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A computational framework to model the lifecycle of a breakthrough neurovascular implant: crimping into catheter and deployment mechanisms

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I. Introduction

Percutaneous treatment of cerebral aneurysms (CAs) has recently gained the attention of researchers and practitioners. The advent of the eCLIPs implant (product of Evasc Neurovascular Enterprises, Vancouver, Canada) has revolutionized the percutaneous treatment of CAs by offering innovative solutions to the challenges pertinent to other neurovascular devices, i.e. excessive vessel injury caused by device and artery interaction and blocking the daughter vessels in bifurcation cases [1]–[3]. However, in a subset of bifurcation CAs with fusiform pathology, eCLIPs fails to provide sufficient neck bridging, where a gap exists between the device structure and the aneurysm/artery wall upon device deployment. We have developed a new design for the eCLIPs (VR-e) by making the length of device ribs variable to cover such an inflow gap [2]. In this study, we have developed a new finite element model to evaluate the device behavior during crimping into a catheter and its expansion at the aneurysm neck, which is not possible by testing a new device for the endovascular application experimentally

II. Method

Contrary to conventional tubular shape FD stents, which are radially crimped into a sheath, eCLIPs is crimped by axially pulling the device into a sheath. Therefore, the new numerical model needs to mimic the actual crimping process of the eCLIPs and VR-e devices. As a self-expanding device, i.e. made of Nitinol, eCLIPs is deployed at the neck by retracting the catheter from the device.

Contrary to tubular-shape stents, the eCLIPs' ribs are free to move at the tip area, which causes some degree of structural oscillation at the end of the expansion process in the FE model. We have developed a new numerical model to simulate a smooth device recoiling by modeling the expansion process in multiple steps. In this model, the device expands into a tube, by pulling back the catheter with its axial displacement. In a subsequent step, the device is fully expanded to its original shape and deployed at the aneurysm neck by radially expanding the tube to the daughter vessel diameter.

III. Results

As described earlier, the ribs of the VR-e are longer than eCLIPs. Subsequently, it is expected that the crimper lumen area be more occupied by the deformed ribs of the VR-e implant compared with eCLIPs, as noted in Figure 1 a.

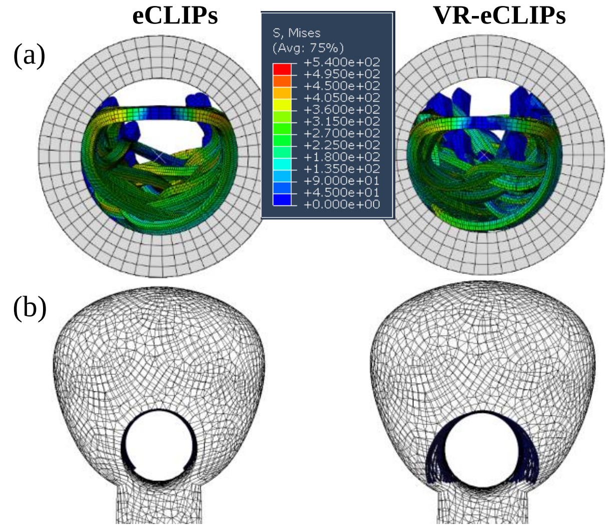

Figure 1. The defamed structure with von-Mises stress distribution for crimped eCLIPs and VR-e implants (a), the front view of fully expanded devices at the aneurysm neck (b)

The Von Mises (VM) stress distribution indicates a high concentration stress area at the convex part of ribs' root, where they are attached to the spine, with the maximum tensile stress lower than the plastic deformation stress (540 MPa for Nitinol in this study). Therefore, neither of devices experience plastic deformation during the crimping process. The VR-e device fully expanded and covered the inflow gap when deployed at the neck, as noted in Figure 1 b.

References

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