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Fluid-structure interaction based study on the physiological factors affecting the behaviors of stented and non-stented thoracic aortic aneurysms

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ABSTRACT

Endovascular aneurysm repair (EVAR) is considered as a promising alternative technique for the treatment of aortic aneurysm. However, complications often occur after EVAR. In this paper, the influence of the physiological factors on the biomechanical behaviors of stented and non-stented thoracic aortic aneurysm (TAA) were presented. Representative TAA models with different intraluminal thrombus (ILT) volume before and after stent-graft (SG) implantation were built. Fluid-structure interaction effect was taken into account. The relative sliding between the SG wall and the aortic wall was allowed. Results showed that the cardiac cycle and ILT volume should be given much more consideration than previously thought in future investigations on TAA compliance. The time-averaged longitudinal displacement of SG necks were not uniformly distributed along circumferential direction of the aortic wall. Drag force increased with the increase of the cardiac cycle and lumen pressure indicated that patient with faster heart rate might be at great risk of aneurysm rupture. The stress absorption effect of the SG was influenced by both ILT and cardiac cycle, which was also found to have strong impact on flow pattern. We believe that this study will bring new insights into further researches on the relevant issues and provide mechanics-based implications for clinical management of EVAR for TAA patient.

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1. Introduction

Thoracic aortic aneurysm (TAA) is a localized irreversible dilation of the thoracic aorta. If left untreated, the aneurysm will continue to expand, and may eventually rupture or dissect (Rizzo et al., 1998). It has been reported that more than 15,000 people in the US die every year due to rupture or dissection of TAA or abdominal aortic aneurysm (AAA) (Elefteriades, 2005). The characteristics of these two aneurysms are very similar. For example, both TAA and AAA can be caused by the same factors including Marfan's Syndrome, Ehlers Danlos Syndrome and hypertension (Kahn and Konstadt, 2002; Ooijen, 1988; Yoshino et al., 2006; Wong et al., 2007). Most TAA and AAA patients are elderly. The geometrical shape of TAA and AAA is usually fusiform or saccular. According to clinical investigation (Rizzo et al., 1998; Brady et al., 2004), both types of aneurysms tend to grow over the year. Takayama et al. (2003) report that a former AAA patient suddenly developed a TAA two weeks after graft replacement of the abdominal aorta. 20-25% of patients with a TAA also have an aneurysm in the abdominal aorta (Crawford and Cohen, 1982;

DeBakey et al., 1978). Also, Juvonen et al. (1997) suggest that the presence of large size AAA is one of the risk factors for TAA rupture. We can see that the problems associated with AAA could also occur at TAA. Thus, the research focuses of AAA including treatment approaches, complication preventions, pre-operative and post-operative behavior analysis should also be considered as the suitable subjects of TAA investigations, since there are very limited number of previous publications concerning these problems of TAAs.

Endovascular aneurysm repair (EVAR) is considered as a promising alternative technique with minimal invasion. The objective of SG implantation is to shield the aneurismal wall from the impact of pulsatile blood pressure, and eliminate blood circulation in the aneurysm cavity. However, many TAA and AAA patients treated by EVAR suffer from various kinds of complications (Mita et al., 2000; Aljabri et al., 2001). Statistics from UNC Vascular Registry and Washington University Vascular Surgery Database show that the migration rate during 40 months after EVAR is about 16.7% (Li, 2005).

In order to investigate factors affecting SG migration, longitudinal traction force acting on the bifurcated SG is defined by Liffman et al. (2001). The term "drag force" is first proposed by Morris et al. (2004). Succeeding researchers such as Li and Kleinstreuer (2006a,b,c) and Howell et al. (2007) have investigated

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