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The Neurovascular Disease Management Course: A Medical Student Opportunity for Early Exposure and Technical Development in Vascular Neurosurgery

Justin Gelman[1], Jean Filo[1], Felipe Ramirez-Velandia[1], Alejandro Enriquez-Marulanda[1], Sarah Blitz[1], Sandeep Muram[1], Anirudh Penumaka[1], Charles Mackel[1], Michael Young[1], Jonathan Pace[2], Hormuzdiyar Dasenbrock[3], Adel Malek[4], Philipp Taussky[1], Justin Granstein[1], Christopher S. Ogilvy[1]

BACKGROUND: **As endovascular neurosurgery techniques continue to evolve, medical students in the United States have widely varying exposures to the field, particularly with respect to opportunities for hands-on experiences. Current medical school curricula could benefit from a novel and adaptive course on vascular neurosurgery to increase student exposure earlier in their training.**

METHODS: **We launched a yearly hands-on vascular neurosurgery course for medical students and residents. The day-long course is a combination of lectures focused on neurovascular disease and management accompanied by hands-on sessions where students practiced fundamental microsurgery and angiography techniques using real microscopes and angiography simulators. We surveyed the students before and after each of the 2 courses. The survey following the second annual course included quiz questions the students had not previously seen.**

RESULTS: **Over 2 courses, we had 149 attendees, 71.8% of which were first and second-year medical students representing fifteen institutions. The average survey completion rate was 41.4% for the 4 surveys across the 2 courses. Attendees' interest in pursuing a surgical specialty ($t = 1.815$, $P = 0.039$) along with their comfort with neuroanatomy ($t = 8.780$, $P \leq 0.001$) and neurosurgical disease ($t = 6.133$, $P \leq 0.001$) was significantly elevated after the completion of the second course. Responses to the post-survey showed a good grasp of the fundamentals with 68% of attendees answering 70% of the quiz questions correctly.**

CONCLUSIONS: **An interactive course on vascular neurosurgery may be an effective vehicle to provide medical students with exposure to the field and the opportunity to learn the fundamentals.**

INTRODUCTION

Neurosurgery is a specialty defined by change and innovation.[1] As neurosurgeons face the constant challenge of staying up to date on new developments and adapting their approaches, neurosurgical education faces a similar challenge to constantly grow with changes in the field.

To this end, education in neurosurgery has changed dramatically over the past 2 null decades. Worldwide, institutions have created new positions and fellowships to keep pace with this rapidly evolving specialty. However, medical school curricula have encountered difficulties in keeping pace with a field undergoing near-daily transformations.[2] The dilemma lies in creating an educational framework that accommodates the constant evolution of neurosurgical knowledge. Moreover, the question arises of how to effectively promote interest and educate medical students on the intricacies of subspecialties within neurosurgery, such as vascular neurosurgery.

The main challenge medical schools face when seeking to integrate vascular neurosurgery into their education curriculum is

Key words
- Angiography
- Curriculum
- Education
- Medical schools
- Microsurgery
- Neurosurgery

From the [1]Neurosurgical Service, Harvard Medical School, Beth Isreal Deaconess Medical Center, Boston; [2]Department of Neurosurgery, Lahey Hospital & Medical Center, Burlington; [3]Department of Neurosurgery, Boston University Chobanian and Avedisian School of Medicine, Boston Medical Center, Boston; and [4]Department of Neurosurgery, Tufts Medical School, Tufts Medical Center, Boston, Massachusetts, USA

Justin Gelman and Jean Filo are co-first authors on this work.

To whom correspondence should be addressed: Christopher S. Ogilvy, M.D. [E-mail: cogilvy@bidmc.harvard.edu]

Citation: World Neurosurg. (2024) 190:e394-e402.
https://doi.org/10.1016/j.wneu.2024.07.146

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

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limited exposure. Many medical schools lack easy access to a neurosurgery department, particularly with respect to opportunities for hands-on experience. While students in other medical disciplines learn by participating in patient care, rounds, and various practical experiences, student experiences in surgical subspecialties are often limited to observation or occasional participation in low-risk procedures like suturing.[3] In vascular neurosurgery, procedures such as suturing a bypass or deploying a flow diverter across the neck of an aneurysm are usually reserved for senior residents and fellows due to their inherent risk and complexity.[4] This dynamic necessitated the adoption of simulation-based training as a safe and credible alternative.[5,6] As simulation platforms evolve, they more accurately replicate the complexity of vascular neurosurgical procedures, enabling students to learn in a controlled setting and bridging the gap between observation and real-life practice, which will ultimately increase their exposure and potentially interest in the field.

There have been a handful of courses that attempt to address this problem within general neurosurgery and other specialties.[7-11] These courses, ranging from under two hours to several weeks and with 12 to 305 participants, showed increased proficiency and interest in their respective fields. Despite emphasizing the importance of simulation and early exposure, they unfortunately remained limited to participants within host institutions therefore limiting their reach. The results of these courses show promise that a similar, yet more accessible, approach would be beneficial in vascular neurosurgery.

In the following paper, we describe our experience developing an annual vascular neurosurgery course for, but not restricted to, medical students from different universities in New England. The course had 3 main objectives: provide medical students with early exposure to vascular neurosurgery, overview fundamentals of neurovascular disease and management, and practice fundamental open- and endo-vascular techniques. The course was highly adaptable, featuring the most cutting-edge simulators and incorporating advances from 1 year to the next. Most importantly, the course is intended as a significant step towards increasing the collective recruitment of students into vascular neurosurgery.

MATERIALS AND METHODS

Course Overview

The neurovascular disease management course is a comprehensive, free, 1-day event open to all medical students interested in neurosurgery. Neurosurgery residents and graduate students interested in a future career in vascular neurosurgery were also encouraged to attend. Recruitment for the event was achieved by contacting members of the neurosurgery interest groups of medical schools in the New England area. Marketing for the event



Figure 1. Photos from the neurovascular disease management course. Students are depicted practicing angiography and mechanical thrombectomy (**A**). Students are depicted practicing aneurysm clipping and cerebrovascular bypass techniques (**B**). Students listening to lecture on aneurysms (**C**). Written permission was granted to publish these photos.

Table 1. Course Agenda

Activity	Time
Morning didactics	
Basic neuroanatomy	8:00 –10:30
Basics of neuroimaging	
Acute ischemic stroke	
Aneurysms	
Vascular malformations	
Carotid disease	
Hands-on session 1	10:30 –12:30
Rapid fire case presentations and lunch	12:30 –2:15
Dural AVM	
Brain AVM	
Spinal AVM	
Aneurysm	
Cavernous malformation	
Acute stroke	
Moyamoya disease	
Extracranial vascular problems: Tumor embolization, epistaxis, and chronic subdural hematomas	
Idiopathic intracranial hypertension*	
Vein of galen malformations*	
Hands-on session 2	2:15—4:00
Wrap-up	
Future of neurovascular medicine: What you will do as a neurovascular neurosurgeon	4:00—4:40
Review and questions	

Table 1: Schedule of the neurovascular disease management course: The day was organized into alternating didactic and simulations sessions with a wrap-up session at the end of the agenda. The morning session and afternoon sessions were interspersed by a lunch session involving case presentations during which time students ate lunch.
AVM, arteriovenous malformation.
*Only presented during the 2022 course.

involved flyers, emails, social media, and registration forms relayed by interest group representatives to each of their respective student bodies, as well as word-of-mouth.

The course was designed with alternating sessions of didactics with hands-on simulations. The first session included an overview of basic neuroanatomy and neuroimaging as well as an introduction to the basics of neurovascular disease. Topics covered included assessment, management, and specific issues of acute ischemic stroke, carotid disease, brain aneurysms, and vascular malformations.

Next, students were encouraged to walk around to different stations and practice neurosurgery techniques with the guidance of faculty and residents. Students had the opportunity to use flow models and simulators for diagnostic angiography, aneurysm coiling and stent deployment, carotid stenting, and difficult arch maneuvering. They also practiced using neurosurgical microscopes for microsurgical suturing and aneurysm clipping and saw a wide display of coils, stents, and flow diverters (Figure 1).

Students then returned to the main room for lunch and a second didactic session organized around rapid-fire case presentations. At this time, presenters guided attendees through the presentation, diagnosis, and neurosurgical management of some of the most common neurovascular diseases. Namely, cases covering dural, brain, and spinal arteriovenous malformations, brain aneurysms, cavernous malformation, acute stroke, carotid disease, tumor embolization, epistaxis, and chronic subdural hematomas were addressed.

For the rest of the afternoon, students participated in a second hands-on session during which they rotated through the stations they had not seen in the prior session. The event ended with a wrap-up session and students stayed to network with each other and the neurosurgeons in attendance. An itinerary of the event is provided in Table 1. The participants and any identifiable individuals consented to the publication of their images.

Data Collection

In the inaugural year of the course (2022), there was a limited effort to collect data on participants. A presurvey was distributed via QR code at the entrance of the event that requested demographic information and asked students to rate their familiarity with neurovascular disease and interest in neurosurgery using a 10-point Likert scale. A postsurvey was then distributed at the end of the course via a QR code. Students were asked to compare their understanding of relevant neuroanatomy, comfort with neurovascular disease, and interest in neurosurgery before and after the course again using a 10-point Likert scale. Data from participants who completed both the precourse and postcourse surveys were analyzed using a paired *t*-test.

In the 2023 course, a more robust effort was undertaken to collect data from the pre-attendance and post-attendance survey, to better understand the effects of this course on their overall interest in the field. In addition to demographic data, the precourse survey inquired about interest in neurosurgery compared to other fields of medicine and access to neurosurgery resources at their home institution. After completing the course, participants were asked to rate their comfort with neuroanatomy and neurovascular disease and their interest in neurosurgery. In addition, they completed a 10-question quiz testing key concepts related to neurovascular disease and the procedures explored during the simulation sessions (Supplementary Table 1). A precourse quiz was intentionally not administered to avoid priming students to the concepts that would be tested in the postcourse quiz. All responses from the precourse survey underwent descriptive analysis, however, only participants completed both the precourse and postcourse surveys were included for comparative analysis.

RESULTS

The campaign to connect with neurosurgery-oriented medical students across New England was successful with representatives from 15 medical schools and hospitals over two years (Figure 1). There

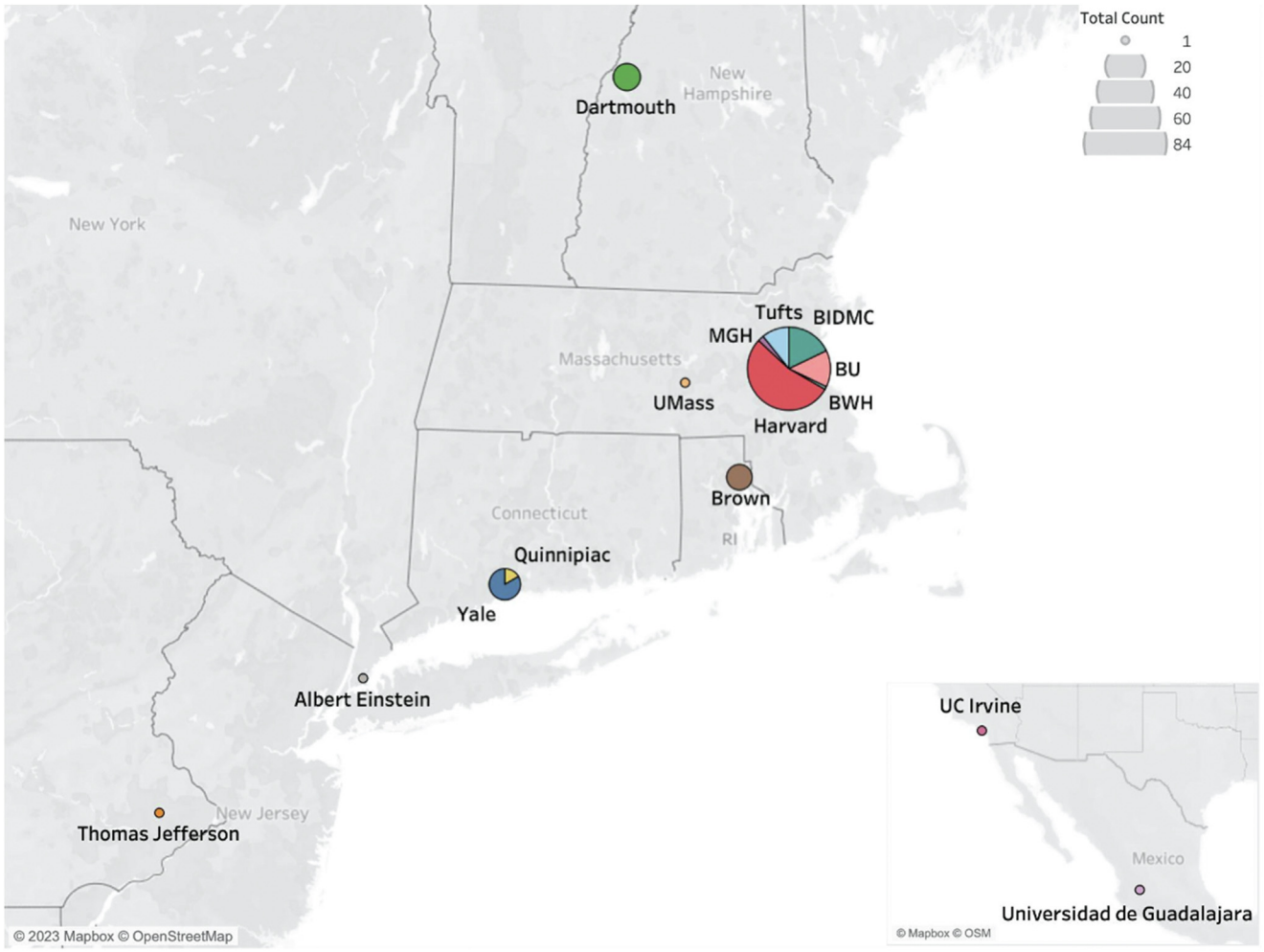


Figure 2. Map of represented institutions. Size of the dot is proportional to number of attendees, as depicted in the legend in the top right corner. Institutions in proximity were combined using a pie chart to show their relative breakdown in attendance. West coast institutions are depicted in the bottom right corner. The following medical schools and hospitals are represented: Dartmouth, Tufts, Massachusetts General Hospital (MGH), Harvard, Brigham and Women's Hospital (BWH), Boston University (BU), Beth Israel Deaconess Medical Center (BIDMC), University of Massachusetts Chan (UMass), Brown, Quinnipiac University Netter, Yale, Albert Einstein, and Thomas Jefferson Kimmel.

were 80 and 77 attendees in the 2022 and 2023 editions, respectively. Most medical students in attendance hailed from Harvard and Boston University medical schools given their proximity to the event. However, there was a tremendous diversity of institutions that were represented, including students from as far as California and Mexico (Figure 2). The majority of attendees at the 2023 course had not participated in the 2022 course (41 out of 50 respondents). Most attendees were early in their training, with the majority of participants being first- or second-year medical students (Table 2). Additionally, more advanced trainees, including third and fourth-year medical students, residents, and graduate students, were in attendance as well.

Unsurprisingly, the participants in this course had greater interest in neurosurgery (6.7 ± 0.3 in 2022 and 8.5 ± 0.3 in 2023) relative to other interventional specialties (5.8 ± 0.3 in 2023). However, before attending the course their comfort with both the principles of neurovascular disease management (4.5 ± 0.6 in 2022 and 3.9 ± 0.3 in 2023) and vascular neuroanatomy (4.4 ± 0.5 in 2022 and 4.7 ± 0.4 in 2023) were subjectively lower (Table 3). Notably, only 13.6% of students who were not from the host institution reported any access to neurosurgical simulation or hands-on opportunities in vascular neurosurgery at their home institutions.

In both iterations of this course, the organizers were met with an overwhelmingly positive response. Following the conclusion of the event, attendees approached the event organizers in person or via email to share their enjoyment of the course, excitement for vascular neurosurgery, and ideas for future events. In addition to

Table 2. Presurvey Demographic Results

Attendee Level of Training	Count (%)	
Level of Training	**2022, n = 41**	**2023, n = 50**
M1	20 (48.8)	21 (42)
M2	11 (26.8)	8 (16)
M3	2 (4.9)	2 (4)
M4	0	4 (8)
MS NOS	6 (14.6)	8 (16)
Graduate student	0	3 (6)
Resident	2 (4.9)	3 (6)
Primary clinical interest (2023)		
Specialty	Count (%)	
Neurosurgery	35 (70)	
Other interventional specialty	8 (16)	
Noninterventional specialty	1 (2)	
Fully undifferentiated	6 (12)	

Percentage of attendees at the 2022 and 2023 courses by level of training. Participants selfidentified by year of medical school (M1, M2, M3, M4), as a medical student without listing their year (MS NOS — Medical Student Not Otherwise Specified), as a graduate student (including research fellow, master's student), or resident. Medical students that attended the 2023 course were asked if their current primary specialty interest was neurosurgery, a surgical or interventional specialty other than neurosurgery (including general surgery, interventional radiology, interventional radiology, etc.), a non-interventional specialty (internal medicine, psychiatry), or fully undifferentiated.

subjective reports of satisfaction, postcourse surveys demonstrated significantly improved comfort with neurovascular disease management (from 4.8 ± 0.6 to 6.6 ± 0.5 in 2022 and 3.9 ± 0.4 to 6.8 ± 0.3 in 2023, $P < 0.01$) and neuroanatomy (from 4.9 ± 0.6 to 6.5 ± 0.4 in 2022 and 4.8 ± 0.4 to 6.9 ± 0.4 in 2023, $P < 0.001$). Furthermore, students performed well on a challenging postcourse quiz testing principles of neurovascular disease and the procedures they practiced during the 2023 course. Forty-one students averaged a score of 7.2 out of 10 with a standard deviation of 2.1.

Students also provided feedback to improve the course going forward. In general, attendees appreciated the hands-on sessions and requested more time or more simulators to prevent bottlenecking of longer simulations such as micro suturing. Furthermore, some students advocated for small-group didactic sessions to facilitate networking among medical students from different schools throughout the event. Finally, many of the first-year medical students suggested that learning materials be distributed before the event so they could better prepare for material they had yet to cover in their respective curricula.

Table 3. Comparison Between Precourse and Postcourse Surveys

Year	Question	Precourse	Postcourse	Paired *t*-Test
2022 (n = 15)	Familiarity with neurovascular disease and neurosurgery	3.1 ± 0.3	–	–
	Interest in pursuing neurovascular neurosurgery	6.2 ± 0.5	7.2 ± 0.5	0.15
	Comfort with neurovascular disease management	4.8 ± 0.6	6.6 ± 0.5	0.003
	Comfort with relevant neuroanatomy	4.9 ± 0.6	6.5 ± 0.4	0.001
2023 (n = 33)	Interest in pursuing neurovascular neurosurgery	8.7 ± 0.3	8.9 ± 0.3	0.419
	Interest in pursuing other interventional specialty	5.9 ± 0.4	6.7 ± 0.4	0.07
	Comfort with neurovascular disease management	3.9 ± 0.4	6.8 ± 0.3	<0.001
	Comfort with relevant vascular neuroanatomy	4.8 ± 0.4	6.9 ± 0.4	<0.001

Participants provided responses to survey questions using a 10-point Likert-like scale before and after the event, with only participants that completed both surveys were included for comparison with paired t-Test. All scores are reported as mean ± standard error.

DISCUSSION

The neurovascular disease management course was a remarkable success, drawing approximately 80 potential future neurosurgeons each year. The attendees, predominantly in their first or second years of training, hailed from 15 different medical schools and hospitals. Despite limited prior exposure to vascular neurosurgery, the interest among students was high. The course not only received positive verbal and written feedback but also led to a statistically significant improvement in students' comfort with vascular neuroanatomy and disease management as demonstrated by the postcourse surveys and quiz performance. Feedback for future courses included requests for more hands-on simulation time and small-group didactic sessions, indicating a robust enthusiasm for the neurovascular specialty among potential future neurosurgeons.

When we set out to create this course, outreach to students who otherwise may not have immediate access to practical education in vascular neurosurgery was of central importance. As most attendees are first- and second-year medical students, the impact of our courses on their residency applications is yet to be determined. However, an interesting future direction of this work is to longitudinally track students who participated in this event to study the impact of early exposure to neurosurgery via simulation on ultimate residency and fellowship decisions. Ostensibly, the course was a

valuable and rare opportunity to simulate the experience of being a vascular neurosurgeon. The responses were also resoundingly positive with many students verbally sharing how they were considering neurosurgery much more seriously after the conclusion of the courses. Looking forward, we plan to establish a more formal method to track how the course influences students' interest in neurosurgery and their decisions to specialize in the field.

Bridging theoretical knowledge with practical skills, the use of simulation in medical education has gained popularity over the past decades in concert with decreasing costs and improving simulation technology. While residents and attendings unsurprisingly have been among the first users of surgical simulation, these tools have been making their way into undergraduate medical education as well, with multiple papers in the literature reporting the efficacy of simulation.[12] In the hands of medical students, simulation has the additional benefit of providing students with scaffolding to encode information they may otherwise only encounter in textbooks. But perhaps most crucially, the physical performance of procedures also provides students with more concrete data to aid in evaluating their future specialty.

The increased implementation of simulation within curricula is reflective of the general need for a sophisticated and multifaceted educational approach. Many institutions are transforming curricula by shortening their preclinical years and focusing on a more case-based interactive style of teaching.[13,14] Increased student engagement with the material has proven to be superior for retention and satisfaction, and utilization of simulation technology is a valuable extension of this trend.[8] Overall, adaptive efforts like the neurovascular disease management course are essential to expose students to the ever-diverging subspecializations in medicine like vascular neurosurgery.

Future Direction

We aim to continue our annual tradition with some modifications. First, we will make our didactics sessions completely case-based and integrate simulations into several of the cases. This will further increase the interaction of the students with the material and hopefully boost their retention and satisfaction. Second, we will build more chances for students to network amongst themselves and with faculty and residents. Students consistently expressed that the opportunity to connect with others interested in the field of neurosurgery from different institutions was valuable in terms of future collaboration as well as building a supportive community in the face of an arduous training path. In the same vein, our last and arguably most important modification will be to increase our outreach to other medical schools. Not only will this increase the diversity of our attendees and provide opportunities to those with interest, it will also encourage institutions in other regions of the country to create interactive courses that are similarly open to all. Ultimately, with early outreach and a collaborative spirit, we can make the future of vascular neurosurgical education more accessible to medical students across the country.

Limitations

As this article is primarily descriptive in nature, the results of this analysis are mostly limited to participants' subjective experiences. Additionally, for objective measures such as the end-of-course survey, there was no comparison group to analyze the performance of students who did not attend the course. It would be interesting to carry out this comparison in the future, as well as analyze more objective measures of performance and knowledge retention postcourse. Additionally, we aim to follow students longitudinally to determine the impact of this course on the ultimate choice of specialty; however, we only report the results of this course over two years at present. We eagerly await the opportunity to further evaluate the impact of the neurovascular disease management course in these contexts.

CONCLUSIONS

An up-to-date and interactive course on vascular neurosurgery may be an effective vehicle to provide medical students with exposure to the field and the opportunity to learn the fundamentals.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Justin Gelman: Writing — review & editing, Writing — original draft, Visualization, Project administration, Methodology, Formal analysis, Conceptualization. **Jean Filo:** Writing — review & editing, Writing — original draft, Visualization, Project administration, Methodology, Formal analysis, Conceptualization. **Felipe Ramirez Velandia:** Writing — review & editing, Project administration. **Alejandro Enriquez-Marulanda:** Writing — review & editing, Project administration. **Sarah Blitz:** Writing — review & editing, Project administration. **Sandeep Muram:** Writing — review & editing, Project administration. **Anirudh Penumaka:** Writing — review & editing, Project administration. **Charles Mackel:** Writing — review & editing, Project administration. **Michael Young:** Writing — review & editing, Project administration, Conceptualization. **Jonathan Pace:** Writing — review & editing, Project administration. **Hormuzdiyar Dasenbrock:** Writing — review & editing, Project administration. **Adel Malek:** Writing — review & editing, Project administration. **Philipp Taussky:** Writing — review & editing, Project administration. **Justin Granstein:** Writing — review & editing, Project administration. **Christopher S. Ogilvy:** Writing — review & editing, Writing — original draft, Supervision, Resources, Project administration, Methodology, Conceptualization.

ACKNOWLEDGMENTS

The authors would like to thank Deidre Buckley, NP for administrative assistance and networking to bring the course to fruition.

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Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 12 March 2024; accepted 20 July 2024

Citation: World Neurosurg. (2024) 190:e394-e402. https://doi.org/10.1016/j.wneu.2024.07.146

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***

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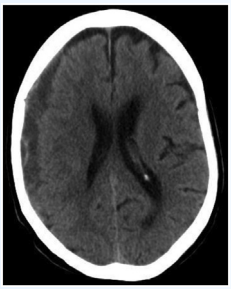
Supplementary Table 1. 2023 Quiz Questions and Answer Key

Question	Answer Choices
What type of brain hemorrhage is aneurysm rupture mostly associated with?	**Subarachnoid hemorrhage**
	Subdural hemorrhage
	Epidural hemorrhage
	Intracerebral hemorrhage
What is the greatest modifiable risk factor for an ischemic and hemorrhagic stroke?	Cigarette smoking
	Age
	Hypertension
	High-fat diet
Which of the following sequences is most sensitive in detecting a recent stroke?	T1 with contrast
	FLAIR
	Non-contrast computed tomography
	DWI
The standard treatment for carotid disease is:	Coiling
	Endarterectomy
	Stenting
	Flow diversion
What is the gold standard test for diagnosing brain aneurysms?	Computed tomography angiography
	Magnetic resonance angiography
	Digital subtraction angiography
	Ultrasound
The catheter is advanced first before the guidewire in angiography.	TRUE
	FALSE
What are the most common access points for cerebral angiography?	Femoral vein and radial vein
	Subclavian artery and femoral artery
	Femoral artery and radial artery
	Radial artery and subclavian artery
Which of these diseases involved both a feeding artery and a draining vein?	Cavernous malformation
	Arteriovenous malformation
	Moyamoya Disease
	Aneurysm
How long after last-known-well are patients eligible for mechanical thrombectomy?	4.5
	6
	24
	48

Quiz questions and answer options from the 2023 course postcourse quiz. Answer options are shown with the correct answer bolded for each question.

Continues

Supplementary Table 1. Continued

Question	Answer Choices
Describe the image:  Case courtesy of Bahman Rasuli, Radiopaedia.org, rID: 160,118	Subarachnoid hemorrhage **Subdural hemorrhage** Epidural hemorrhage Intraparenchymal hemorrhage

Quiz questions and answer options from the 2023 course postcourse quiz. Answer options are shown with the correct answer bolded for each question.