STENT-GRAFTS DERIVED FROM AUXETIC UNIT CELLS: NUMERICAL SIMULATION OF DEPLOYMENT INTO A CURVED ARTERY

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Introduction

In tortuous aneurysms associated with abdominal aortic and iliac aneurysms, Endovascular aneurysm repair (EVAR) has faced severe complications which has been linked with diminished SG flexibility [1,2]. Stent design has been recorded to greatly influence SG mechanical behavior (flexibility and durability) [3,4]. Our team has investigated the potential of auxetic stents for EVAR applications [5] and the mechanical behavior of SG with novel stents derived from auxetic unit cells [6] when subjected to 180° angulation using finite element (FE) simulations respectively. In this work, we intend to expand on [6] by numerically simulating the deployment of novel SGs derived from auxetic unit cells in an idealized curved iliac aneurysm [7] using FE simulations and examine their in-vivo mechanical behavior in interaction with tortuous vessels.

Methods

Successful novel SG iliac limb candidates from our most recent work [6] CRE-DIA (chiral re-entrant - diamond) and CS-DIA (chiral star - diamond) that contain a combination of auxetic and positive Poisson s' ratio unit cells respectively are represented as FE models with Timoshenko beam elements B31 elements and 4-node quadrilateral S4 shell elements for the Nitinol based stent and PET graft respectively on Abaqus as depicted in figure 1 with similar stent diameter and graft length. The clinically relevant iliac aneurysm geometry and modelling of vessel wall properties can be found in previous study [7], where a frictional coefficient of 0.2 was utilized to model friction between SG and arterial vessel wall on Abaqus.

Figure 1: CS-DIA (left) & CRE-DIA (right) SGs

We followed a deployment methodology from a prior work [7] to insert the SG longitudinally into the idealized iliac aneurysm using an Abaqus explicit solver. To qualitatively evaluate the deployment of the novel SG candidates, we check for any visible kinks or arterial wall apposition defects and quantitatively, we examine the maximal reduction of SG cross-sectional area ($CSAR_{MAX}$) and distance between stents and arterial wall (DSA) [7].

Results

In Figure 2, both CRE-DIA & CS-DIA SGs display no severe kinks when subjected to 180° bending and pressurization [6], which is an encouraging sign considering that commercial Z-stented SGs when deployed in curved arteries, displayed kinks & reductions in luminal cross-section analogous to its bending behaviour when subjected to 180° angulation [7]. On basis of preliminary results, CRE-DIA SG & CS-DIA SG demonstrate reduced $CSAR_{MAX}$ and DSA values in comparison to the respective $CSAR_{MAX}$ and DSA values of Z-stented SGs reported in [7]. However, the presence of a minor gap between the distal stents and vessel wall at the inner curvature of aneurysm is noted for both novel SGs similar to results reported for Z-stented SGs in a previous work [7].

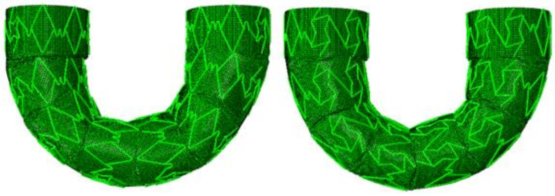

Figure 2: Deformed state of CS-DIA (left) & CRE-DIA (right) SGs after 180 degree bending and intraluminal pressurization [6].

Discussion

Perrin et al., [7] had demonstrated that all Z-stented commercial SGs faced kinks and reduced juxtaposition onto the inner vessel curvature of prior mentioned curved iliac aneurysm post-deployment. CRE-DIA & CS-DIA SGs show promising results in comparison to Z-stented SG, but further optimization of stent-design will be conducted on these candidates to improve their mechanical performance.

References

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