INSIGHTS FROM COMPUTATIONAL FLUID DYNAMIC MODELLING FOR AORTIC ARCH PATHOLOGIES

Massimiliano M. Marrocco-Trischitta, MD, PhD

Objectives. To assess whether the geometrical and hemodynamic reappraisal of the Ishimaru's Aortic Arch Map according to Aortic Arch Classification in Type I, II, and III, may provide valuable information regarding the suitability for thoracic endovascular aortic repair (TEVAR), and the risk of aortic dissection.

Methods. Anonymized thoracic computed tomography scans of healthy aortas were reviewed, and stratified according to the Aortic Arch Classification. Twenty patients of each Type of Arch were selected. Further processing allowed calculation of angulation and tortuosity of each proximal landing zones. Data were described indicating both proximal landing zone and Type of Arch (*e.g.* 0/I).

Also, among these 60 CT angiography scans, 15 were selected, 5 per Type of Arch, for further analysis. Computational fluid dynamics were performed to compute displacement forces, exerted by pulsatile blood flow on the aortic wall in the defined landing areas. Equivalent surface tractions were computed dividing the displacement forces magnitude of each proximal landing zone by the corresponding area. The three-dimensional orientation (x,y,z) of displacement forces was described as an upward (z direction), and a sideways component (x-y plane).

Results: Angulation was severe (>60°) in 2/III, and in 3/III. Comparisons between Types of Arch showed an increase in proximal landing zones angulation and tortuosity depending on the Type of Arch (*P*<.001 and *P*=.009). Comparisons within Types of Arch showed no change in angulation and tortuosity across proximal landing zones within Type I arch (*P*=.349 and *P*=.409), and increases in angulation and tortuosity towards more distal proximal landing zones within Type II (*P*=.003 and *P*=.043) and Type III (*P*<.001 in both).

The comparison between Types of Arch showed that Equivalent surface tractions in 3/III and in 3/II was two-fold greater than in 3/I (P<.01). Comparisons within Types of Arch showed no change in Equivalent surface tractions across proximal landing zones within Type I arch (P=.3), and Type II arch (P=.05), whereas Equivalent surface tractions increased towards more distal proximal landing zones within Type III (P<.02). Between adjacent areas, Equivalent surface tractions were greater in 3/III than in 2/III (P<.02), and in 3/II than in 2/II (P<.02). The greater changes in displacement forces magnitude in 3/II and 3/III were related to the upward component, that was four times greater in 3/II compared to 2/II (P<.01), and five times greater in 3/III compared to 2/III (P<.01). On the contrary, in Type I arch the upward component did not differ through PLZs (1-3).

Conclusions. The newly proposed Modified Aortic Landing Areas Nomenclature (MALAN), which merges Ishimaru's map with the Aortic Arch Classification in Type I to III, is associated with a consistent geometric and hemodynamic pattern of the Aortic Arch Map. Our results allow identifying specific landing areas with a hostile hemodynamic environment for stent-graft deployment that may increase the risk of endograft migration or endoleak. Our findings regarding displacement forces magnitude and orientation may have implications also in the development of proximal

entry tears in spontaneous Type A and Type B aortic dissections, and allow identifying landing areas at higher risk for post-TEVAR retrograde dissections.