MCB, vol.16, supplemental 1, pp.19-21, 2019

Finite Element Analysis for Type B Aortic Dissection Treated with Two Types of Stent Grafts

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1 Background

Retrograde type A dissection (RTAD) and stent graft-induced new entry (SINE) is one of the most common post-TEVAR complications, and is defined as a new tear caused by the stent-graft itself [Dong, Fu, Wang et al. (2009)]. Presumably, the mechanical action and potential damage of stent-graft to the aorta is related to the stent-graft and the anchoring position, mainly from two aspects: (1) the metal skeleton functions to fix the whole support to the wall of the aorta because it is self-inflating and strong in radial force; (2) after implantation, the stent-graft is bent into the arch like a bent spring, with a tendency to be straight. This may result in elastic recoil force to the aortic wall. This study investigated the occurring reasons of new lesions from the biomechanical and mechanobiological view when stent-grafts were implanted into the true lumen to treat an aortic dissection.

2 Methods

Based on the CTA images, a three-dimensional geometric model of a patient-specific aortic dissection was established through image segmentation and reconstruction. The artery wall of aortic dissection model was assumed as an isotropic, linear-elastic material with Young's modulus of 5.0MPa, Poisson's ratio of 0.35, and its thickness was assumed uniform 1.0mm. The stent grafting rings with different geometric parameters were designed in CAD software. The stent was modeled as isotropic, homogeneous and incompressible; the hyper-elastic constitutive model in ABAQUS 6.14 was selected for the metal wires and the linear elastic constitutive was set for the membrane material with the thickness of 0.08 mm, Young's modulus of 1840 MPa, and Poisson's ratio of 0.35 [Di Martino, Guadagni, Fumero et al. (2001)]. The two types of stent-grafts: cTag and Valiant were implanted virtually into the true lumen of the model to treat the aortic dissection with finite element method by using ABAQUS 6.14 software. Eight-node linear brick was used to mesh the stent in Hypermesh13.0, and the graft as membrane was meshed into tetrahedral element. The compression and flexion of stent-grafts were achieved with a cylinder. The cylinder was defined as rigid surface, and was meshed into

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four node reduction integral elements in the surface cell.

3 Results

The device-related forces on the aortic wall were evaluated and quantified with von Mises stress to indicate possible aortic wall injury. After eight seconds in all simulations, the deployed stent-graft reached the stable status. The maximum von Mises stress of the aorta was located where the bare stent or the small nickel-titanium alloy ring interacted with aortic wall, and the maximum values for cTag and Valiant are 0.393 and 0.505 respectively.

4 Conclusion

When a stent graft is implanted to treat Stanford type B aortic dissection, its bare stent and thinner nickel-titanium alloy ring generate the higher stress at the aorta wall, and the radial force plays a more dominant role than the elastic recoil support. The long-term higher von Mises stress in the aortic wall may lead to the emergence of new lesions in these areas [Lombardi, Cambria, Nienaber et al. (2014)], therefore Valiant has more risk than cTag to induce new lesions.

Acknowledgement: Supported by the Natural Science Foundation of China (No. 81571128, No. 81770474, No. 81770508), and International Cooperation Program sponsored by the Science and Technology Committee of Shanghai Municipality (No. 16410722900).

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