

Investigation of the Effectiveness of Aspiration Technique in Simplified Artery with Clot Using Artificial Neural

Arda ATAÇ¹, Ezgi IŞIK¹

¹Yeditepe University, Faculty of Engineering, Department of Mechanical Engineering, Kayisdagi Cad., 34755, Istanbul, Turkey

Corresponding author's e-mail address:
ardaatac1@gmail.com

Burak KALAYOĞLU^{1,3}, Ali Bahadır OLCAY^{1,2}

²Padnos College of Engineering, Grand Valley State University, Grand Rapids, MI 49504, USA

³Daimon Mühendislik Müşavirlik A.Ş., Yücetepe Mahallesi İlk Sokak No:28/2 Çankaya/Ankara

Abstract—In this study, the application of aspiration thrombectomy, which is the treatment for strokes occurring in the cerebral vessel, is simulated. As the study progressed, there was a gradual evolution from a simplified vessel geometry to a more realistic vessel geometry. The simulations are performed using Ansys Fluent at each stage. The thrombectomy application is simulated by adjusting specific parameters. Parameters such as vessel diameter, vessel length, intravascular blood flow rate, catheter vacuum pressure, and the viscosity of blood clots are varied. The aim is to determine how these changed parameters affected the thrombectomy application. Blood fluid physiology, mechanics, and parameters are observed during thrombectomy application in ANSYS Fluent. The effects of each parameter on thrombectomy application are calculated using MATLAB's Neural Network Tool and presented in this study. As a result, when all simulations were fitted to the Artificial Neural Network, it was observed that the changing parameters had, from largest to smallest, an effect on thrombectomy performance: vessel diameter, viscosity, vacuum pressure, blood velocity, and vessel length. When the Area Weighted Average (AWA) values of clot taken during thrombectomy were examined according to flow time, the parameters increased at zero point zero one five seconds of the simulations, respectively, for increasing vessel diameter (sixty-six point fifteen percent to ten point forty-three percent), viscosity (thirty point ninety-four percent to ten point twenty-five percent), and vacuum pressure (eleven point forty percent to twenty-three point twenty-five percent). The reason for the inverse ratio in vacuum pressure is that the percentage of clot AWA decreases as pressure increases. For increasing blood velocity (seventy-three-point forty-five percent to sixty-six-point fifteen percent) and for vessel length (thirty-one-point seventeen percent to twenty-seven-point fifteen percent).

Keywords: thrombectomy, stroke, aspiration catheter, vacuum pressure, computational fluid dynamics (CFD), artificial neural network (ANN), middle cerebral artery (MCA).

I. INTRODUCTION

Thrombosis occurs when blood clots within a vein and adheres to the inner surface of the vessel. If this clot detaches and travels through the bloodstream to another tissue or organ, causing a blockage, it is referred to as an embolism. This blockage can impede blood flow by partially or entirely closing

the vessel. When a cerebral vessel is obstructed, it can lead to severe consequences such as vision loss, paralysis, memory loss, or even death. Embolism is more common among middle-aged and elderly individuals due to an increased propensity for blood clotting with age.

Thrombectomy is a clinical procedure that removes blood clots from blood vessels, primarily performed to treat thrombosis. A thrombectomy is a critical medical procedure that removes the blood clot that obstructs the vessel and restores normal blood flow. This procedure requires meticulous care and precision. Various suction systems are available for performing thrombectomy. In this study, the application of thrombectomy is examined under various scenarios with different boundary conditions in each simulation. The goal is to determine the impact of these changing boundary conditions on the effectiveness of thrombectomy.

Simulations are conducted using Ansys Fluent, with parameters such as catheter vacuum pressure, blood vessel length, vessel diameter, blood viscosity, and blood flow rate being altered. The effects of these varying conditions are subsequently analyzed using MATLAB's Neural Network Tool to assess their influence on thrombectomy application.

II. METHODOLOGY

In the first of the three successive stages, vessel geometry is simplified, with the catheter covering the entire vessel. The vessel diameter and length are set to 3 and 10 millimeters, respectively. Gravity was 9.81 meters per second squared. Blood and clot densities are taken as 1060 kilograms per cubic meter and 1300 kilograms per cubic meter, respectively. Blood viscosity is set to 0.0035 kilograms per meter times second, and clot viscosity is modelled as 0.035 kilograms per meter times seconds, which is ten times that of blood. Surface tension is 0.15 newton per meter. Intravascular pressure is set at 13 kilopascals, and vacuum pressures are taken as 30, 60, and 90 kilopascals in the present study.

In the second stage, a catheter is added to the simulation geometry, and the vessel geometry is modified. The catheter diameter and length are set to 1 millimeter and 2 millimeter respectively, and the vein length is increased to 20 mm. The

densities of blood and clot are assumed to be the same and are considered equal to 1060 kilograms per cubic meter. Clot viscosity is simulated at 1, 10, and 100 times that of blood. Vacuum pressure is kept at the same three values as in the first stage. Simulations are performed as multiphase flow in Ansys Fluent, with varying pressures at the vessel outlet and inlet.

In the third stage, further modifications are made to approach real-world applications as closely as possible. M1 segment modelling of the MCA is performed, with vessel lengths set to 13, 15, and 17 millimeters, and twice these lengths for developed intravascular flow.^[10] Vessel diameters are set to 3, 4, and 5 millimeters,^[11] with a tapering rate of 0.88 ± 0.15 .^[12] 5 French range was selected as the catheter from the French catheter scale, and its diameter is 1.667 millimeters. The surface density of blood is chosen as a constant value of 0.054 Newton per meter.^[13] The viscosity value of blood is taken as a constant value of 0.0055 kilograms per meter times seconds.^[14] The highest blood viscosity value is chosen to simulate the worst-case scenario. Clot viscosity is simulated at 100, 250, and 500 times that of blood. When catheter vacuum pressures are taken according to the suction systems used in literature, they are determined as 40 kilopascals, 60 kilopascals, and 80 kilopascals, negative gauge pressure values. Blood velocity is taken as 50 centimeters per second for male patients and 60 centimeters per second for female patients. The average intravascular pressure is accepted as 12.5 kilopascals. The length of the blood clot is the same for each simulation and is chosen as 8 millimeters. The vessel geometry of each stage described above is shown in Table 1.

TABLE I. SIMPLIFIED GEOMETRY OF EACH SIMULATED STAGE

Stages	Simplified Geometries
Stage 1	
Stage 2	
Stage 3	

If the patient has a clot, a susceptibility-vessel sign (SVS) can be visualized during magnetic resonance imaging (MRI) or magnetic resonance angiography (MRA) and can take different shapes. These are S-shape SVS, Y-shape SVS, and L-shape SVS.[6] The S-shape SVS is examined within the scope of this project. According to that, the clot is designed with a cell register and not a perfectly cylindrical shape, and there will be three different sizes of its geometry.

III. RESULTS

The effects of changing parameters and the accuracy of MATLAB NN-Tool have been clarified from nearly 1000 simulations run in Ansys Fluent. Of the 1000 simulations obtained, 15% were used for validation, 15% for test data, and the remaining 70% for training data. As seen in Graph 1, a high accuracy value of 98.395% was obtained in the test data after validation and training. Afterwards, as observed in Graph 2, the error approached zero, and the graph converged to zero error. As a result, MATLAB can make predictions with high accuracy.

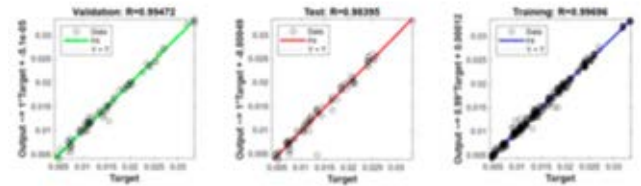


Fig. 1. Validation, test and training vs. target data

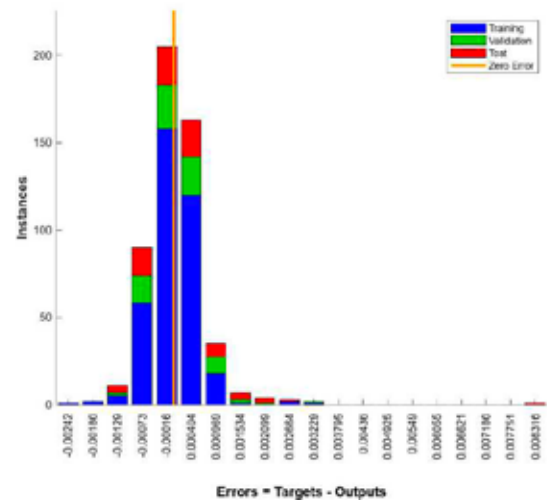


Fig. 2. Error histogram of neural network

When the data is simulated in ANSYS Fluent and used as input for the MATLAB Neural Network Tool (NN-Tool), the effect of each changing parameter is illustrated in Graph 3 below.

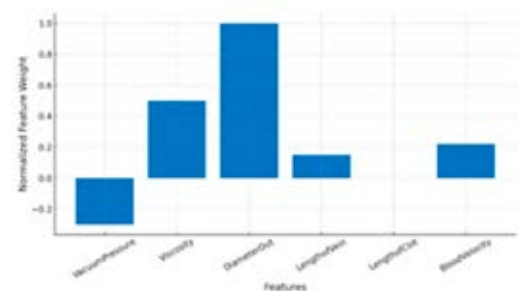


Fig. 3. Weight table of parameters affecting thrombectomy application

As seen in Graph 3, the viscosity of the clot, vessel exit diameter, vessel length, and intravascular blood flow rate are shown with positive values. Positive values indicate that as the values of these parameters increase, the time required to remove the clot from the vein also increases. These parameters are directly proportional to the time taken for clot removal. In contrast, catheter vacuum pressure represents a negative value, meaning that as the catheter vacuum pressure increases, the clot removal time decreases. Among all the parameters, ranked from most to least effective, they are vascular output diameter, clot viscosity, vacuum pressure, blood flow rate, and vascular length. Since the length of the clot, as shown in Graph 3, is consistent across all simulations, it has no impact and is therefore assigned a value of zero.

IV. LIMITATIONS AND FUTURE WORK

This study represents a preliminary computational exploration of aspiration thrombectomy performance and, as such, is based on several simplifying assumptions. The vascular geometries employed in the simulations were idealized, and blood properties were treated as uniform to reduce computational complexity and to isolate the effects of key parameters. While this approach provides essential baseline insights, it does not fully capture the heterogeneity of real vascular systems or the variability of blood rheology in patient populations. Similarly, the absence of patient-specific geometries limits the direct clinical translation of the present results. We acknowledge that validation against real clinical data is essential to confirm the applicability of the simulation outcomes. The integration of patient-specific vascular models and experimental or clinical datasets will be pursued in future work to strengthen model reliability. Additionally, while our artificial neural network provided a relative influence of the studied parameters, a structured sensitivity analysis would further clarify the robustness of the findings. Finally, the framework outlined here should be considered an early feasibility step; advancing toward clinical application will require systematic validation and alignment with treatment protocols, particularly to ensure consistency across diverse patient populations.

V. CONCLUSION

Neural networks (NN) and artificial intelligence (AI) have significant applications in various sectors, including diagnosis and treatment. Their remarkable accuracy in forecasting outcomes makes them intriguing tools for addressing complex medical problems. While NNs may be educated on previous doctor judgments, interdisciplinary methods are required for reliable results. For instance, in this study, integrating doctors' real-life experiences, patient data, knowledge of fluid mechanics, CFD programs, and NN tools was crucial. When the observed data approaches the truth, this study will shed light on complex operations, reduce the risk factor, and affect both the quality of the operation and human health. For this reason, this study demonstrates that CFD programs, knowledge of fluid mechanics for analysis, and NN tools will be essential and inevitable for doctors and patients in the future. In particular, the issue of clot removal requires rapid decision-making. A pre-prepared system can almost instantly process clot geometry and

determine variables such as the necessary pressure and time with very high accuracy.

In this project, systemic simplifications are made to limit the Ansys simulation time. The next step for future work is to remove these simplifications and utilize real patient data and geometries. Adding more detailed and accurate data will improve the efficiency of NN outcomes. Patients with varying circumstances and profiles (e.g., age, cholesterol levels, blood sugar levels, general health, morale, speed of intervention, and degree of blockage) may help improve the model. As data becomes increasingly important, global data cooperation can significantly advance progress in the field. In the medium term, comparable models built globally using cloud computing may play a critical role in treating patients in various regions. In conclusion, it is clear that the three most important factors affecting thrombectomy are primarily vessel diameter, followed by clot viscosity and vacuum pressure. By evaluating these three critical parameters before surgery, it is aimed to increase the success rate of the procedure. These predictions aim to save the lives of many patients.

VI. ACKNOWLEDGMENT

This study was developed by integrating the Engineering Project works of Arda Ataç, Ezgi Işık, and Burak Kalayoğlu, conducted within the Department of Mechanical Engineering at Yeditepe University.

REFERENCES

- [1] c. W. H. D. N. G. K. K. W. Jianhuang Wua, Guiying Liub, "Transient blood flow in elastic coronary arteries with varying degrees of stenosis and dilatations: cfd modelling and parametric study,"
- [2] .
- [3] E. S. S. M. L. G. W. A. B. W. M. D. G. M. G. K. M. P. M. M. G. L. M. W. Adrien Guenego¹, Robert Fahed² and J. J. Heitl^{*}, "Impact of clot shape on successful m1 endovascular reperfusion," *Frontiers in Neurology*
- [4] Alwatban, M. R., Aaron, S. E., Kaufman, C. S., Barnes, J. N., Brassard, P., Ward, J. L., ... & Billinger, S. A. (2021). Effects of age and sex on middle cerebral artery blood velocity and flow pulsatility index across the adult lifespan. *Journal of Applied Physiology*, 130(6), 1675-1683.
- [5] Nader, E., Skinner, S., Romana, M., Fort, R., Lemonne, N., Guillot, N., ... & Connes, P. (2019). Blood rheology: key parameters, impact on blood flow, role in sickle cell disease and effects of exercise. *Frontiers in physiology*, 10, 1329.
- [6] Reçi, V., & Bexheti, S. (2019). Variations of shape, length, branching, and end trunks of the M1 segment of the middle cerebral artery. *Journal of Neurology, Neurological Science and Disorders*, 5(1), 052-056.
- [7] Gunnal, S. A., Farooqui, M. S., & Wabale, R. N. (2019). Study of the middle cerebral artery in the human cadaveric brain. *Annals of Indian Academy of Neurology*, 22(2), 187.
- [8] Lauric, A., Greim-Kuczewski, K., Antonov, A., Dardik, G., Magida, J. K., Hippelheuser, J. E., ... & Malek, A. M. (2019). Proximal parent vessel tapering is associated with an aneurysm at the middle cerebral artery bifurcation. *Neurosurgery*, 84(5), 1082-1089.



- [9] Yadav, S. S., Sikarwar, B. S., Ranjan, P., Janardhanan, R., & Goyal, A. (2020). Surface tension measurement of normal human blood samples by pendant drop method. *Journal of Medical Engineering & Technology*, 44(5), 227-236.
- [10] Nader, E., Skinner, S., Romana, M., Fort, R., Lemonne, N., Guillot, N., ... & Connes, P. (2019). Blood rheology: key parameters, impact on blood flow, role in sickle cell disease and effects of exercise. *Frontiers in physiology*, 10, 1329.
- [11] Kim, S., & Lee, J. Y. (2022). Comparison of vacuum pressures and suction forces generated by different pump systems for aspiration thrombectomy. *Frontiers in Neurology*, 13, 978584.
- [12] Alwatban, M. R., Aaron, S. E., Kaufman, C. S., Barnes, J. N., Brassard, P., Ward, J. L., ... & Billinger, S. A. (2021). Effects of age and sex on middle cerebral artery blood velocity and flow pulsatility index across the adult lifespan. *Journal of Applied Physiology*, 130(6), 1675-1683.
- [13] Krejza, J., Arkuszewski, M., Kasner, S. E., Weigele, J., Ustymowicz, A., Hurst, R. W., ... & Messe, S. R. (2006). Carotid artery diameter in men and women and the relation to body and neck size. *Stroke*, 37(4), 1103-1105.
- [14] Rossi, R., Fitzgerald, S., Gil, S. M., Mereuta, O. M., Douglas, A., Pandit, A., ... & Doyle, K. M. (2021). Correlation between acute ischaemic stroke clot length before mechanical thrombectomy and extracted clot area: impact of thrombus size on number of passes for clot removal and final recanalization. *European Stroke Journal*, 6(3), 254-261.