In-situ observation and characterization of dissection mechanisms in rabbit aortas using synchrotron X-ray microtomography

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Aortic dissection is a life-threatening event associated with a high mortality rate. The dissection process being intramural and dynamic, direct observation is particularly challenging. Consequently, experimental studies in the literature remain far from in vivo conditions [1]. In the present study, the objective was to describe and quantify the micromechanisms involved in the propagation of a dissection by performing in situ tension-inflation tests with synchrotron X-ray tomography.

The descending aortas of 6 rabbits were harvested, sutured and an initial tear was manually created on the intimal side of the specimens. They were mounted in an X-ray compatible tension-inflation device, and pre-stretched. The arterial segments were pressurized while scans were taken every 100 mmHg until complete dissection occurred. The scan time was 240s and voxel size 3 µm³.

The individual medial lamellae were clearly visible on the images (Fig. 1 A). The observed dissection mechanism was the following: (i) the initial tear gradually propagated in the radial direction, slowly breaking individual medial lamellae, (ii) near the media-adventitia interface, the crack suddenly propagated in the longitudinal direction due to the weaker cohesion of this interface, (iii) delamination occurred in the antegrade and retrograde directions (Fig. 1 B) until pressure dropped due to complete failure. Critical pressures ranged from 291 to 902 mmHg. Significant correlations were found between the different morphological dimensions of the notch and the critical pressure. An elastic recoil of the flap between 5.3% and 12.3% was measured on the X-ray images.

This is the first study reporting direct observations of the 3D morphology of the aorta at different stages of the dissection process. This original data could help developing and validating numerical models of aortic dissection [2].

Fig. 1: Segmented X-ray volume of the initial tear, highlighting a few broken medial lamellae (A) and 3D configuration after dissection, before complete failure of the specimen (B).

References