Experimental Study of the Dissection Properties of Porcine Aorta

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Abstract

Aortic dissection can be a fatal disease and its biomechanics is still unclear. A full study of the dissection of healthy porcine aortas was carried out via two different experimental tests. The study includes the dissection of all layers through different locations of the aorta.

Introduction

Arterial dissection is a tear in the layers of a vessel wall. It can be provoked by external trauma, in medical interventions, or even spontaneously. This tear, starting in the intimal layer, can propagate through the medial layer and create a false lumen. This could make the artery narrow or even close. If the dissection propagates to the adventitial layer and causes rupture, the result is most often fatal. Acute aortic dissection has a mortality of 90% in the absence of intervention [1].

Despite the relevant incidence and high mortality, the biomechanics of this pathology remains unclear. Some studies have performed dissection tests on the medial layer of different arteries [1, 2], others have studied the dissection behaviour of different layers in a specific location [3, 4]. So far, no study has reported a complete dissection study, including the behaviour through different locations of the vessel and dissection between all layers.

In this study, we perform a full dissection study in a porcine aorta. The dissection of the two interfaces (intima-media and media-adventitia), as well as the medial layer, all through different zones of the aorta, i.e., the ascending, descending thoracic and abdominal aorta, is studied via two different dissection tests.

Materials and methods

Obtention of samples

In the present study, a total of 7 healthy porcine aortas were harvested. All vessels included the three zones of study: the ascending aorta, the descending thoracic aorta and the abdominal aorta, except for 2 arteries, in which the portion of the abdominal aorta was missing. The arteries were kept frozen at -80ºC and brought to 4ºC 24 hours before testing.

Experimental procedure

The specimens were cut in a dimension of 20 x 5 mm aproximmately, in both the longitudinal and circumferential directions. An initial incision was performed in order to assure that the separation ocurrs between the layers of interest.

In these specimens, two different dissection tests were carried out: a peel test, which reproduces a mode I of fracture, and a mixed test, involving a mixed mode of fracture that includes modes I and II, see Fig. 1.

In both tests, the tongues of the specimens are fixed by two clamps. In the peel test, both clamps move at a speed of 1 mm/min, whereas in the mixed test, only one clamp moves at that speed while the other is fixed.

The force-displacement curves are recorded and subsequently processed. The values of force are divided by the width of the specimen to avoid the effect of differences in this dimension.

Results

The dissection of samples in the longitudinal and circumferential directions required similar force in the ascending aorta, while the specimens oriented longitudinally were harder to dissect in the remaining parts of the vessel, see Fig. 2a. This result can be explained by the more isotropic layout of the fibers in the ascending aorta, resulting in smaller differences of behaviour among directions. Regarding the descending and abdominal aorta, the samples oriented longitudinally were harder to dissect as collagen fibers are mostly oriented circumferentially, and the tear would need to rupture this fibered structure.

In general, the dissection of specific layers, that is, the intima-media or the media-adventitia, required less force tan the dissection of the medial layer, see Fig. 2b. This is because the separation of the medial layer requires the rupture of its internal lamellar layers of collagen and elastin.

These results suggest that the aorta has an anisotropic behaviour in terms of dissection properties. Therefore, these properties should be characterised in terms of location and layer of the vessel. With these results, a finite element model could be designed to obtain the damage and cohesive properties of the aorta.

Conclusions

A complete study of the dissection of the aorta was carried out. This study highlighted the anisotropy of the aortic artery and the need to characterise the dissection properties as function of the location.

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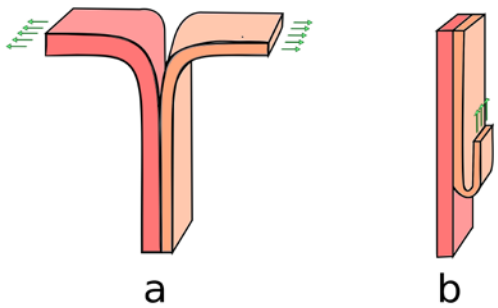

Figure 1: Representation of the two experimental tests carried out. a) Peel test. The two tongues of the specimen are pulled apart at a speed of 1 mm/min. b) Mixed test. One side of the specimen is fixed and the other side is pulled in the longitudinal direction at a speed of 1 mm/min.

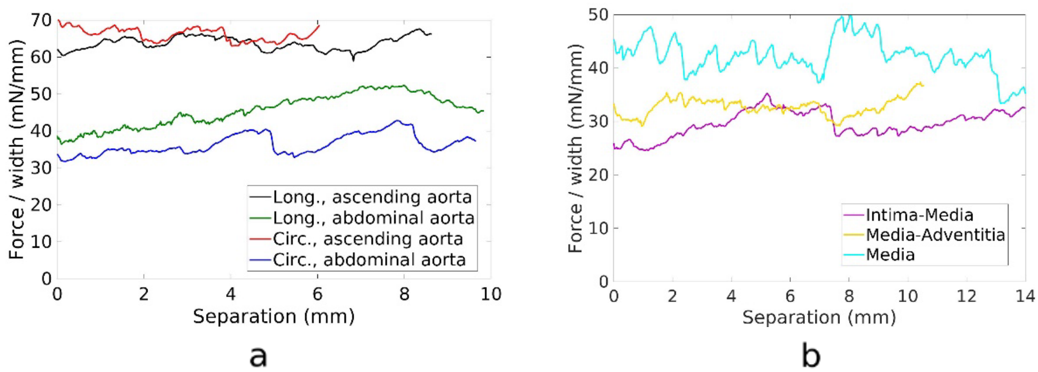

Figure 2: Mean force/width curves of the peel test. a) Dissection of the medial layer in the ascending and abdominal aorta, in circumferential and longitudinal directions. b) Dissection of the 3 interfaces in the descending aorta in the longitudinal direction.