Effect of smooth muscle activation in the static and dynamic mechanical characterization of human aortas

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The rupture of aortic aneurysms causes around 10,000 deaths each year in the USA. Prosthetic tubes for aortic repair present a large mismatch of mechanical properties with the natural aorta, which has negative consequences for perfusion. This motivates research into the mechanical characterization of human aortas to develop a new generation of mechanically compatible aortic grafts.
Experimental data and a suitable material model for human aortas with smooth muscle activation are not available in the literature despite the need for developing advanced grafts; the present study closes this gap. Mechanical characterization of human descending thoracic aortas was performed with and without vascular smooth muscle (VSM) activation. Specimens were taken from 13 heart-beating donors. The aortic segments were cooled in Belzer UW solution during transport and tested within a few hours after explantation. VSM activation was achieved through the use of potassium depolarization and noradrenaline as vasoactive agents. In addition to isometric activation experiments, the quasi-static passive and active stress-strain curves were obtained for circumferential and longitudinal strips of the aortic material. This characterization made it possible to create an original mechanical model of the active aortic material that accurately fits the experimental data. The dynamic mechanical characterization was executed using cyclic strain at different frequencies of physiological interest. An initial pre-stretch, which corresponded to the physiological conditions, was applied before cyclic loading. Dynamic tests made it possible to identify the differences in the viscoelastic behavior of the passive and active tissue. This work illustrates the importance of VSM activation for the static and dynamic mechanical response of human aortas. Most importantly, this study provides material data and a material model for the development of a future generation of active aortic grafts that mimic natural behavior and help regulate blood pressure. The regulation of the vascular tone (i.e. the level of VSM contraction) also plays a key role in hypertension and its treatment. Therefore, the relationship between VSM activation and arterial mechanical properties is also relevant to address hypertension.