How does thrombus composition influence the thrombectomy outcome? An in silico study

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Abstract:
Endovascular thrombectomy (EVT) aims at restoring blood flow in case of acute ischemic stroke by removing the thrombus occluding a large cerebral artery. During the procedure with stent-retriever, the thrombus is captured within the device, which is then retrieved, subjecting the thrombus to several forces, potentially leading to its fragmentation. Histological analysis on retrieved thrombi allowed to associate the thrombus composition (in terms of RBCs and fibrin content) to the outcome of the procedure: fibrin-rich thrombi are more difficult to retrieve, while RBC-rich thrombi are more prone to fragmentation. Moreover, in silico studies, along with mechanical characterisation of thrombi, can enhance our understanding of the EVT, helping the development of new devices and interventional strategies. Our group previously validated a numerical approach to study EVT able to account for thrombus fragmentation in the commercial software LS-DYNA.

In this study, the same methodology was employed to explore the applicability of the chosen failure criterion to EVT simulations and the impact of thrombus composition on the outcome of the in silico procedure. For the first time, human clot analogues experimental data were applied to this methodology. Clot analogues of three different compositions (0% RBCs, 1% RBCs, and 40% RBCs) were tested, and a material model incorporating failure was calibrated, followed by a verification analysis. Finally, the calibrated material model was used to perform EVT simulations, combining the three tested thrombus compositions with three different stent retriever models.

The experimental tests confirmed a compression-tension asymmetry in the stress-strain curves, showing decreasing stiffness with increasing the red blood cell (RBC) content. Applying the resulting material models to EVT simulations demonstrated: (i) the dependency of the failure criterion on the thrombus mesh size, (ii) a greater tendency for RBC-rich thrombi to fragment, and (iii) increased difficulty in retrieving RBC-poor thrombi compared to RBC-rich thrombi.