Medial Physicist and Radiologists, a winning team: definition of a new biomarker for the assessment of small aortic aneurysm rapid growth risk

Ramiro Moreno 1,5, Olivier Meyrink 1,2, Charline Zadro 1,2, Anou Souworn 1,5, Herve Rousseau 1,2, Alexis Jacquier 4, Laurence Bal 5

(1) Institute of Cardiovascular and Metabolic Diseases, Toulouse, France (2) Toulouse Rangueil University Hospital (CHU), Radiology, Toulouse, France (3) Hospital La Timone de Marseille, Vascular medicine and surgery, aortic center, Marseille, France (4) Hospital La Timone de Marseille, Radiology, Marseille, France, (5) ALARA Expertise, Strasbourg, France.

Abstract: Abdominal Aortic Aneurysm (AAA) is a common pathology which surgical intervention decision is mostly made upon measurement of maximal diameter, despite known limitations. The purpose of this study was to identify volumetric and computational fluid dynamics (CFD) parameters to predict AAA rapid growth risk. Material and methods: In our multi-centric and prospective study, we included 82 patients with an AAA from September 2012 to June 2014. Patients underwent two CT examinations separated by a one-year interval to assess aneurysms growth. Fifty patients were eligible for CFD analysis. Based on a 10 mm threshold of total volume growth, we classified patients into slow and rapid growth groups. Aneurysms initial morphological and functional parameters were analyzed including: maximal diameter and surface, thrombus and lumen volumes, maximal wall pressure and wall shear stress (WSS). Results: There was a significant difference between the two groups regarding aneurysm lumen volume (P=0.0051) and mean WSS variation (P=0.0240) unlike maximal diameter (P<0.71). We found significant correlation of aneurysm volume growth with lumen volumes and reduction of the mean WSS variation value (respectively R=0.47, P=0.0015 and R=0.42, P=0.0062) and total aneurysm volume growth. Combining these parameters, we computed an AAA growth-predicting model which featured better area under ROC than the only measurement of maximal diameter as well as the prediction risk assessment crucial for AAA management. Since the 70's many works proved that AAA diameter is correlated with the rate of rupture. However, sole use of maximal diameter measurement seems insufficient to predict rapid growth rate among this heterogeneous population. Therefore, we need different prognostic tools to assess rapid growth risk of small AAA, especially since the 5-year rupture risk for AAA is predominantly highly prevalent compared to larger AAA leading to non negligible rupture events. Volumetric analysis seems promising for rupture risk and growth rate assessment. Besides, it allows detection of morphological changes that do not affect maximal diameter. Over the last decade, we have seen the rise of functional vascular analysis based on computational fluid dynamics (CFD), studying many hemodynamics parameters. The purpose of this prospective study was to identify morphological and functional parameters to assess small AAA growth risk, based on volumetric and CFD analysis compared to conventional clinical measurements.

Introduction: Abdominal aortic aneurysm (AAA) is a serious and common pathology which development goes along with aging. Since the discovery of the abdominal aortic aneurysm (AAA), the risk of rupture and subsequent rupture risk assessment crucial for AAA management. Since the 70's many works proved that AAA diameter is correlated with the rate of rupture. However, sole use of maximal diameter measurement seems insufficient to predict rapid growth rate among this heterogeneous population. Therefore, we need different prognostic tools to assess rapid growth risk of small AAA, especially since the 5-year rupture risk for AAA is predominantly highly prevalent compared to larger AAA leading to non negligible rupture events. Volumetric analysis seems promising for rupture risk and growth rate assessment. Besides, it allows detection of morphological changes that do not affect maximal diameter. Over the last decade, we have seen the rise of functional vascular analysis based on computational fluid dynamics (CFD), studying many hemodynamics parameters. The purpose of this prospective study was to identify morphological and functional parameters to assess small AAA growth risk, based on volumetric and CFD analysis compared to conventional clinical measurements.

Material & methods:

Study design

Patients were considered for inclusion in the prospective registry if they had a maximum diameter of the abdominal AAA. Exclusion criteria were acute aortic disease syndromes (aortic dissection, thrombosis, acute aortic surgery, spontaneous rupture), recent (less than 6 months) abdominal or pelvic surgery, and pregnancy. Patients older than 65 years with a diameter >4 cm, asymptomatic patients older than 55 years with a diameter >3 cm and patients with a history of aortic disease were included in the study. Patients underwent two CT examinations separated by a one-year interval to assess aneurysms growth. We used a 10 mm threshold to classify patients into slow or fast.

Morphological analysis

We gathered the CT images using a workstation (Aquilion One, Toshiba, Tokyo, Japan) and the volume was measured using the software TeraRecon (Helicon3D, Foster City, CA). The initial volume was calculated as: Volume = 4/3π×(diagonal/3)^3.

Functional CFD analysis

We gathered the CT images using a workstation (Aquilion One, Toshiba, Tokyo, Japan) and the volume was measured using the software TeraRecon (Helicon3D, Foster City, CA). The initial volume was calculated as: Volume = 4/3π×(diagonal/3)^3.

Results:

Population characteristics

Morphological analysis

We gathered the CT images using a workstation (Aquilion One, Toshiba, Tokyo, Japan) and the volume was measured using the software TeraRecon (Helicon3D, Foster City, CA). The initial volume was calculated as: Volume = 4/3π×(diagonal/3)^3.

Discussion & conclusion: Two first, high WSS within aneurysm appears as a protective factor regarding aneurysmal growth rate. Second, increased lumen volume is correlated with the aneurysm volumetric growth. Previous studies found significant correlation of AAA and ILT volumes with aneurysmal growth rate. However, we did not find such significant differences considering AAA and ILT volumes between the slow and rapid growth groups. Conversely, we found a significant difference regarding lumen volume in favor of the rapid growth group. This could imply that even if lumen is slightly enlarged, it may have a stronger impact than ILT volume on aneurysmal growth. Since the beginning of CFD-based models, a few studies have discussed WSS impact on abdominal aortic aneurysm pathogenesis and its correlation with the onset of rupture. Our recent and previous findings suggest a protective role of high WSS values from aneurysmal growth, after having played a role in the initiation of the disease, reaching an equilibrium. Finally, combined analysis of lumen volume and WSS may provide better information than AAA rapid growth risk.