Online December 29, 2020
Journal of Neuroendovascular Therapy 2021; 15: 417–420
DOI: 10.5797/jnet.oa.2020-0111

Original Article

A Method to Evaluate Vessel Deviation during Withdrawal of a Stent Retriever Using a Silicon Vascular Model

Mao Yokota,[1] Tomotaka Ohshima,[2] Yoshitaka Nagano,[3] Reo Kawaguchi,[1] and Shigeru Miyachi[1,2]

Objective: Catastrophic complications may develop because of vessel deviation during device delivery into intracranial vessels for neurointerventions. We report a novel method using a silicon model capable of evaluating vessel deviation as a numerical value.

Methods: In all, 10 tiny markers, each with a pitch of approximately 5 mm, were attached to the vessel model along the long axis. We used a high-resolution camera to record movies of the deviation of the vessel model while employing different stent retrievers. The movies were reviewed to determine the maximum deviation of each marker on the vessel model.

Results: As expected, stent retrievers of the same type exhibited more vessel shifts when they had a larger diameter and longer length. On the other hand, stents with a segmental structure demonstrated less vessel deviation than those with a tubular structure, regardless of the large lumen and long length.

Conclusion: If the degree of vessel stress can be represented by a numerical value, areas where the careful use of different devices for neurointerventions is required may be able to be identified. Moreover, this method may be useful for training.

Keywords ▶ endovascular treatment, silicon model, stent retriever, vessel shift

Introduction

In neuroendovascular treatment, dynamic stress is loaded on the vascular wall when devices are passed through blood vessels. In blood vessel regions without strong supportive tissue, such as the intracranial region, stress from devices induces vessel deviation. This vessel deviation is influenced by numerous conditions such as the type of device, guiding technique, speed of pulling out, and anatomical structure. We investigated a method to present vessel deviation as a numerical value using a silicon vascular model. If the level of stress loaded on blood vessels can be represented by a numerical value, a method to use blood vessel-protective devices may be identified. In this report, this method and vessel deviation when different stent retrievers were pulled out at a constant speed are presented, and the efficacy is discussed.

[1]*Department of Neurosurgery, Aichi Medical University, Nagakute, Aichi, Japan*
[2]*Neuroendovascular Therapy Center, Aichi Medical University, Nagakute, Aichi, Japan*
[3]*Department of Electronic Control and Robot Engineering, Aichi University of Technology, Gamagori, Aichi, Japan*

Received: June 5, 2020; Accepted: October 8, 2020
Corresponding author: Tomotaka Ohshima. Neuroendovascular Therapy Center, Aichi Medical University, 1-1, Yazakokarimata, Nagakute, Aichi 480-1195, Japan
Email: tmtkoh@gmail.com

Materials and Methods

A silicon vascular model from United Biologics (Santa Ana, CA, USA) was used. The model was prepared by die cutting a region from the left common carotid artery over the distal middle cerebral artery. The diameter of the common carotid artery was 6.5 mm, that of the cervical internal carotid artery was 4.0 mm, that of the intracranial internal carotid artery was 3.6 mm, and those of M1, M2, and M3 of the middle cerebral artery were 2.3, 1.5, and 1.0 mm, respectively. The full length was 20 cm and the thickness of most of the vascular wall was 0.5 mm. The proximal and distal ends were fixed to the foundation. The internal lumen was filled with tap water to which a surfactant was added. Using a commercial water-based red marker (POSCA extra fine pointed pen, Mitsubishi Pencil Co., Ltd., Tokyo, Japan), marks were made every 1 cm along the longitudinal axis from M2 over the internal carotid artery in the vascular model. Ten points were added along the longitudinal axis of the model (**Fig. 1**).

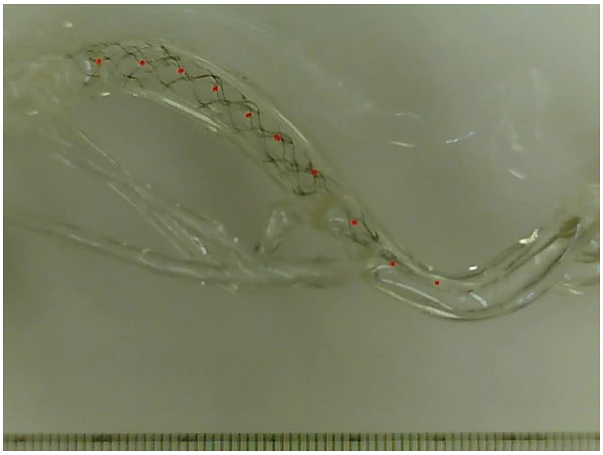

Fig. 1 The silicon vascular model is presented. Ten red markers were added to trace deviation.

When the device was guided or retrieved, the entire vascular model was imaged using a high-precision CCD video camera (Dino-Lite Digital Microscope AM-2001; AnMo Electronics Corporation, New Taipei City, Taiwan).

The following stent retrievers were used: (1) Solitaire 4 × 40 (Medtronic, Irvine, CA, USA), (2) Solitaire 6 × 40 (Medtronic), (3) EmboTrap 5 × 33 (Cerenovus, Johnson & Johnson, New Brunswick, NJ, USA), (4) Trevo 6 × 25 (Stryker, Kalamazoo, MI, USA), and (5) Tron 4 × 20 (TERUMO, Tokyo, Japan). For (1) and (2), the half deployment method[1)] ((1)' and (2)') was also tried, in which deployment was limited to 20 mm. After manual guidance and deployment, the device was pulled out at a constant speed of 10 mm/s using a ball screw-type linear actuator.[2)] By superimposing acquired movies on a computer, the 10 markers were traced at 1-second intervals, and the maximum fluctuation of each marker was measured and recorded (**Fig. 2**). Each procedure was repeated five times and the mean maximum fluctuation was recorded. The mean of the 10 points was interpreted as the mean vessel deviation.

Results

The mean value of each stent retriever is shown in **Table 1**. The largest deviation was 11.5 mm by (2) Solitaire 6 × 40, followed by 9.8 mm by (4) Trevo 6 × 25, 9.5 mm by (1) Solitaire 4 × 40, 8.0 mm by (2) Solitaire 6 × 20, 3.5 mm by (3) EmboTrap 5 × 33, and 3.4 mm by (1)' Solitaire 4 × 20. The smallest deviation was 2.9 mm by (5) Tron 4 × 20 mm.

Discussion

In neuroendovascular treatment, dynamic stress from devices loaded on the blood vessel may lead to serious complications. As an example, vessel deviation during pulling the stent in mechanical thrombectomy causes vasospasm, vascular dissection, and subarachnoid hemorrhage induced by pulling the perforating branch.[3)] For these events, techniques minimizing vessel deviation, such as partial deployment of the stent[1)] and the

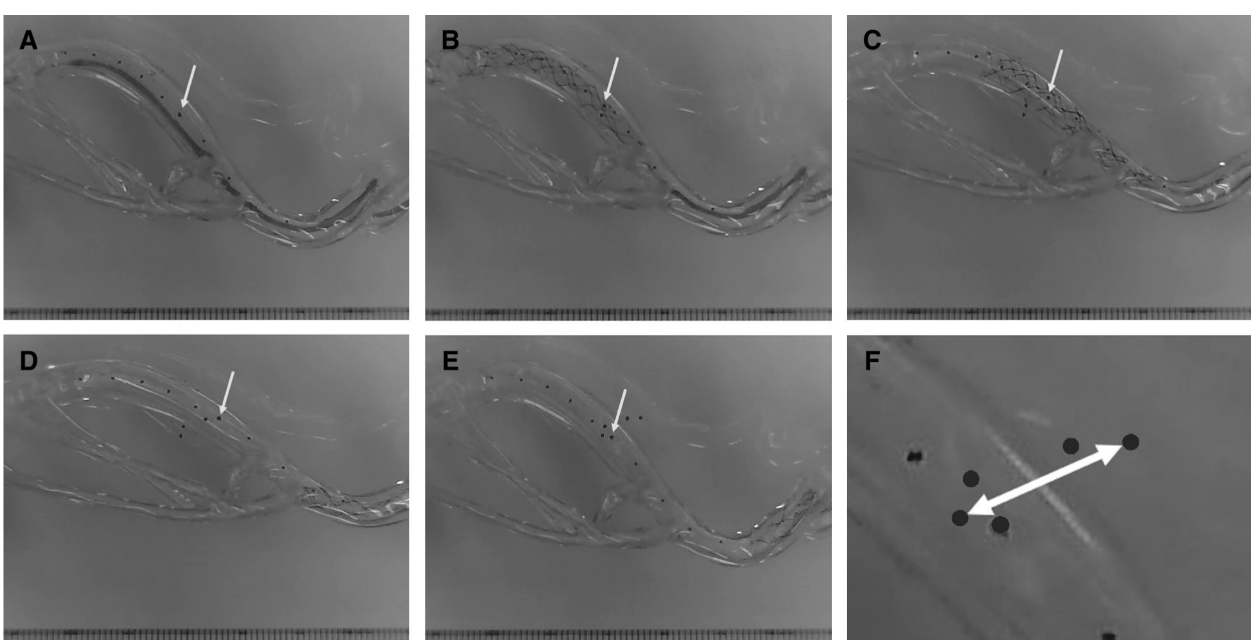

Fig. 2 (**A–E**) Photographs captured from movies showing the stent retriever being pulled out from the left peripheral side. The 6th marker from the distal side of the vascular model is indicated with yellow arrows. Movements of the markers were traced with bright red points. (**F**) The distance between two points of the most distant markers (white arrow) was measured.

Table 1 Mean distance of marker deviation (mm)

	Marker 1	Marker 2	Marker 3	Marker 4	Marker 5	Marker 6	Marker 7	Marker 8	Marker 9	Marker 10	Average
Stent retriever											
① Solitaire 4 × 40	3.65	4.54	5.29	6.54	8.19	9.64	11.3	15.27	15.46	15.6	9.548
①' Solitaire 4 × 20	1.44	1.65	2.03	2.33	2.83	3.22	4	4.97	6.09	5.5	3.406
② Solitaire 6 × 40	2.63	4.22	6.25	8.35	10.86	13.15	16.34	11.51	21.28	20.47	11.506
②' Solitaire 6 × 20	2.05	2.99	5.07	6.17	7.02	8.12	9.92	11.09	12.86	14.91	8.02
③ EmboTrap 5 × 33	1.53	2.01	2.69	3.07	3.17	3.85	3.77	4.15	5.02	6.14	3.54
④ Trevo 6 × 25	6.35	7.67	8.63	9.49	9.36	10.16	10.36	11.16	11.8	12.9	9.788
⑤ Tron 4 × 20	1.93	2.22	2.71	2.88	2.97	3.06	3.07	3.26	3.45	3.55	2.91

aspiration catheter with proximal balloon (ASAP) method,[4] have been reported. Other methods, including the Push & Fluff method,[2,5,6] have been reported, aiming at highly entangled thrombus difficult to remove using a stent, but it is unclear how much stress opening the stent places on the blood vessel.

We hypothesized that if vessel deviation can be presented as a numerical value, the characteristics of different devices can be understood, leading to their safe use. However, the size of the stent retriever and degree of vessel deviation were not correlated in this study.

Of the stent retrievers investigated, vessel deviation increased as the diameter and effective length of the stent increased, even for the same product, and half deployment reduced deviation. These findings were consistent with reports by Ohshima et al.[6] and Ulm et al.,[7] in which stents with a large diameter and long effective length had a higher thrombus-pulling force. In addition, Haussen et al.[8] reported that the use of a long stent aided in acquiring a favorable outcome in actual clinical practice. To our knowledge, no study directly comparing vessel deviation by stents has been reported, but the strength of expansion and thrombectomy capacity may be proportional to the degree of vessel deviation. The degree of vessel deviation can be roughly divided into two groups based on the measured numerical value: The group with a large deviation comprised (2), (4), (1), and (2)', and the mean deviation was 9.7 mm, whereas the group with a small deviation comprised (3), (1)', and (5), and the mean deviation was 3.3 mm. Of these, the vessel deviation by (3) EmboTrap was 3.5 mm, being small despite its size of 5.0 × 33 mm. This may have been due to the stent segment structure.

The biggest limitation of this study was the difference between silicon and natural blood vessels. Silicon is not uniform, and the coefficient of friction of the inner wall is diverse depending on the diameter and thickness of the wall. Shortening in the longitudinal axis direction in an accordion-like pattern often observed in the body is difficult to reproduce. To make the accuracy closer to that in clinical practice and homogeneous, further investigation is necessary. Moreover, as the time point at which a marker exhibited the maximum fluctuation varied among markers, the maximum deviation at a certain moment was not reflected. An evaluation method taking into account the total fluctuation of the markers and time integration of fluctuation is needed.

Conclusion

A method to present vessel deviation as a numerical value using a silicon vascular model was reported. If the stress level loaded on blood vessels can be clarified by numerical values, methods that protect vessels for each device can be identified. As the deviation can be evaluated based on the numerical value, this method may also be applied for training of operators.

Disclosure Statement

Tomotaka Ohshima and Shigeru Miyachi received rewards, such as lecture fees, from MEDTRONIC JAPAN CO., LTD (Tokyo). The first and the other co-authors have no conflicts of interest to disclose.

References

1) Wan Y, Yang IH, Orru E, et al: Endovascular thrombectomy for distal occlusion using a semi-deployed stentriever: report of 2 cases and technical note. *Neurointervention* 2019; 14: 137–141.
2) Kawaguchi R, Ohshima T, Nagano Y, et al: Experimental evaluation of stent clot retrieval using the confront clot scrambling method with an equitable automatic withdrawal machine. *Asian J Neurosurg* 2019; 14: 1165–1167.
3) Leishangthem L, Satti SR: Vessel perforation during withdrawal of Trevo ProVue stent retriever during mechanical thrombectomy for acute ischemic stroke. *J Neurosurg* 2014; 121: 995–998.
4) Goto S, Ohshima T, Ishikawa K, et al: A stent-retrieving into an aspiration catheter with proximal balloon (asap) technique: a technique of mechanical thrombectomy. *World Neurosurg* 2018; 109: e468–e475.
5) Haussen DC, Rebello LC, Nogueira RG: Optimizating clot retrieval in acute stroke: the push and fluff technique for closed-cell stentrievers. *Stroke* 2015; 46: 2838–2842.
6) Ohshima T, Kawaguchi R, Nagano Y, et al: Experimental direct measurement of clot-capturing ability of stent retrievers. *World Neurosurg* 2019; 121: e358–e363.
7) Ulm AJ, Khachatryan T, Grigorian A, et al: Preclinical evaluation of the NeVaTM stent retriever: safety and efficacy in the swine thrombectomy model. *Interv Neurol* 2018; 7: 205–217.
8) Haussen DC, Al-Bayati AR, Grossberg JA, et al: Longer stent retrievers enhance thrombectomy performance in acute stroke. *J Neurointerv Surg* 2019; 11: 6–8.