Air bubble release and flow-induced forces in stent grafts

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Background:

Stent grafts are used to treat aortic aneurysms, as a minimal invasive alternative to open surgery. The aorta is accessed via percutaneous punctures in the groins and insertion of guide wires. A stent graft is advanced over the guide wire and deployed in the desired position, using x-ray fluoroscopic guidance. The procedure significantly reduces short-term morbidity and mortality compared to open repair, but has a higher rate of late complications and re-interventions. Two possible complications are: release of air bubbles during thoracic stent graft deployment may lead to cerebral embolization and immediate stroke, and long-term migration due to flow-induced forces may lead to leakage into the aneurysm sack and remaining risk of aortic rupture.

Objectives:

Stent grafts are compressed in a long, soft and thin delivery catheter. Once the stent graft is in position, the surgeon withdraws the catheter, allowing the self-expanding stent graft to expand radially to the artery wall, or to a previously inserted stent graft. The stent graft is kept in place by the expansion force of the over-sized stent, and in some cases by anchoring hooks. Despite a strict preparation procedure, there is a risk that air is trapped in the compressed stent graft and released into the aorta during deployment. The present work describes two of our studies. In the first experimental study we measure the total amount of air released by two different brands of thoracic stent grafts and investigate the size and origin of the air bubbles. In the second experimental and numerical study angulated iliac limbs stent grafts are mounted in a pulsatile flow model to determine the flow-induced displacement forces under a variety of conditions.

Methods:

The air release measurements and visualizations are performed by inserting and deploying stent grafts in a closed water-filled container. A high-resolution and high-speed camera is used to capture the air release process, and the total amount of air collected in the container is measured. An experimental pulsatile flow model, with conditions similar to aortic in vivo conditions, is used to measure the proximal and distal displacement forces of iliac stent grafts under different angulations, pulsation frequencies, pressures, and configurations (tapered, tubular, bellbottom). Fluid-structure interaction simulations are used to determine the forces numerically.

Results:

We found that air is released during deployment of thoracic stent grafts and that the largest bubbles come from the proximal end. There is a significant difference between the two brands of stent grafts that have been investigated. The flow-induced forces are under some conditions comparable to the forces required to extract the iliac limb stent grafts. Both the forces and the graft movements increase with angulation and with perfusion pressure, but not with stroke rate. The distal displacement forces are particularly large for the bellbottom configuration. The origin of the forces is mainly the pressure, while the contributions of shear force and flow redirection are insignificant. The flexibility of the stent graft material reduces the forces (by 15% under the conditions in the numerical simulations in the present work).

Conclusions:

New packing and/or preparation procedures should be developed to reduce the amount of air released during deployment of thoracic stent grafts. Improved anchoring of the distal ends of stent grafts should be considered.

References

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