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The effect of suction pressure on suction force for remote aspiration thrombectomy – a CFD study

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Background: Acute ischemic stroke is the most common type observed in the clinic. Several techniques were developed for contact aspiration thrombectomy, but there is a paucity of data for situations where the tip of the catheter does not engage the clot. The aim of our computational study was to understand the clot suction force for remote aspiration using models with zero, one or two side branches, over a range of applied suction pressures.

Methods: Geometry: An idealized vascular model with length 550 mm and inner diameter 4 mm was used. The model had two side branches (SB) of 1.5 mm inner diameter, each of which can be either open or closed to create different aspiration environments (Fig. 1). The model included a catheter (2 mm outer diameter, 1.78 mm inner diameter) positioned 39 mm proximal to the clot. Boundary conditions: When a SB was open, a pressure of 16 kPa was applied. When a SB was closed, wall boundary conditions were used. The suction pressure applied at the proximal end of the catheter was varied from -20 to -100 kPa. Solver: Steady-state flow was simulated using a $k-\epsilon$ turbulence model with CFX (ANSYS 18.2). Cases: three cases were simulated: 1) both SBs open; 2) proximal SB closed, distal SB open; 3) both SBs closed. Simulation results yielded the pressure on the clot proximal cross-section (P_p), and the pressure on the clot distal cross-section (P_d) was set to 16 kPa. The suction force on the clot was then calculated as $F = F_d - F_p = P_d A_d - P_p A_p$, where A_p and A_d were the clot proximal and distal cross-sectional areas.

Results: When varying the suction pressure for the 3 cases, the ranges of resulting suction forces were as follows: Case 1: -0.18 N to -0.109 N; Case 2: -0.161 N to 0.064 N; and Case 3: 0.009 N to 1.245 N (Fig. 1).

Conclusions: The SB status (open/closed) significantly influenced the suction force. When both SBs were open, the suction force was negative and aspiration was not possible. When the distal SB was open and the proximal SB was closed, the suction force increased, becoming positive when the suction pressure ranged from -80 kPa to -100 kPa. The suction force was largest for all suction pressures when both SBs were closed. These results indicate that if the side branches are closed, the suction force applied to the clot can be greatly increased. If implemented clinically through the use of balloons, such a solution could lead to better aspiration thrombectomy results and help decrease the intervention time.

Figure 1:

