ORIGINAL PAPER

Nagoya J. Med. Sci. **85**. 50–58, 2023
doi:10.18999/nagjms.85.1.50

Differences in gaze behaviors between trainees and experts during endovascular therapy for cerebral aneurysms: a preliminary study using a cerebral aneurysm model

Takafumi Otsuka[1], Takashi Izumi[1], Masaya Yamamoto[2], Yusuke Seshita[2], Takeshi Kohama[3], Masahiro Nishihori[1], Tetsuya Tsukada[1] and Ryuta Saito[1]

[1]Department of Neurosurgery, Nagoya University Graduate School of Medicine, Nagoya, Japan
[2]Department of Electronic Robot Engineering, Aichi University of Technology, Gamagori, Japan
[3]Department of Computational Systems Biology, Faculty of Biology-Oriented Science and Technology, Kindai University, Kinokawa, Japan

ABSTRACT

In the neuroendovascular field, the training of operators has become an important issue. Recently, eye-tracking technology has been introduced into various fields of medical education. This study aimed to apply eye-tracking technology to the training of neuroendovascular therapy. Six neurosurgeons, including three neuroendovascular specialists and three trainees, at our institution and related facilities participated in the study. Eye movement was recorded by the eye-tracking device during the microcatheter navigation and coil placement into the silastic aneurysm model under biplane X-ray fluoroscopy. Eye-tracking analysis during neuroendovascular therapy was feasible in all six subjects. In microcatheter navigation, specialists tended to more frequently switch their attention between frontal and lateral images than trainees. In coil embolization, the overall gaze frequency tended to increase, and the average fixation duration tended to decrease as the number of experienced cases increased. Inexperienced operators tend to fix their gaze when they are operators than when they are assistants. More experienced operators tended to look at the microcatheter longer in the coil insertion task. The eye-tracking analysis may be useful for operator training in neuroendovascular therapy. Experts may have moved their eyes more frequently than trainees to gaze at the right place. In the future, it will be necessary to collect gaze data for more operators in various tasks.

Keywords: eye tracking, endovascular therapy, coil embolization

INTRODUCTION

The number of neuroendovascular treatments has been increasing since the benefits of coiling for cerebral aneurysms or mechanical thrombectomy for acute cerebral infarction have been proven.[1,2] Therefore, the training of operators has become an important issue. Conversely, the

Received: December 27, 2021; accepted: February 21, 2022
Corresponding Author: Takashi Izumi, MD, PhD
Department of Neurosurgery, Nagoya University Graduate School of Medicine,
65 Tsurumai-cho, Showa-ku, Nagoya 466-8550, Japan
Tel: +81-52-744-2354, Fax: +81-52-744-2785, E-mail: my-yuzu@med.nagoya-u.ac.jp

opportunities for trainees to practice under the supervision of their instructors have become limited due to patient safety concerns. This has led to the need for training methods to acquire skills more efficiently.

Eye-tracking technology is used in various fields, such as sports and driving,[3,4] and its effectiveness has been reported in large numbers in the field of medical education.[5] Wilson et al pointed out the difference in gaze behaviors between novices and experts in laparoscopic surgery training and reported the effectiveness of the training method using eye tracking.[6,7]

Neuroendovascular operators are required to have the ability to recognize situations from fluoroscopic imaging. The eye-tracking technology makes it possible to recognize where the operator is focusing attention. Trainees may be able to improve their skills more efficiently by learning where skilled operators are focusing attention.

Only a few studies have introduced eye tracking into neuroendovascular treatments,[8,9] and the difference in gaze behavior depending on the experience level is unclear. This preliminary experiment aimed to verify the difference in gaze behavior between trainees and experts in aneurysm coil embolization using a cerebral aneurysm model.

MATERIALS AND METHODS

This study was approved by the Bioethics Review Committee of the Nagoya University Hospital. This study was performed in accordance with the ethical standards in the Declaration of Helsinki.

Subjects

Six neurosurgeons (three specialists and three non-specialists of the Japanese Society for Neuroendovascular Therapy) at our institution and related facilities participated in the present study. The numbers of experienced cases as operators of neuroendovascular therapy was 14, 20, 110, 295, 600, and 2000, three of whom participated as subjects as well as researchers because this was a preliminary study.

Task

The task was to navigate a microcatheter and place a detachable coil into a silastic cerebral aneurysm model (EVE, FAIN-Biomedical, Okayama, Japan) under biplane X-ray fluoroscopy (Siemens Artis Q BA Twin, Forchheim, Germany). A 6-Fr guiding catheter had already been placed in the internal carotid artery of the cerebrovascular model, from which the subjects navigate SL10 microcatheter (Stryker, Kalamazoo, Michigan, USA) to the middle cerebral artery aneurysm with Chikai14 microguidewire (Asahi Intecc Co, Ltd, Aichi, Japan). The aneurysm has a maximum diameter of 3.4 mm and a neck of 2.9 mm (Figure 1A). The subject placed a detachable coil (Target360 4 mm × 8 mm; Stryker) into the aneurysm. We selected an oversized coil that was difficult to place just by pushing the delivery wire and required adjustment of the microcatheter position for insertion. At our institution, neuroendovascular procedures were mainly performed by two individuals, an operator, and an assistant. This experiment was also performed by two individuals. Three pairs consisted of a combination of specialists and trainees, and the operator-assistant was replaced to record a total of six sessions. The operator manipulates the microguidewire and coil, and the assistant manipulates the microcatheter. The operator has the initiative to instruct the assistant to manipulate the microcatheter. The C-arm and operating table were fixed, and all experiments were performed under the same fluoroscopic images. The aneurysm neck and two branches were separated in the lateral view. The frontal view was set as the down-the-barrel view (Figure 1A).

Eye tracking

Each subject wore a glass-like eye-tracking device (Pupil Core; Pupil Labs GmbH, Berlin, Germany) during the procedure. The eye-tracking device was equipped with near-infrared cameras to record eye movements and a video camera to record the visual field in front of the subjects. The coordinates of the gaze points were calculated and overlaid on the recorded video of the visual field. Calibration was performed using the default method of the device before the start of the recording. The recording frequency was 120 Hz. Under ideal conditions, the gaze accuracy is 0.6° and the precision is 0.02°. To stabilize the recording, the eye-tracking device was connected via a cable to a recording computer. Voice data were recorded simultaneously so that the procedure contents could be verified later from the operator's instructions.

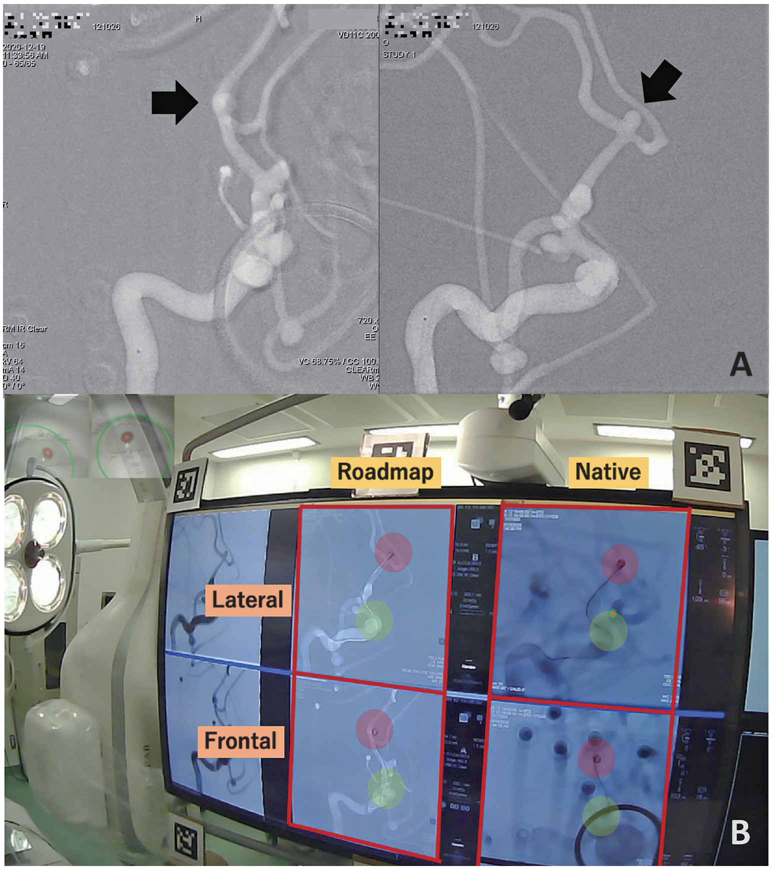

Fig. 1 Target aneurysm and the regions of interest

Fig. 1A: Roadmap image of the target aneurysm. The left side is the frontal image, and the right side is the lateral image. The black arrows point to the target aneurysm.

Fig. 1B: In the coil insertion task, the regions of interest were set around the aneurysm and the proximal marker of the microcatheter on each of the four images: frontal view native and roadmap images and lateral view native and roadmap images.

Data analysis

Microcatheter navigation. We set the time of interest as the time from the start of the microcatheter navigation to the end of navigation into the aneurysm. The frequency of each operator's switching attention between the frontal and lateral images was calculated.

Coil embolization. We set the time of interest from the time the tip of the coil reached the tip of the microcatheter to the time the operator completed coil placement into the aneurysm. Region of interests were set around the aneurysm and the proximal marker of the microcatheter on each of the four images: frontal view native and roadmap images and lateral view native and roadmap images (Figure 1B). Those fixed within approximately 1° of the visual angle for ≥100 ms were manually extracted as a gaze. The extracted gaze was assigned to the above eight regions of interest (the red and yellow circles in Figure 1B) or other points by comparing the camera images of the eye-tracking device to the recorded fluoroscopy images. The gaze frequency per minute and average fixation duration was calculated. The total gaze time for each region of interest was calculated by multiplying the average fixation duration by the total number of gazes, and the ratio of the gaze time on the native versus the roadmap image, frontal versus lateral image, and aneurysm versus microcatheter was calculated for each subject. Moreover, we set another time of interest as the time of pushing or pulling the microcatheter. This time of interest was the time from the operator's instructions to the end of the microcatheter operation by the assistant. Using the Pupil Player (Pupil Labs GmbH), heat maps of the gaze point in the microcatheter push-or-pull situations were created.

Statistical analysis

The relationship between each parameter and the number of experienced cases was tested using Spearman's rank correlation coefficients. Statistical analyses were performed using SPSS version 25 (IBM, Armonk, NY, USA).

RESULTS

All subjects completed the procedure. The average time required for the procedure was 141.8 s for microcatheter navigation and 270.9 s for coil embolization.

Microcatheter navigation

The frequency of switching attention between frontal and lateral images during microcatheter navigation ranged from 1.8 to 15.4 (times per minute). Two trainees, subjects 1 and 3, less frequently switched their attention. There was no statistically significant association between the number of experienced cases and frequency of switching attention between the frontal and lateral images (Table 1).

Coil embolization

The results of gaze frequency and average fixation duration of each subject as the operator are shown in Table 1. All parameters, except for the frequency of gaze at other points, were not significantly associated with the number of experienced cases. Excluding subject 2, the overall gaze frequency tended to increase, and the average fixation duration tended to decrease as the number of experienced cases increased. The frequency of gaze at other points increased as the number of experienced cases increased, and most of the other points were reference images on the left side of the screen. Figure 2A/B shows the difference in total gaze frequency and

Table 1 Summary of gaze parameters in each subject

			1	2	3	4	5	6	ρ	P
Subject			1	2	3	4	5	6		
Experience (cases)			14	20	110	295	600	2000		
Specialist certified by JSNET			–	–	–	+	+	+		
Microcatheter navigation										
Time required (sec)			230	140	111	105	88	177	–0.43	0.40
Frequency of the switching attention between the frontal and lateral images (times per min)			1.80	15.4	3.80	16.0	10.9	12.5	0.37	0.47
Coil embolization, Gaze frequency (times per min) / Average fixation duration (sec)										
Time required (sec)			286	437	241	308	78	275	–0.49	0.33
Total			7.25 / 7.35	28.8 / 1.87	8.46 / 6.56	17.3 / 3.32	24.6 / 2.11	30.3 / 1.76	0.66 / –0.66	0.16 / 0.16
Roadmap	Frontal	Aneurysm	1.10 / 0.64	3.89 / 1.35	3.73 / 13.2	2.89 / 1.33	8.46 / 2.59	0.44 / 0.57	–0.09 / –0.14	0.87 / 0.79
		Microcatheter	0 / –	0 / –	0.50 / 3.73	0.21 / 2.89	1.54 / 0.43	0 / –	0.33 / –	0.52 / –
	Lateral	Aneurysm	3.74 / 13.7	11.8 / 2.51	3.48 / 1.64	8.04 / 6.28	10.0 / 2.57	5.02 / 1.32	0.14 / –0.54	0.79 / 0.27
		Microcatheter	0 / –	4.03 / 0.67	0.75 / 3.48	4.54 / 0.43	2.31 / 1.29	0.22 / 1.02	0.14 / –0.10	0.79 / 0.87
Native	Frontal	Aneurysm	0 / –	0.14 / 0.75	0 / –	0 / –	0.77 / 0.77	3.93 / 1.94	0.70 / –	0.12 / –
		Microcatheter	0 / –	0 / –	0 / –	0 / –	0 / –	0 / –	– / –	– / –
	Lateral	Aneurysm	0.44 / 0.58	7.50 / 2.03	0 / –	0.62 / 1.34	0 / –	13.5 / 1.98	0.20 / –0.03	0.70 / 0.96
		Microcatheter	1.98 / 0.55	1.39 / 0.51	0 / –	0.21 / 0.10	0.77 / 0.10	6.33 / 1.77	0.09 / 0.06	0.87 / 0.91
Other points			0 / –	0 / –	0 / –	0.82 / 0.51	0 / –	0.87 / 0.71	0.88 / –	0.02 / –

JSNET: Japanese Society for Neuroendovascular Therapy
ρ: spearman's ρ

total average fixation duration depending on the role of each subject. All three non-specialists had decreased gaze frequency and increased mean fixation duration when they were operators compared to that when they were assistants. Comparing the total gaze time between the native and roadmap images, the roadmap image was watched more frequently, except for subject 6 (ρ = 0.09, Figure 2C). Comparing the frontal and lateral images, the lateral image was watched more frequently, except for subject 3 (ρ = 0.49, Figure 2D). Comparing the aneurysm and microcatheter, the aneurysm was watched more frequently in all subjects. Although it was not statistically significant, the gaze time of the microcatheter tended to increase as the number of experienced cases increased (ρ = 0.71, Figure 2E).

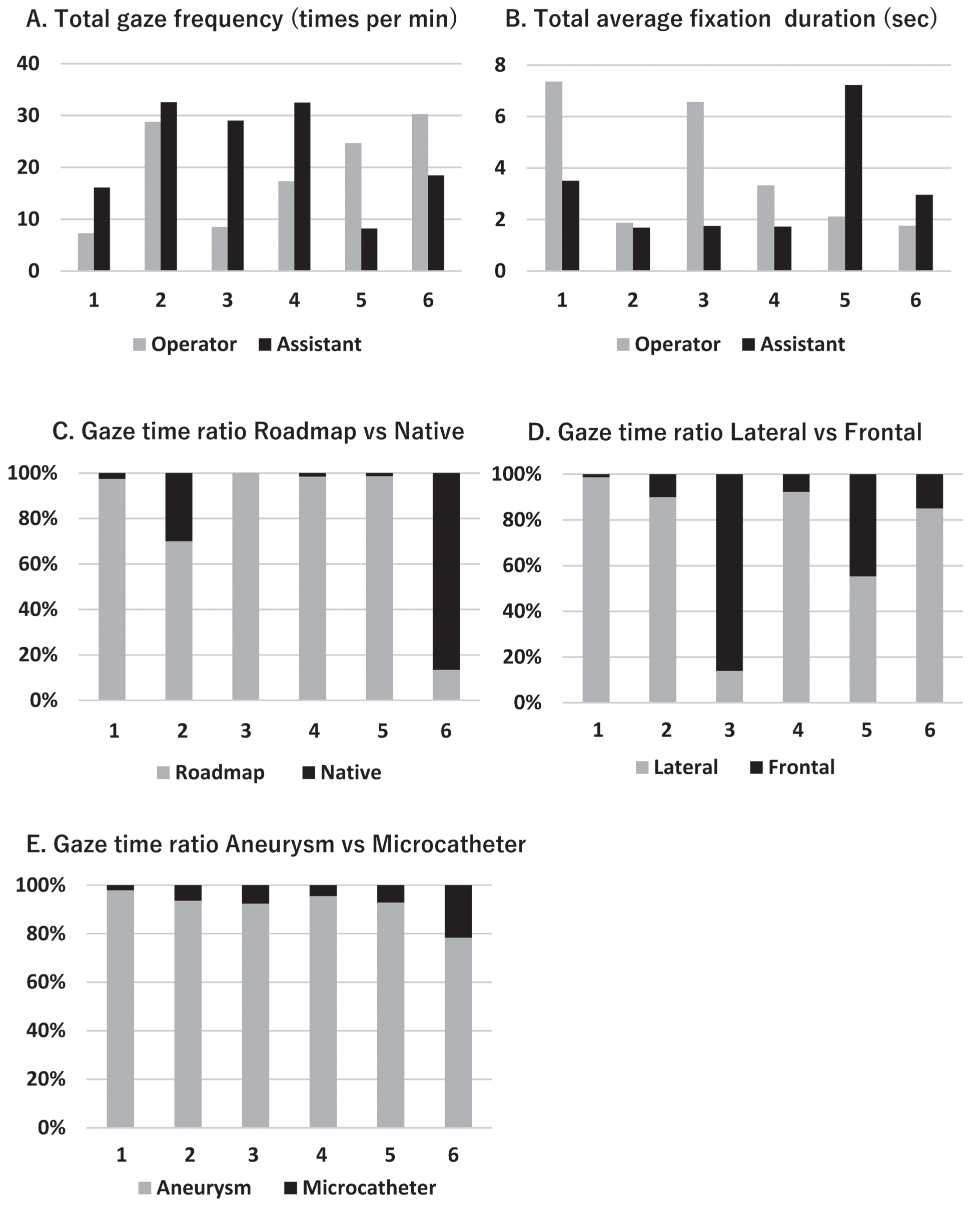

Fig. 2 Bar graphs of gaze parameters for each surgeon

Fig. 2A–2B: Difference in total gaze frequency (2A) and total average fixation duration (2B) depending on the role of each subject.

Fig. 2C–2E: Gaze time ratio of the roadmap versus native (2C) and lateral versus frontal (2D) and aneurysm versus microcatheter (2E) in each subject when they were operators. Spearman's ρ that verified the relationship with the number of experienced cases is 0.09 in percentage of gaze time for native images, 0.49 in frontal image, and 0.71 in microcatheter.

Heat map of catheter push-or-pull situations

A total of five catheter push-or-pull situations were recorded in six sessions. Figure 3 shows a heat map of a 10-s gaze of a catheter push situation that was shown in an experiment in which subject 6 was an operator and subject 1 was an assistant. While the gaze of the least experienced subject 1 was concentrated around the aneurysm, the gaze of the most experienced subject 6 was concentrated around not only the aneurysm but also the microcatheter.

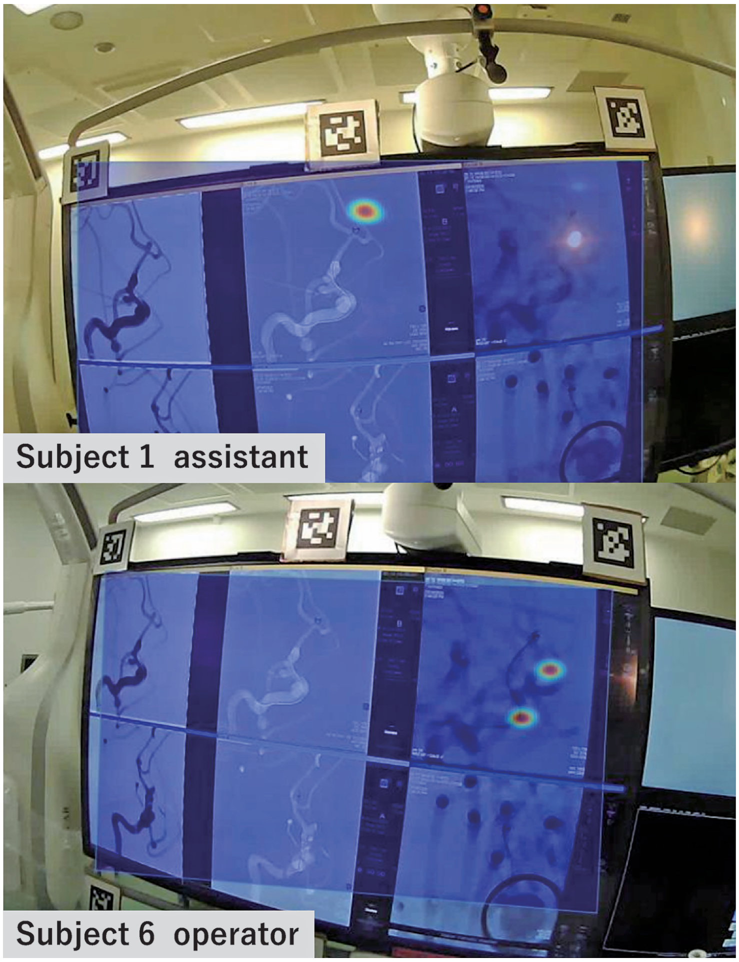

Fig. 3 Differences in gaze during catheter push situation

A heatmap of a 10-s gaze of a catheter push situation that appeared in an experiment in which subject 6 was an operator and subject 1 was an assistant. While the gaze of the least experienced subject 1 was concentrated around the aneurysm (top), the gaze of the most experienced subject 6 was concentrated around not only the aneurysm but also the microcatheter (bottom).

DISCUSSION

In this preliminary study, differences in gaze behaviors between trainees and experts were observed in the coil embolization task. In both microcatheter navigation and coil insertion, experts tended to move their eyes more frequently. In addition, experts tended to watch the microcatheter longer in the coil insertion task. These results of current study suggest that gaze behaviors can be used an indicator of the surgeon's level of experience, or improvement in skill level through training.

Eye-tracking analysis during neuroendovascular therapy was feasible in all six subjects. The gaze was focused on the screen in all six subjects during both microcatheter navigation and coil insertion. Inexperienced operators spent more time looking out of the screen, mainly looking down at their hands, than experienced operators.[8] In the current study, even the least experienced subject 1 had some experience of neuroendovascular therapy and did not need to look down at his hands during the procedure.

During microcatheter navigation, specialists tended to more frequently switch their attention between frontal and lateral images than non-specialists, excluding subject 2. In the cerebrovascular model used in this experiment, there were multiple aneurysms on the way to reach the target aneurysm. Some aneurysms were easier to watch in the frontal image, while others were easier to watch in the lateral image. It was considered that specialists could navigate the microcatheter safely by switching their attention more frequently to examine the parent artery's course and aneurysms along the way during microcatheter navigation.

In the coil insertion procedure, the total gaze frequency tended to increase and the total mean fixation duration tended to decrease as the number of experienced cases increased, excluding subject 2. This result was consistent with those by a study by Shojima et al.[9] Coil embolization is a procedure in which situations such as the shape of the inserted coils, position of the tip of the microcatheter, or deflection of the microcatheter change from moment to moment during coil insertion. Experts may be aware of these changes by moving their gaze more frequently. Conversely, inexperienced operators tend to fix their gaze when they are operators than when they are assistants. For this reason, inexperienced operators are likely to overlook device behavior and make misoperations. Most subjects performed the procedure focusing on the lateral image where the aneurysm neck was widely visible, which was considered a natural outcome. The gaze time ratio of the native and roadmap images was not related to the experience level. The roadmap image provides a positional relationship between coil mass and aneurysm or parent artery. The shape of the coil mass is easier to see in the native image. In the parent artery occlusion using multiple coils, more experienced subjects reported to spend more time looking at the native image.[8] The lack of association in the current study was due to the task to place only one framing coil, which reflects only a part of coil embolization in clinical practice. In the clinical cases of aneurysm embolization by multiple coils, experts may look at the native image more frequently. Conversely, more experienced operators tended to watch the microcatheter longer in the coil insertion task. As shown in Figure 3, it was even more pronounced during the microcatheter push-or-pull situations. When the microcatheter is pushed, the proximal side of the microcatheter bends, and the tip advances. When the microcatheter is pulled, the proximal side of the microcatheter is flexed, and the tip is lowered. Skilled operators adjust the position of the microcatheter tip more delicately by paying attention to not only the catheter tip but also the deflection of the microcatheter. The gaze at the microcatheter during push-or-pull situations in coil embolization may be one of the differences between trainees and experts.

There were several limitations in this study. This is the result of eye-tracking analysis during the single task performed by only six subjects selected only from our institution and related facilities. To support the current study, it is necessary to increase the number of subjects. Furthermore, the gaze behavior may differ from procedure to procedure. It is also necessary to confirm the difference in gaze behavior depending on the experience level in other procedures, such as stent placement. Subject 2, who was a trainee, demonstrated gaze parameters similar to those of specialists. From this result alone, it was difficult to judge whether he was truly skillful or not. Especially for trainees, it may be necessary to consider not only the number of experienced cases as operators but also the number of cases as visitors or assistants. Three subjects also participated as researchers. In this point, the current study may lack objectivity. However, those three subjects were not involved in the data analysis. The manual mapping assigning fixations to the region of interest might cause some spatial errors. The push-or-pull situation of the microcatheter appears by chance and is difficult to reproduce.

The eye-tracking analysis may be useful for operator training in neuroendovascular therapy. To verify the current result, it is necessary to acquire gaze data for more subjects and various tasks. In order to use this technology as an indicator of the improvement in individual skill levels, it would also be meaningful to investigate how training changes the gaze behaviors of trainees.

DISCLOSURE STATEMENT

The authors have no conflict of interest to declare.

REFERENCES

1 Molyneux AJ, Kerr RS, Yu LM, et al. International subarachnoid aneurysm trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet*. 2005;366(9488):809–817. doi:10.1016/S0140-6736(05)67214-5.

2 Goyal M, Menon BK, van Zwam WH, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet*. 2016;387(10029):1723–1731. doi:10.1016/S0140-6736(16)00163-X.

3 Kredel R, Vater C, Klostermann A, Hossner EJ. Eye-tracking technology and the dynamics of natural gaze behavior in sports: a systematic review of 40 years of research. *Front Psychol*. 2017;8:1845. doi:10.3389/fpsyg.2017.01845.

4 Carr DB, Grover P. The role of eye tracking technology in assessing older driver safety. *Geriatrics (Basel)*. 2020;5(2):36. doi:10.3390/geriatrics5020036.

5 Ashraf H, Sodergren MH, Merali N, Mylonas G, Singh H, Darzi A. Eye-tracking technology in medical education: a systematic review. *Med Teach*. 2018;40(1):62–69. doi:10.1080/0142159X.2017.1391373.

6 Wilson M, McGrath J, Vine S, Brewer J, Defriend D, Masters R. Psychomotor control in a virtual laparoscopic surgery training environment: gaze control parameters differentiate novices from experts. *Surg Endosc*. 2010;24(10):2458–2464. doi:10.1007/s00464-010-0986-1.

7 Wilson MR, Vine SJ, Bright E, Masters RSW, Defriend D, Mcgrath JS. Gaze training enhances laparoscopic technical skill acquisition and multi-tasking performance: a randomized, controlled study. *Surg Endosc*. 2011;25(12):3731–3739. doi:10.1007/s00464-011-1802-2.

8 Shojima M, Okamoto Y, Niizuma K, et al. Preliminary study of eye tracking to investigate the differences in gaze behaviors depending on the experience of neuroendovascular therapy. *Surg Neurol Int*. 2020;11:351. doi:10.25259/SNI_543_2020.

9 Shojima M, Okamoto Y, Ohta M, Niizuma K, Sakai N, Tominaga T. Preliminary study of eye-tracking during the coil insertion task in a Silastic model of intracranial aneurysms. *World Neurosurg*. 2020;139:e827-e835. doi:10.1016/j.wneu.2020.05.012.