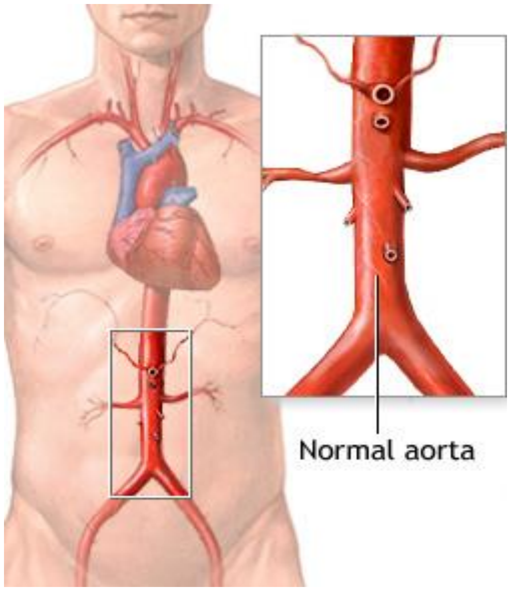
https://www.circulationfoundation.org.uk/help-advice/abdominal-aortic-aneurysm/endovascular-aneurysm-repair-evar

Disclosures

- None

Introduction (1)

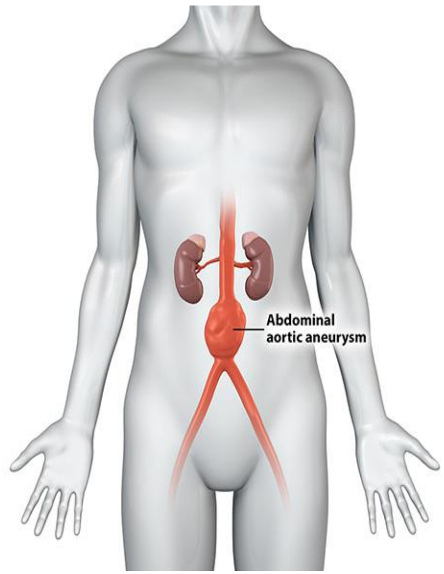
Abdominal Aorta



The abdominal aorta begins from the diaphragm and distally extends to the iliac bifurcation in the lower abdominal region and as the main artery supplying blood to most of the major organs.

https://medlineplus.gov/ency/article/000162.htm

Abdominal Aortic Aneurysm (AAA)



AAA is a pathological condition commonly associated with abdominal aortic wall degeneration, resulting in a weakened wall that continues to dilate over time, along with the development of intraluminal thrombus and calcifications in the enlarged aorta.

http://www.sydneyvascularsurgery.com.au/abdominal-aortic-aneurysm.html

AAA Treatment Methods

- Open Surgical Repair (OSR): It is a traditional and aggressive approach where the AAA is surgically exposed so that the aneurysmal section can be repaired by prosthetic grafts.
- Endovascular Repair (EAVR): It is a minimally invasive approach where a catheter is introduced, from the iliac artery at the groin to the AAA, and deploys stent-grafts (SG) to exclude the aneurysmal sac.

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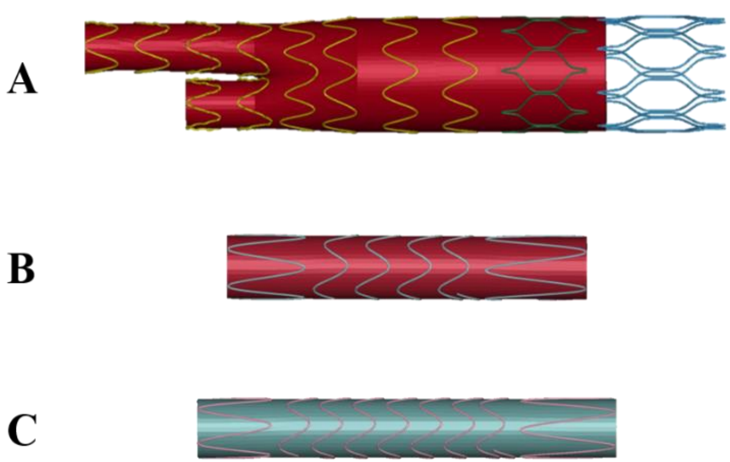
Introduction (2)

The preoperative planning phase of endovascular aneurysm repair (EVAR) has been overlooked as a crucial treatment stage. Using Finite Element software, it is possible to predict the procedure outcome and even reduce the complication risk factors. In recent years, virtual EVAR simulation models have been suggested to aid physicians in sizing stent-graft (SG), planning the endovascular approach, and improving visualization on the 3D roadmap. However, a lack of a universal model can be seen in the literature. We proposed a versatile and realistic model in an optimized application to improve the effectiveness of virtual EVAR simulation.

Methods (1)

The model has been developed for a patient-specific geometry in three stages: SG compression, delivery device navigation, and SG deployment. The vascular structure deformation biomechanical model had been validated previously for medical device navigation [1]. The model composition similar to the previous study had non-linear geometry of the bone structure, surrounding tissue, intraluminal thrombus, and vascular structure for elastic, viscoelastic and hyperplastic material properties. However, this study developed one integrated model to simulate the complete EVAR procedure and stent-graft deployment. After image registration and calibration, the final simulation results were evaluated via patient postoperative CT scan data for stents position.



SGs model of A) ZALB-26-98 B) ZSLE-13-56-ZT C) ZSLE-13-74-ZT.

A 74 years old male patient was selected for developing the Virtual EVAR model who underwent EVAR in the centre hospitalier de l'Universite de Montreal (CHUM), Montreal, Canada. The patient signed the informed consent form, which The CHUM ethics committee approved. Three SGs were used for patient treatment, and the figure shows the CAD models.

Methods (2)

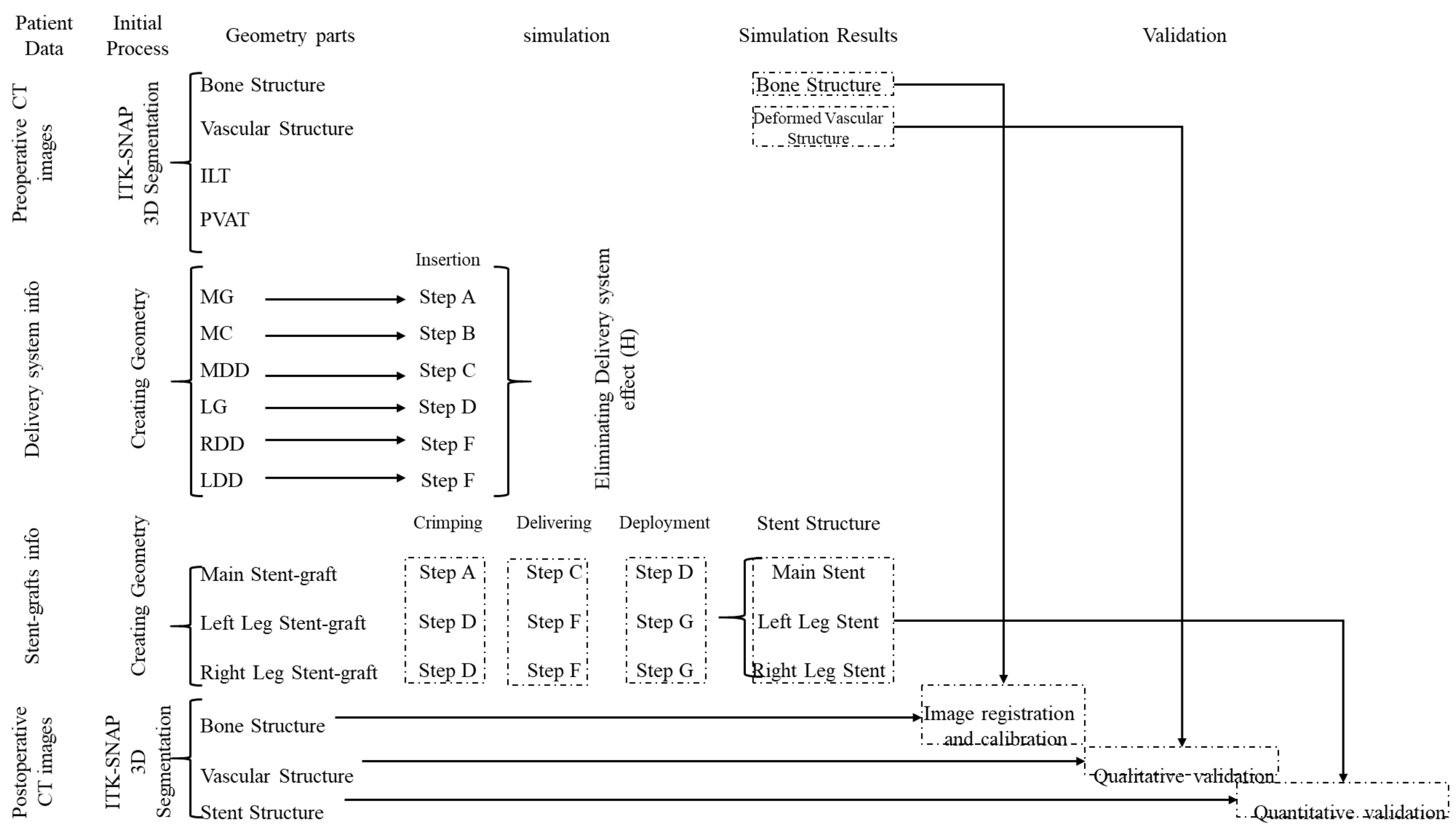


Illustration of the general numerical workflow via simulation steps (A to H) with respect to the clinical process. Intraluminal thrombus (ILT), Perivascular Adipose Tissue (PVAT), Main Guidewire (MG), Main Catheter (MC), Main Delivery Device (MDD), Left Guidewire (LG), Right Delivery Device (RDD), Left Delivery Device (LDD).

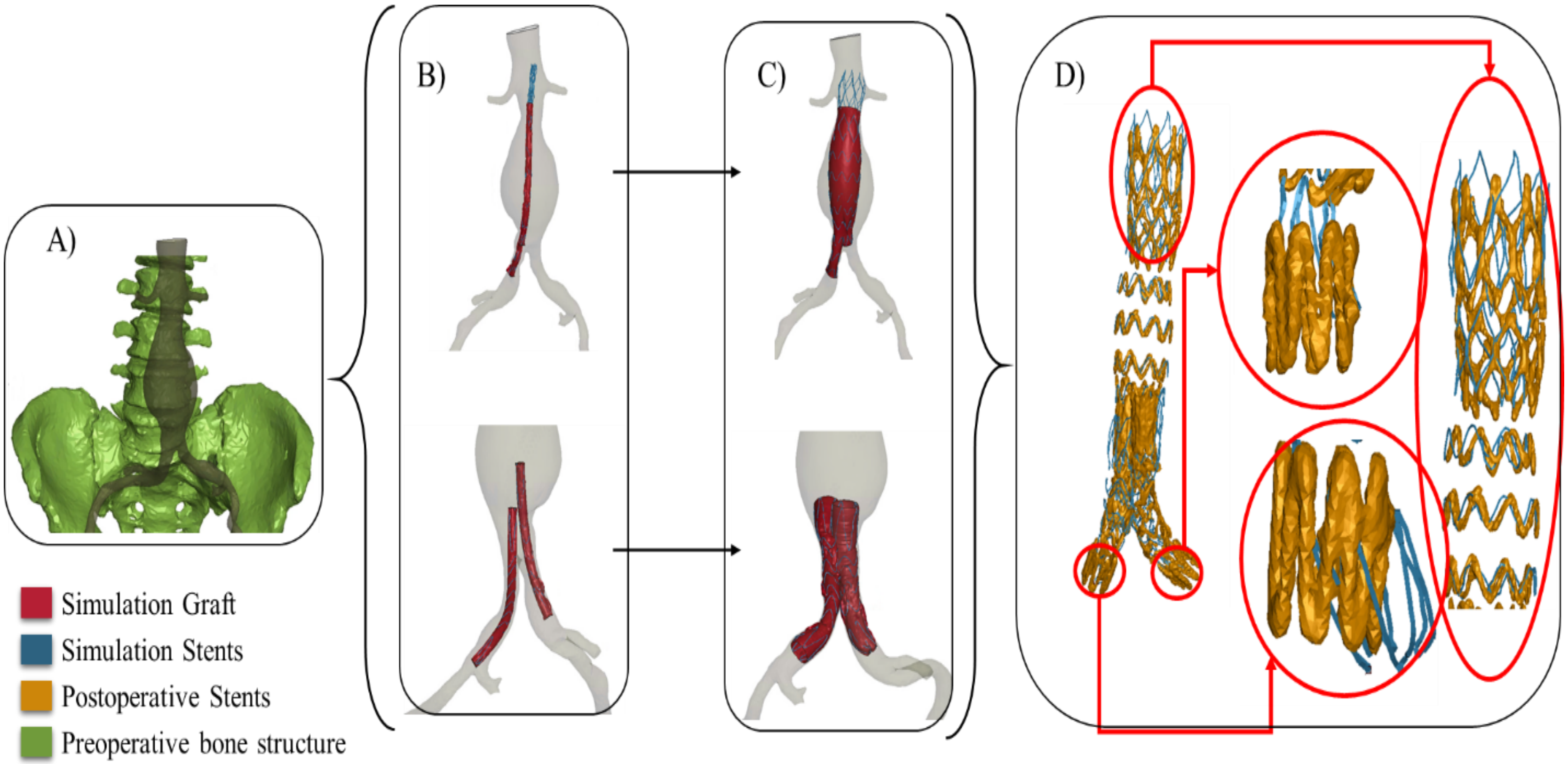
Results (1)

The novel design of the SG compression part was done perfectly without any numerical instability, which was reported by a similar investigation [2,3]. The maximum compression rate was up to 24 percent of initial diameters.

After SG crimping for A) ZALB-26-98 B) ZSLE-13-56-ZT C) ZSLE-13-74-ZT

Results (2)

As the navigation part of the simulation was validated before, for SGs deployment validation, the mean distance between the postoperative and simulation outcome for the stents mass center position had been measured which the error was 3.34 ± 2.87 mm. This error indicated a promising accuracy for a model accomplished in five hours.



A) The initial configuration of the Virtual EVAR model for the patient-specific geometry, the transparency shape is vascular structure. B) delivering the Main (top) and leg (bottom) SGs C) deployment of SGs at desirable points. D) compare final results with clinical results to indicate the accuracy of the model

Conclusion

- This virtual simulation model can predict vascular structure deformation and stent-graft deployment during EVAR procedure in every procedural step and potentially improve the planning and guidance of the EVAR procedure, reduce fluoroscopy time, and use contrast agents. Further, this simulation tool results can be used to train physicians.

- No study had been found with complete three mentioned stages simulation and without morphing methods. However, presenting the physical effect of perivascular tissue, bone structure, and ILT in such a model will close our simulation to the real-time procedure quantifying arterial deformation during EVAR.

References

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