Displacement Forces in Iliac Landing Zones and Stent Graft Interconnections in Endovascular Aortic Repair: An Experimental Study

H. Roos [a,*], M. Ghaffari [a], M. Falkenberg [b], V. Chernoray [c], A. Jeppsson [a,d], H. Nilsson [c]

[a] Department of Cardiovascular Surgery, Sahlgrenska University Hospital, Gothenburg, Sweden
[b] Department of Radiology, Sahlgrenska University Hospital, Gothenburg, Sweden
[c] Department of Department of Applied Mechanics, Chalmers University of Technology, Gothenburg, Sweden
[d] Department of Molecular and Clinical Medicine, Institute of Medicine, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

WHAT THIS PAPER ADDS

The proximal fixation of a stent graft has been improved but the distal fixation and interconnections depend on self-expansion forces only. This experimental study demonstrates that pulsatile flow through a tubular untapered stent graft causes displacement forces of similar magnitude at both ends of the stent graft and induces graft movements. Peak forces are close to those previously reported to be required to extract a stent graft. The forces and movements increase with increased graft angulation and perfusion pressure but not with stroke rate. Improved anchoring of the distal end of stent grafts may be considered.

Objectives: Stent graft migration influences the long-term durability of endovascular aortic repair. Flow-induced displacement forces acting on the attachment zones may contribute to migration. Proximal fixation of aortic stent grafts has been improved by using hooks, while distal fixation and stent graft interconnections depend on self-expansion forces only. We hypothesized that flow-induced displacement forces would be significant at the distal end, and would correlate with graft movements.

Methods: As part of an experimental study, an iliac limb stent graft was inserted in a pulsatile flow model similar to aortic in vivo conditions, and fixed—mounted at its proximal and distal ends to strain gauge load cells. Peak displacement forces at both ends and pulsatile graft movement were recorded at different graft angulations (0—90°), perfusion pressures (145/80, 170/90, or 195/100 mmHg), and stroke frequencies (60—100 b.p.m.).

Results: Flow-induced forces were of the same magnitude at the proximal and distal end of the stent graft (peak 1.8 N). Both the forces and graft movement increased with angulation and perfusion pressure, but not with stroke rate. Graft movement reached a maximum of 0.29 ± 0.01 mm per stroke despite fixed ends. There were strong correlations between proximal and distal displacement forces ($r = 0.97$, $p < .001$), and between displacement forces and graft movement ($r = 0.98$, $p < .001$).

Conclusions: Pulsatile flow through a tubular untapered stent graft causes forces of similar magnitude at both ends and induces pulsatile graft movements in its unsupported mid-section. Peak forces are close to those previously reported to be required to extract a stent graft. The forces and movements increase with increasing graft angulation and perfusion pressure. Improved anchoring of the distal end of stent grafts may be considered.

Article history: Received 6 August 2013, Accepted 29 November 2013, Available online 18 January 2014

Keywords: Stent graft, EVAR, Blood flow, Displacement force, Aortic aneurysm, Angulation

INTRODUCTION

Endovascular aortic repair (EVAR) significantly reduces short-term morbidity and mortality in the treatment of abdominal aortic aneurysms compared with open repair, but it has a higher rate of late complications and reinterventions.[1,2] Two serious complications are stent graft migration and type I and III endoleaks. Both migration and endoleaks are closely associated with the anchoring of the stent graft. Modern stent graft designs effectively prevent distal migration of the proximal end by using hooks or barbs[3] while distal fixation and stent graft interconnections still depend on stent expansion only. Studies have shown that the force needed to extract a stent graft anchored solely by the self-expanding force of the stent is in the 2—4 N range.[3—6]

Flow through a tubular construction induces a force on the tube wall. In the case of an angulated stent graft, the force is mainly due to perfusion pressure, while the shear force contributes only 1—3%.[7—10] The force is transferred through the tube structure to the upstream (proximal) and downstream (distal) tube attachments and may also cause

* Corresponding author. H. Roos, Department of Vascular Surgery, Sahlgrenska University Hospital, SE-413 45 Gothenburg, Sweden.
E-mail address: hakan.roos@vgregion.se (H. Roos).
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http://dx.doi.org/10.1016/j.ejvs.2013.11.015

movements of the flexible graft. Computational studies have estimated the magnitude of these forces,[7—9,11] but none of the previous studies have directly measured flow-induced displacement forces acting on an endovascular stent graft and their relation to graft configuration and the movements of the graft.

We hypothesized that the displacement forces induced by pulsatile flow are substantial in both the proximal and distal attachment of an iliac limb stent graft, and that these forces could induce pulsatile movement of the graft. To test the hypothesis, a pulsatile flow model was constructed. A stent graft was inserted in the model and forces and graft movement were quantified at different clinically relevant stent graft angulations, perfusion pressures, and stroke frequencies.

MATERIALS AND METHODS

Aortic perfusion model

A pulsatile flow model was constructed to mimic in vivo aortic pressures[12] and to establish a flow that was in the range of expected physiological flow through an iliac limb stent graft. The model is shown in Fig. 1. To resemble aortic perfusion, water at room temperature was perfused in a circuit consisting of a roller pump (HL-10; Gambro, Lund, Sweden) and ½″ silicone tubing (Sorin Group, Milan, Italy). Peripheral resistance was achieved with water-/air-filled container in combination with pinch valves. By adjusting the pinch valves and water level in the containers, the fluid pressure could be altered with high accuracy. To minimize disturbances in the pulse curve, an additional water-/air-

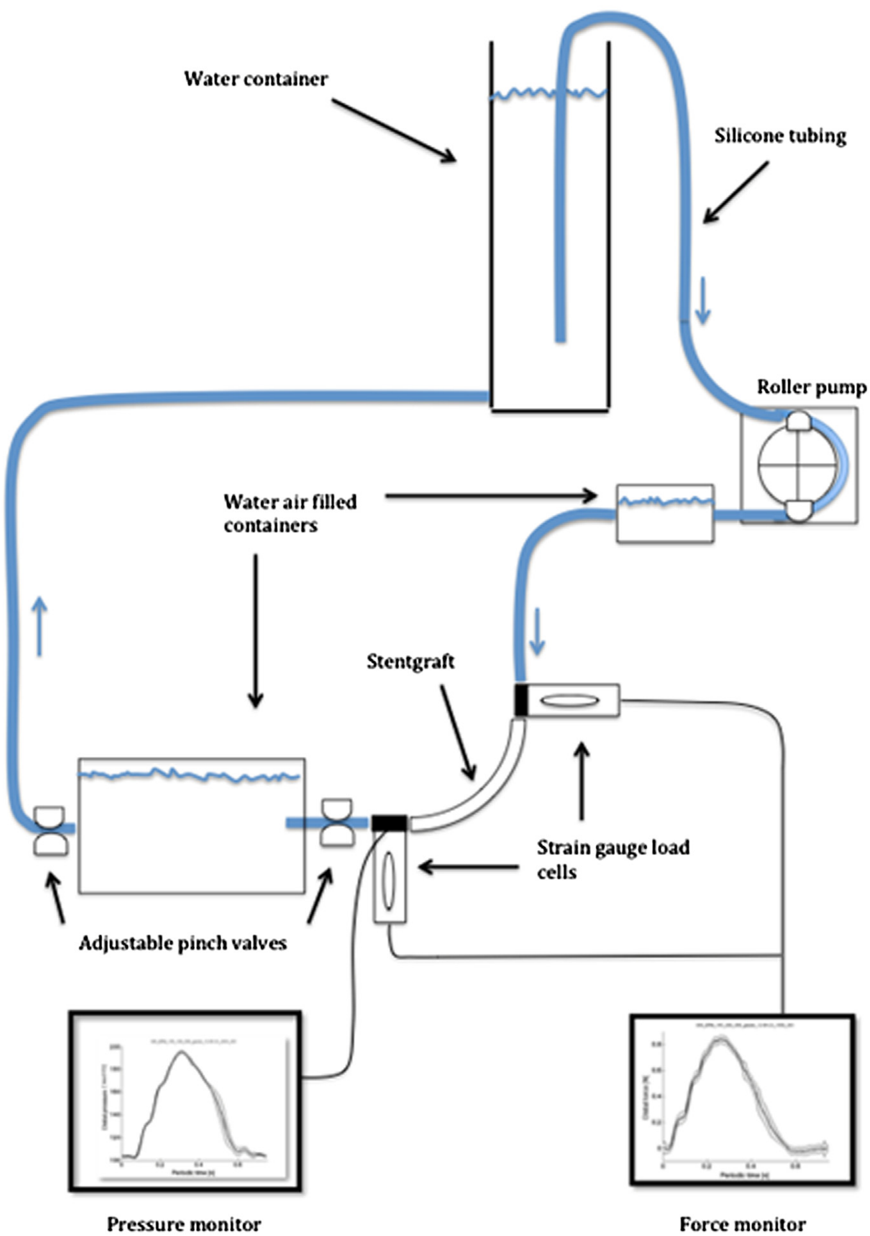

Figure 1. Perfusion model.