An automated procedure based on Computer Fluid Dynamics to evaluate risk on abdominal aortic aneurysm.

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Introduction / aim of the study

Current treatment approaches rely heavily on the size of the abdominal aortic aneurysm (AAA) to decide on the most appropriate time for clinical intervention and treatment. However, in recent years, several alternative indicators have been proposed although there is no reliable criterion to predict the risk of rupture. In fact, some AAAs between 4 and 5.5 cm are still subject to rupture even today. In recent years various studies have been carried out to apply Computer Fluid Dynamics methods to evaluate behaviour of fluid and wall but this approach has not been applied in clinical practice until to now. In this work we present an approach to implement CFD simulations in real context as a tool to evaluate rupture risk on AAA. The approach is based on the automatic integration of all the phases concerning geometric modelling of aneurism, CFD pre-processing and simulations, post-processing and related risk evaluation.

Methodology

Automatic procedure is based on 2D aorta geometry reconstruction from angio-CT scan data and CDU images; then an intelligent CFD pre-processing based on best practice to obtain valid 2D CFD grids generates the input for a CFD simulations; finally results are post-processed to generate report on parameter used to evaluate risk. We developed software modules to obtain 2D geometry, to pilot 2D grid generation and generate final data report. For what concern 2D CFD analyses, an open source software (ElmerSolver, CSC Institute of Technology, Finland) was employed. Fig.1 documents an example of AAA. The usage of bidimensional models eases the usage of CFD tools in terms of general usability and speed of processing (See Fig. 2, 3). The procedure previously described is totally automated; it can be executed from a not-skilled CFD user (for example, a physician) and requires only an interactive cut of the image area that can be processed. Parameter used to evaluate risk is the Oscillatory Shear Index (OSI); it was calculated either in non-aneurysmatic aorta (control group) or in case of AAA (study group)(See Fig.4). Patients' characteristics were evaluated if related to the OSI parameter (gender, age, diabetes, cardiopathy, arteriopathy, dislipidemia, COPD, obesity, smoke abuse, renal insufficiency, hypertension).

Results

There were 102 patients, mean age 74.6 years, 77% (79) were male. 71 patients suffered from an AAA (10 cases, 14% were ruptured) and 31 had a non-aneurysmatic aorta. Mean diameter and SD in the study and control group were 5.62±2.0 cm and 2.29±0.29 cm respectively. The OSI index was significantly higher in the study vs. the control group (mean value ± SD, 0.419 ± 0.12 vs. 0.195 ± 0.12; $p<0.028$) (see Fig.5). All AAA ruptured occurred with diameter > 5.5 cm and, in case of AAA rupture the OSI value was always >0.475. (mean value ± SD, 0.494 ± 0.007). The distribution of OSI along with the AAA diameter is shown in Fig. 6.

This diagram could be divided in four regions: AAA diameter <= 4.5 cm and AAA diameter > 4.5 cm; OSI value < 0.4 and >= 0.4. All the ruptures occurred in the region AAA diameter > 4.5 and OSI > 0.4. The Risk Score could be defined according to the below table

AAA Diam. [cm]	Osi Value	Risk	Activity
< 4.5	< 0.4	low	---
> 4.5	< 0.4	medium	Follow up
< 4.5	> 0.4	medium	Follow up
> 4.5	> 0.4	high	Surgery

Conclusions

The procedure has been used for all the patients giving a possible quantitative criterion to address the AAA surgery, enabling the usage of CFD tools to users non-specifically skilled. This study showed that an OSI value > 0.4 and AAA diameter > 4.5 cm could be used to define a quantitative risk score to drive surgery. The possible clinical role of this risk score in the management of AAA needs to be validated in independent cohorts at a variety of centers before it can be recommended for application. A review of the results using 3D models to check their validity is ongoing.

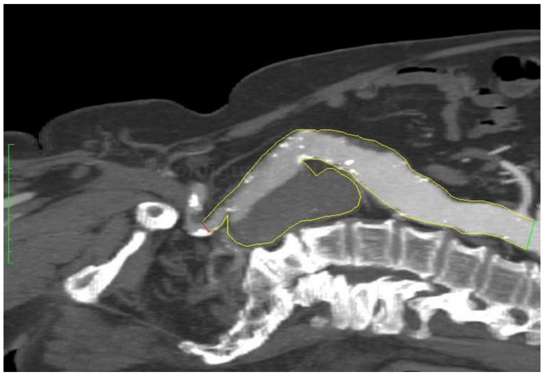

Fig. 1 AAA 2D geometry

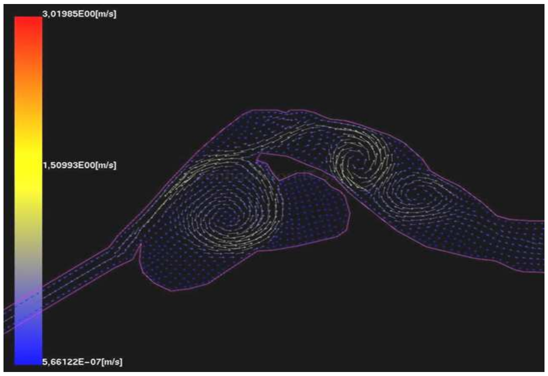

Fig. 2 Velocity fields in the model with inlet/outlet extension

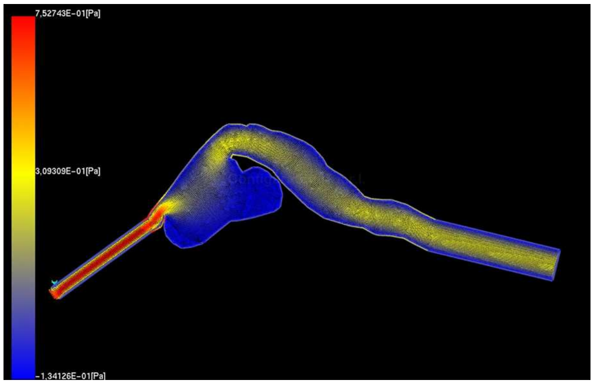

Fig. 3 WSS distribution

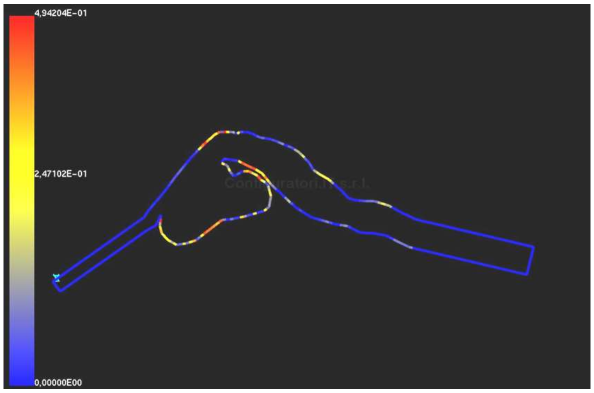

Fig. 4 OSI value distribution

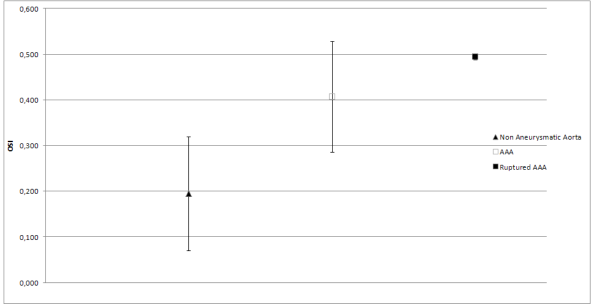

Fig.5 OSI Values for study and control groups

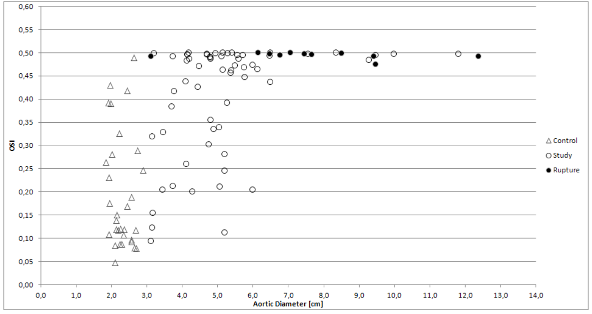

Fig.6 Distribution of OSI along with the AAA diameter