RANS MODELLING of the patient-specific ASCENDING THORACIC AORTIC ANEURYSM

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INTRODUCTION

Cardiovascular diseases are responsible for roughly **45% of all deaths in Europe [1]**. Nowadays, ascending Thoracic Aorta Aneurysms (**aTAA**) are the **19th most common cause of death [2]** and is stated that the incidence can be significantly higher since aTAA are usually asymptomatic until the occurrence of acute events. The treatment of aneurysms involves a prophylactic surgery that has an inherent **mortality risk of about 5% [3]**, thus it is only recommended if the risk of occurring acute complications exceeds this value. To this day, the risk of rupture or dissection is assessed considering a geometric criterion, the growth rate of the aneurysm and the existence of certain risk factors such as bicuspid aortic valve or Marfan syndrome.

However, this decision method proved to not be fully reliable since more than half of the patients with aortic dissection has a normal aortic diameter (between 40 and 50 mm) at the time of the event **[4]**. The integration of biomechanical patient-specific computational models, which also considers the results of imaging tests, can be developed as a tool to support clinical decision regarding the identification of patients who despite having a normal aortic diameter, may benefit from earlier treatment. Throughout this paper the implementation of a numerical model (**Fig. 1**) that comprises the non-Newtonian behavior of blood and turbulence using the OpenFOAM software is presented.

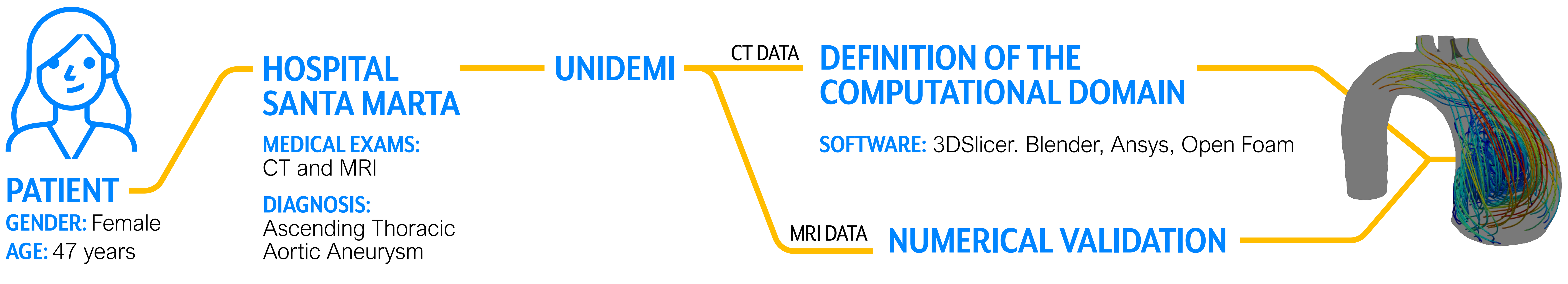

Fig. 1 – Schematic representation of the workflow that gave rise to the patient-specific numeric model presented in this paper.

MATERIALS & METHODS

The **computational domain** was defined using **CT data**. For the geometrical reconstruction, the 3D Slicer software was used. After a correction phase in Blender, the model was imported into ICEM CFD where an unstructured mesh was imposed. At the limits of the model, hemodynamic physiological boundary conditions were defined. In the region close to the aortic valve, an inlet condition was imposed to simulate the presence of the blood jet. At the other limits a time dependent pressure outlet condition was imposed. Both of these **boundary conditions** were obtained using data from the **MRI** performed on the pilot patient (**Fig. 2**).

Regarding the numerical modeling, the open-source toolkit OpenFOAM was used. OpenFoam applies a finite volume method to solve the RANS equations. The k-ε and Yasuda-Carreau models were selected for turbulence and rheological modelling, respectively.

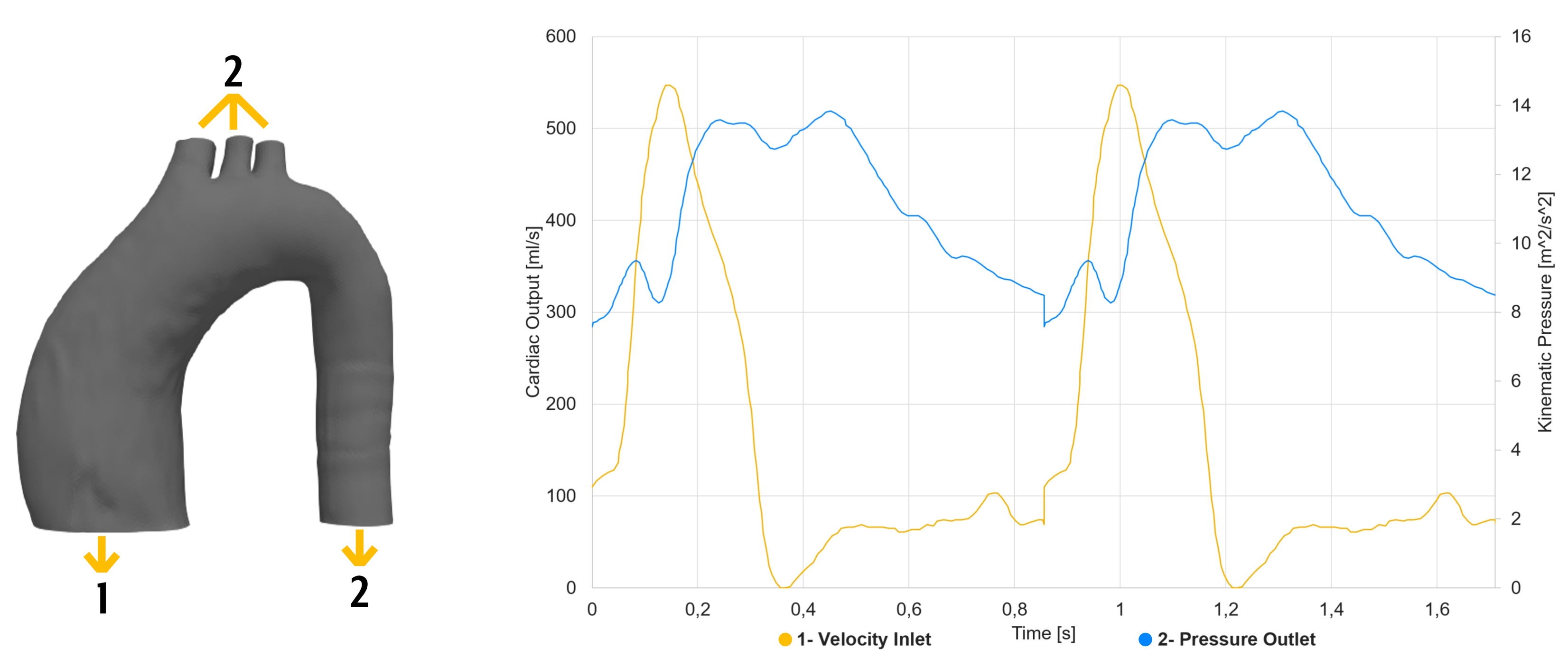

Fig. 2 – Geometric reconstruction of the pilot-patient thoracic aorta (left) and location and values of the chosen boundary conditions.

The simulation was performed during two cardiac cycles using a variable time-step with an initial guess of 0.1 ms. The convergence of the solution was achieved when the numerical residuals presented values less than 10^{-5}.

RESULTS & DISCUSSION

Analyzing the results presented in **Figure 3**, at the beginning of the cardiac cycle the flow presents high velocity due to the high volume of ejected blood. After the systolic peak (t > 120 ms), the blood ejection decreased and the flow inside the ascending aorta slowed down. In addition to this aspect, it is relevant to explain that the increase in Wall Shear Stress (WSS) was due to the impact of the blood jet on the wall. As the jet flows at high velocity, the WSS applied in this region are also high, which promotes the wear and deformation of the aortic wall.

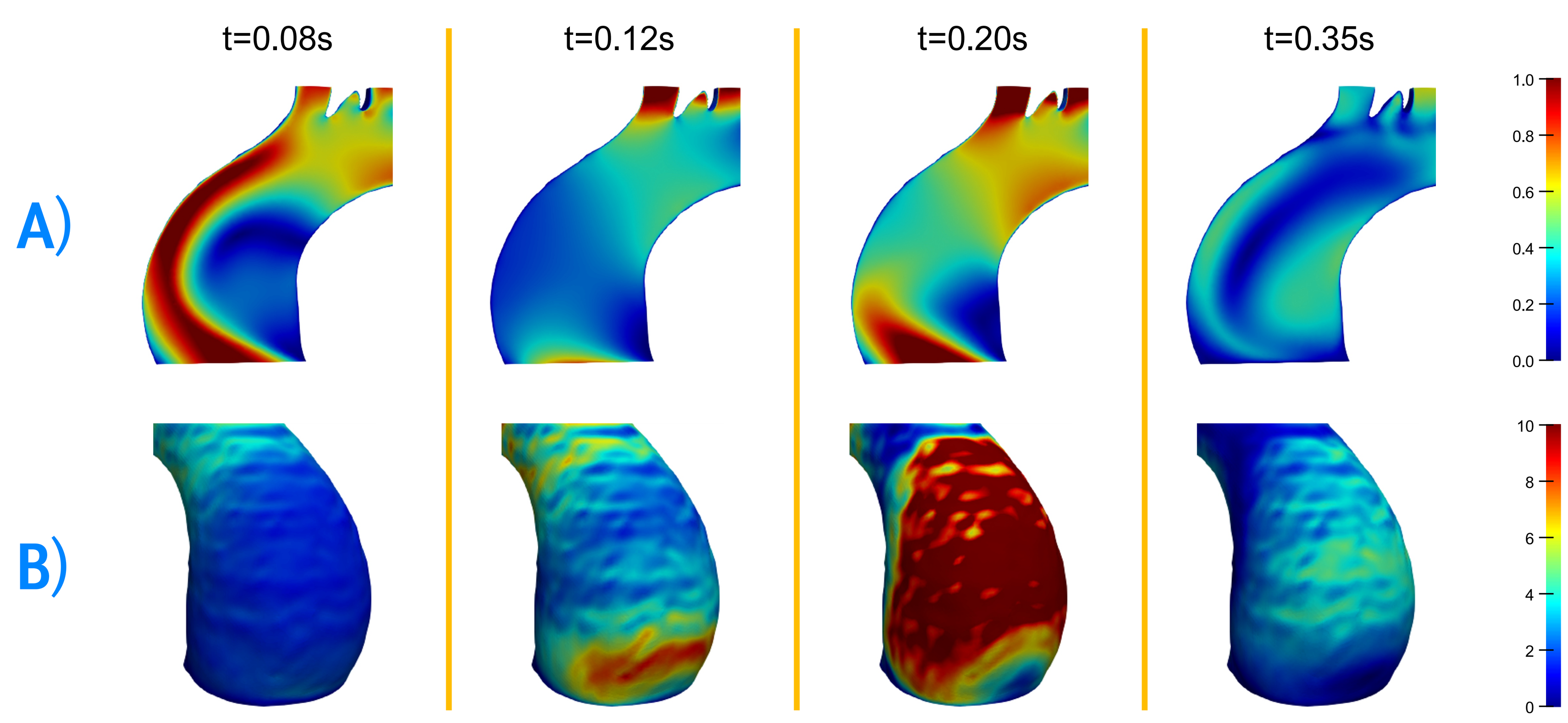

Fig. 3 – Evolution of **A)** blood flow and **B)** WSS in ascending aorta, throughout the second cardiac cycle.

CONCLUSION

The developed model proved to be able to accurately predict the hemodynamics in aTAA. Thus, this model represents an innovative approach to the process of diagnosing certain pathologies, such as aneurysmal diseases. In future works is intended to include models that characterize the elastic properties of the aortic wall and the fluid-structure interaction. In this way aiming at providing a full integration with clinical practices that are able of classifying the risk index of acute events, such as aortic rupture or aortic dissection.

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