CHAPTER 2

Simulation of Acute Neurology

Neurology has many subspecialties. Among these, acute neurology (or neurocritical care) stands out because it involves acute care of disorders that are potentially life threatening or that may lead to major permanent disability. In addition, multisystem care is anticipated in acute neurologic conditions and is often disease specific. The care of the multitude of these problems requires close cooperation with emergency medicine physicians, neurosurgeons, and infectious disease consultants but also rehabilitation physicians and palliative care specialists. These numerous links to other specialties open up a wide range of simulation possibilities.[1−6]

It is no exaggeration to say that current curricula do not guarantee adequate exposure to major neurologic emergencies for physicians in training simply because these emergencies occur infrequently and at all hours of the day.[7,8] The key question is whether simulation can fill this void. Simulation of acute neurology, compared with other emergency specialties, is in its infancy.[9] Simulation challenges the traditional didactic methods of classroom lectures and direct observation of trainees' clinical skills. However, comparing these two educational methods for efficacy would be cumbersome in the absence of established metrics. Moreover, not all acute neurologic illnesses are conducive to simulation simply because specific technology is not available or actors are not able to reasonably mimic the disorder.

In this chapter, we introduce the rationale for simulation of acute neurology including future opportunities. Simulation of acute neurology and neurocritical care is achievable. Acute neurology can be simulated as long as scenarios concentrate on management of the disorder rather than portrayal of neurologic signs. Simulation of acute neurologic conditions is far from being established and standard. Adjustments to scenarios—mostly major improvements rather than simple tweaks—are expected in institutions working through a simulation program and each institution will have a number of specific challenges and preferences.

TEACHING ACUTE NEUROLOGY

Simulation in acute neurology must center on clinical decision-making.[9] These decisions may involve developing a plan of action, administering appropriate drugs, interpreting neuroimaging, making a clinical diagnosis, and understanding and addressing systemic complications related to acute neurologic injury. Scenarios can be built to foster a sense of urgency, while teaching avoidance of errors[11,12] and actions to address the intricacies of cerebral resuscitation. Morbidity and mortality meetings offer good ideas for building scenarios (Chapter 3), but simulation must go beyond teaching near misses or errors to focus on recognition of difficult presentations and how to work rapidly through a differential diagnosis.[13] Teachable scenarios may include recognition of imminent neuromuscular respiratory failure, recognition of a deteriorating patient with an acute brain lesion, and treatment of refractory status epilepticus. One area in which simulation might outshine all other teaching methods is the area of interpersonal communications (i.e., communication with patients, family members, and other medical staff). For example, scenarios can point out the unique challenges involved in managing a patient emergency while fielding questions from their family, giving "bad news," or discussing brain death. This type of role-play can reinforce important communication techniques and strategies.

When it comes to teaching acute neurology, there are both opportunities and roadblocks. First, its urgency may not be appreciated (enough) by physicians. Second, opportunities to teach decision-making skills at the point of care, and management of critical neurologic states rarely occur in clinical practice, and third, what defines "competency" in handling these acute situations is unknown. Most problematically, major components of the neurologic examination do not lend themselves to any form of simulation, and as mentioned in the previous chapter, the costs and labor involved are high. Finally, neuroemergencies have been duly established as an entrustable professional activity (EPA) correlated to milestones within the Accreditation Council for

Graduate Medical Education core competencies. Unlike the other five EPAs, however, neuroemergency EPAs are not consistently taught.[5,7,8,10]

Acute neurology as a specialty encompasses diseases with high levels of morbidity and mortality. The morbidity of neurologic illness involves the personalities and emotional lives of our patients. Discussing goals of care and ethical conflicts with acutely distraught patients and families in the setting of acute neurologic illness—where some time pressure may exist—requires practice but can be taught. Video playback documents the learner's body language, use of medical jargon, and handling of ethical dilemmas. Such complex personal interplays, not infrequently seen in emergency settings, can only be created in a simulation center and not in general teaching rooms.

APPLICATION OF SIMULATION TO ACUTE NEUROLOGY

Simulation-based education in general practice correlates positively with physician performance and even patient outcomes.[15,16] Incorporating neurology-specific scenarios into simulation can ensure that specific EPAs are met. Simulation provides an artificial environment in which to manage neurologic emergencies, choose appropriate tests, and also to hone skills and strategies for communicating with family members. Effective learning often occurs when physicians err while facing neurologic emergencies. In contrast to traditional teaching methods, simulation can induce a stress response that very effectively mimics what learners will eventually feel when faced with a "real" emergency, an unknown clinical situation in flux, or a complication as a result of treatment decisions or an error. However, simulation is not all about "doing" (i.e., performing a physical examination); it often involves focused "thinking" (e.g., interpretation of the clinical history, neurophysiology, and neuroimaging).

Under the direction of a creative, committed instructor, neurosimulation can assume as much urgency as any other critical care simulation (e.g., cardiac arrhythmia, cardiopulmonary resuscitation, polytrauma). Neurosimulation presents the principles of brain protection and exposes learners to largely unfamiliar drugs and side effects (e.g., osmotic diuretics, antiseizure drugs, and thrombolytics). It can also provide a window into end-of-life care for a comatose patient, which differs significantly from general palliative care measures.

Setup and Equipment

Simulation of acute neurology requires rooms and hardware currently standard in most simulation centers. The setup and rooms needed are shown in Fig. 2.1. Successful learners will be busy from start to finish of the exercise. Instructors will use the Sim man when appropriate and specifically when pulmonary complications are part of the scenario (Fig. 2.2). Some scenarios such as trauma (Chapter 4) lend themselves best to demonstration of team work and leadership (Fig. 2.3).

How to Portray Neurologic Disease?

Elusive, mysterious, and only for well-trained neurologists, the neurologic examination has been considered the "crown jewel" of physical examination. How then is it even possible to simulate such a complex examination? Would any attempt at imitating a finding be ridiculous (or awkward at best)? Would acting it out devalue the beauty of the examination? Is it not already laughable or painful to watch actors portray a patient with a neurologic disease (with the possible exceptions of Daniel Day Lewis in *My Left Foot* and Emmanuelle Riva in *Amour*)? Would cynics say that only psychogenic weakness can be imitated?[17,18]

These valid criticisms cannot be fully countered, but the current experience is quite different—indeed better—than what most of us initially expected. Simulation centers with mannequins, actors, and well-prepared instructors can create a very teachable situation.

Actors (often experienced nurses) can do more than most physicians intuitively believe, and we and others have been impressed with what they are able to simulate (Fig. 2.4).[19,20] As long as scenarios focus on a few major signs, several classic neuroemergencies can be imitated. Examples of applications to simulation in acute neurology are shown in Table 2.1. Several disorders can be taught quite nicely, and while the teaching of specific scenarios is further discussed in the second part of this book, we offer the following examples.

To encourage learners to recognize and manage the early complications of aneurysmal subarachnoid hemorrhage, an actor describes symptoms when asked (Chapter 7). When the learner elicits a history of thunderclap headache and orders a CT scan, the scan shows diffuse subarachnoid blood and early hydrocephalus. The monitor displays severe hypertension with a BP of 190/140 mmHg. Shortly after antihypertensive drug administration, the patient suddenly develops a severe headache, has a "seizure," and becomes unresponsive with a Cushing reflex. At this point, the learner ideally

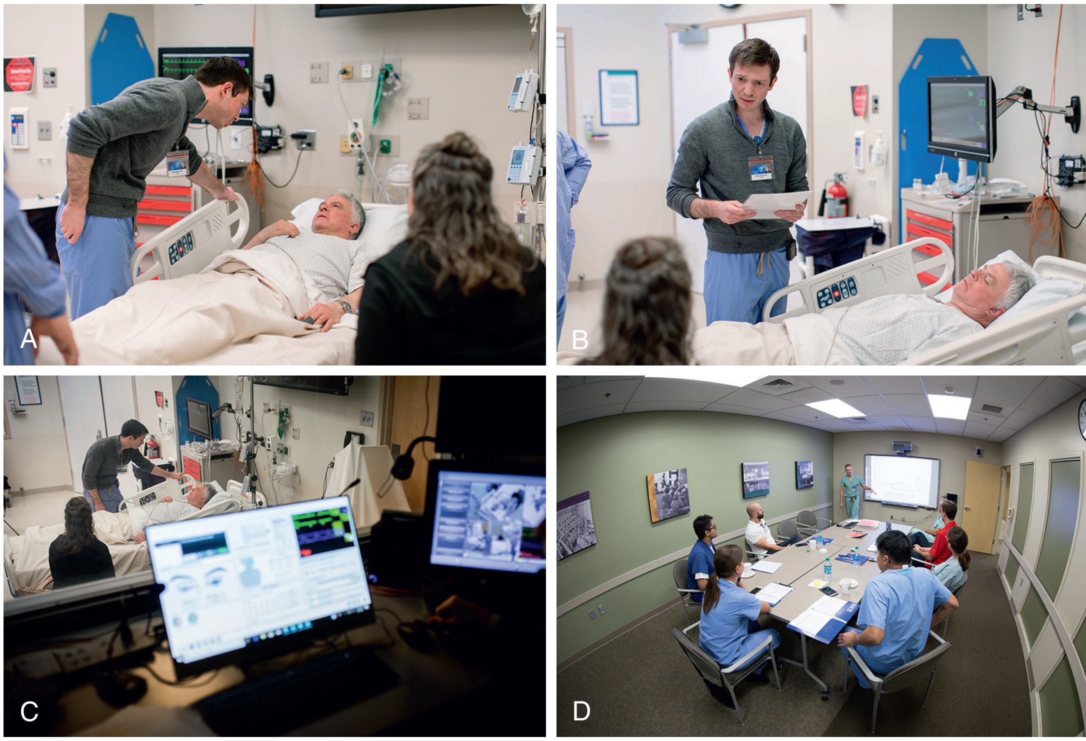

FIG. 2.1 Setup of simulation, showing interview of the simulated patient **(A)**, taking history of family **(B)** Control room **(C)**. Debriefing room allowing discussion of the scenario and also reviewing of taped interactions **(D)**.

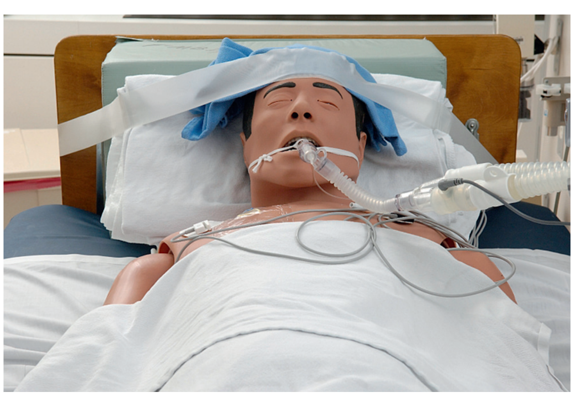

FIG. 2.2 Example of a simulation mannequin (SimMan 3G, Laerdal Medical, Wappingers Falls, NY).

recognizes aneurysmal rebleeding, reexamines the patient, and assesses the airway. Concerned about progressive hydrocephalus, the learner should request a CT scan and neurosurgical evaluation. At this point, if the learner states that emergent cerebrospinal fluid (CSF) diversion is needed, the scenario ends. Alternatively, if the resident does not answer appropriately, the heart rate drops to 30 bpm and BP increases to 230/110 mmHg resulting in respiratory and circulatory arrest. This scenario highlights two serious early complications of subarachnoid hemorrhage: rebleeding and hydrocephalus. Teaching points include early avoidance of beta blockade, as the patient is at risk for bradycardia due to a Cushing reflex during rebleeding; worsening hydrocephalus; early aggressive blood pressure control to reduce the risk of rebleeding; and recognition of hydrocephalus and the need for emergent CSF diversion.

We found myasthenic crisis to be ideally suited to simulating neuromuscular respiratory weakness (Chapter 11). Neuromuscular respiratory failure can be simulated by an actor instructed to use interrupted speech while catching a breath, to lean forward, to elevate the shoulders, and to breathe paradoxically in the supine position. Moisture is applied to the actor's forehead while tachycardia and hypertension are displayed on the monitor. If this is not recognized as imminent failure and appropriately managed, the patient develops frank

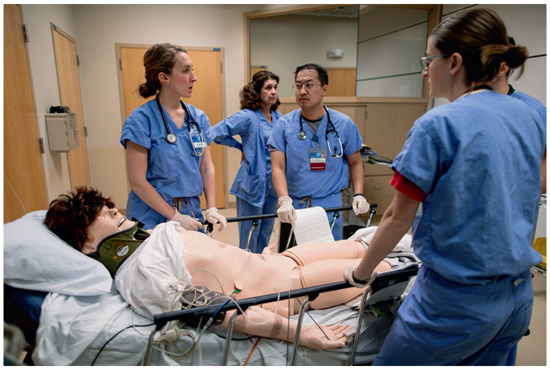

FIG. 2.3 Setup of trauma mannequin emphasizing team work, individual responsibilities, and leadership skills.

respiratory failure that requires intubation. While the learner communicates and writes admission orders, the patient becomes drowsier, the heart rate increases, and oxygen saturation declines. Where noninvasive ventilation may have previously sufficed, the learner now must call for emergent intubation and deal with the risks therein including apnea and cardiovascular collapse. If the learner recognizes impending neuromuscular respiratory failure, triages the patient to an intensive care unit, and initiates noninvasive ventilation or endotracheal intubation and mechanical ventilation, the patient survives without complications.

Treatment for status epilepticus can be taught in different ways (Chapter 12). The patient may develop refractory shock after receiving lorazepam, fosphenytoin, and pentobarbital loading for refractory status epilepticus. Laboratory evaluation can show a marked metabolic acidosis with an elevated serum lactate level, hyperosmolality, and increased osmolar gap. The teaching point for the learner is to appreciate that propylene-glycol toxicity can complicate a barbiturate coma and, consequently, to substitute another drug for the pentobarbital infusion. Alternatively, the patient may develop a cardiac arrhythmia during fosphenytoin loading, which, if recognized, should prompt the learner to discontinue the infusion and treat with an appropriate alternative.

Focal status epilepticus in the setting of epidural empyema can also be simulated. The actor is instructed to keep his eyes open and stare forward, repetitively move the fingers or arm on one side of the body while not moving the other, and remain unresponsive. Ultimately, the actor may be prompted to have generalized stiffening; clenching of the teeth; extension of the neck, trunk, and legs; and flexion of the previously motionless side. Fever may be shown. Teaching points can include the importance of CT scan before lumbar puncture, empiric initiation of antimicrobial agents, and indications for emergent electroencephalography. An ideal neurosimulator would show a number of eye-movement abnormalities (nystagmus, ocular bobbing) and changes in eye position with vestibular stimulation. Different coordinated, synchronized motor movements (decorticate, decerebrate posturing) could potentially be simulated with a computer monitor displaying preset EEG patterns, transcranial Doppler data, and other monitoring data including intracranial pressure from a placed probe.

Portraying aphasia and hemiparesis through neurosimulation is perhaps inadvisable, but global aphasia (not Wernicke's aphasia) can be successfully directed simply by having the actor say one repeated word such as "no," or "good." Hemiparesis and hemiplegia can be shown as a drift or complete flaccidity, respectively (testing of muscles for hemiparesis would show give-way weakness, and thus, we avoid this level of detail). Motor movements are limited, but convulsions with eye deviation could convey sufficient reality. The same applies to picking behaviors and chewing with focal seizures.

However, certain findings cannot be imitated; these are clonus, pyramidal weakness, increased tone, many movement disorders, and gait ataxia. Any of these would be indistinguishable from functional disorders. Traumatic brain injury can be extended to polytrauma but also may teach initial management of intracranial hypertension, prevention of further spinal cord injury, and initial resuscitation measures (e.g., which fluids to use, appropriate blood pressure targets, and best practices for monitoring potential instability of vital signs). A team approach may be best for practicing a level 1 trauma.

How to Teach Successful Family Conferences on Patients With Neurologic Injury?

Simulation centers are ideal for role-play with carefully constructed scenarios (Chapter 18). Such role-play can include leading a family conference for a patient with a catastrophic neurologic disorder. Families play large roles in decision-making, and conflicts can be easily simulated. The importance of these interactions cannot be emphasized enough because (1) they are unique, (2) they require clear explanations of the neurologic disability in lay terms, and (3) they draw on the real-life experiences of

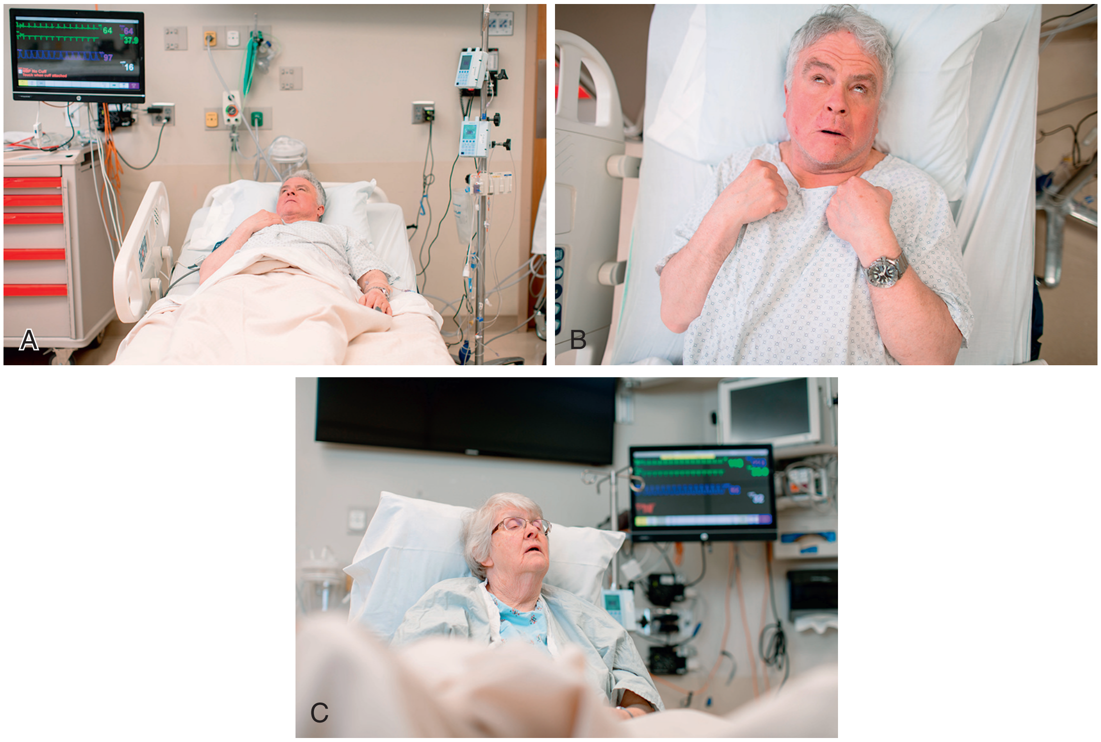

FIG. 2.4 Examples of portrayals by actors (**A**, stroke with hemiplegia and neglect favoring one side; **B**, seizure with flexed arms and rolled-up eyes; **C**, myasthenia with ptosis, bifacial palsy, and shortness of breath).

neurointensivists or emergency physicians who do this every day. One scenario might be a conference with the family of a comatose patient with a catastrophic hemorrhage. Confederates can portray estranged siblings fighting about the plan of treatment based on their own values. The learner must (1) explain the families' role as surrogate decision maker to them while emphasizing that the focus should be on what the patient would want, (2) help family members identify what their loved one would find acceptable if she could speak for herself, (3) allow family members to speak individually about their concerns, and (4) identify a course of action acceptable to all. This scenario can play out in many different ways. If the learner sides with one faction or the other, reinforcing the divide between them and angering the other party, he or she must then defuse the situation created. Others may lose control of the discussion, get lost in the individual beliefs of both surrogates, and ultimately, fail to redirect the focus to the wishes of the patient. The addition of time urgency to the discussion can significantly alter the difficulty level of these scenarios.

TABLE 2.1
Neurologic Signs Suitable for Portrayal by Actors

• Forced gaze deviation and apraxia of eyelid opening
• Facial twitching (cheek)
• Hemianopia
• Vertical eye movements only (locked-in syndrome)
• Neck stiffness
• Global aphasia (mute or only "no" or "good")
• Complete paralysis—arm[a]
• Complete paralysis—leg[a]
• Complete paraparesis[a]
• Sensory level (to be detected with pinprick)[a]
• Neglect and anosognosia
• Seizures (some types)
• Myoclonic twitches, asterixis (possibly)
• Accessory respiratory muscle activation and paradoxical breathing (neuromuscular respiratory failure)
• Posturing

[a] Pain stimuli are mentioned—not applied.

What Props and Devices Are Available?

Mannequins are commonly used for training,[19,21,22] although they are not suited for simulation of most neurologic diseases. Mannequins can simulate eye opening, blinking, pupillary changes (limited to reactivity and symmetry), and "shaking" or shivering. If necessary, mannequins can "talk" when an instructor in the control center serves as the "voice-over," offering simple comments such as "it hurt so bad, never had this before." In some situations, such as subarachnoid hemorrhage, they can make the mannequin moan as if from a headache. Independent of the mannequin, the simulation software can display changes in vital signs, which can include cardiac arrhythmias (e.g., during phenytoin loading), hypotension (e.g., sepsis with bacterial meningitis), hypothermia (e.g., myxedema coma), and hypoxemia (e.g., after seizure).

In acute neurology, neuroimaging (mostly CT and CT angiogram, chest and cervical X-rays) should be available on a workstation in the room. Laboratory values are presented on paper or recorded on a whiteboard as requested by the learner. Pupillary abnormalities can be displayed on a photograph but frequently do not add enough diagnostic value to justify the reduction in realism.

Moulage is useful to show skin abnormalities. Some examples, including needle tracks in a comatose patient, make-up rash in encephalitis or bacterial meningitis, and pre-made sweat formulas, are available to portray patients with acute neuromuscular respiratory failure, and edible moulage can mimic a tongue bite from a seizure. The use of props requires innovative thinking and a willingness to suspend reality, but learners accept these limitations.

Future Challenges in Neurosimulation

The question remains if we can build (or need) a neurosimulator. An ideal neurosimulator would be able to demonstrate eye-movement abnormalities (e.g., nystagmus, ocular bobbing) and changes in eye position with vestibular stimulation. It should be able to simulate coordinated, synchronized motor movements (decorticate or decerebrate posturing). The computerized neurosimulator could theoretically show preset EEG patterns, transcranial Doppler data, and intracranial pressure from a placed probe. Both lumbar puncture and ophthalmoscope models are already commercially available, but whether a neurosimulator (or any specialist-driven simulator) is financially feasible is unknown.[23−26] It remains to be seen whether neurologic findings are conducive to computer simulation.

Other opportunities have presented themselves, and there is interest in using telemedicine for simulation. Simulation of acute ischemic stroke using telestroke has been validated as an instrument to improve skills.[27]

CONCLUSIONS

As outlined in Chapter 1, simulation, even as currently practiced, requires substantial resources, including time, space, money, staff, and expertise, to maintain sustainability.[28] Instructors must be creative and committed. However, for the first time in neurology, educational opportunities exist to teach neuroemergencies safely. The challenge remains to write a scenario that is useful to the learner—not just a bag of tricks seeking to entrap him or her. In our experience, the response of the learners has been positive. Indeed, many commented that they entered into the exercise so fully that they forgot it was a simulation. One learner said, "Simulation makes me nervous—it is unreal." Actors can provide the basic neurologic findings needed to make a scenario successful. While learners know it is not a real stroke or seizure, they clearly and immediately recognize it as such and proceed with treatment. This book will show how these scenarios may effectively simulate situations encountered in acute neurology and how they have worked for us.

REFERENCES

1. Dhar R, Rajajee V, Finley Caulfield A, et al. The state of neurocritical care fellowship training and attitudes toward accreditation and certification: a survey of neurocritical care fellowship program directors. *Front Neurol*. 2017;8:548.
2. James ML, Dority J, Gray MC, et al. Survey of anesthesiologists practicing in American neurointensive care units as neurointensivists. *J Neurosurg Anesthesiol*. 2014;26:11−16.
3. Marcolini EG, Seder DB, Bonomo JB, et al. The present state of neurointensivist training in the United States: a comparison to other critical care training programs. *Crit Care Med*. 2018;46:307−315.
4. Markandaya M, Thomas KP, Jahromi B, et al. The role of neurocritical care: a brief report on the survey results of neurosciences and critical care specialists. *Neurocrit Care*. 2012;16:72−81.
5. Napolitano LM, Rajajee V, Gunnerson KJ, et al. Physician training in critical care in the United States: update 2018. *J Trauma Acute Care Surg*. 2018;84:963−971.
6. Wijdicks EF. The history of neurocritical care. *Handb Clin Neurol*. 2017;140:3−14.
7. Lerner DP, Kim J, Izzy S. Neurocritical care education during residency: opinions (NEURON) study. *Neurocrit Care*. 2017;26:115−118.

8. Moore FG, Chalk C. How well does neurology residency mirror practice? *Can J Neurol Sci*. 2005;32:472–476.
9. Papangelou A, Ziai W. The birth of neuro-simulation. *Neurocrit Care*. 2010;13:167–168.
10. Sheth KN, Drogan O, Manno E, et al. Neurocritical care education during neurology residency: AAN survey of US program directors. *Neurology*. 2012;78:1793–1796.
11. Dworetzky BA, Peyre S, Bubrick EJ, et al. Interprofessional simulation to improve safety in the epilepsy monitoring unit. *Epilepsy Behav*. 2015;45:229–233.
12. Salas D, Wilson KA, Lazzara EH, et al. Simulation-based training for patient safety: 10 principles that matter. *J Patient Saf*. 2008;4:3–8.
13. Stone J. Morbidity and mortality meetings for neurologists. *Pract Neurol*. 2008;8:278–279.
14. Kelly MA, Hager P, Gallagher R. What matters most? Students' rankings of simulation components that contribute to clinical judgment. *J Nurs Educ*. 2014;53:97–101.
15. Brydges R, Hatala R, Zendejas B, et al. Linking simulation-based educational assessments and patient-related outcomes: a systematic review and meta-analysis. *Acad Med*. 2015;90:246–256.
16. Cook DA. How much evidence does it take? A cumulative meta-analysis of outcomes of simulation-based education. *Med Educ*. 2014;48:750–760.
17. Hocker S, Schumacher D, Mandrekar J, Wijdicks EFM. Testing confounders in brain death determination: a new simulation model. *Neurocrit Care*. 2015;23:401–408.
18. MacDougall BJ, Robinson JD, Kappus L, et al. Simulation-based training in brain death determination. *Neurocrit Care*. 2014;21:383–391.
19. Micieli G, Cavallini A, Santalucia P, et al. Simulation in neurology. *Neurol Sci*. 2015;36:1967–1971.
20. Musacchio Jr MJ, Smith AP, McNeal CA, et al. Neurocritical care skills training using a human patient simulator. *Neurocrit Care*. 2010;13:169–175.
21. Braksick SA, Kashani K, Hocker S. Neurology education for critical care fellows using high-fidelity simulation. *Neurocrit Care*. 2017;26:96–102.
22. Ermak DM, Bower DW, Wood J, et al. Incorporating simulation technology into a neurology clerkship. *J Am Osteopath Assoc*. 2013;113:628–635.
23. Barsuk JH, Cohen ER, Vozenilek JA, et al. Simulation-based education with mastery learning improves paracentesis skills. *J Grad Med Educ*. 2012;4:23–27.
24. Gupta DK, Khandker N, Stacy K, et al. Utility of combining a simulation-based method with a lecture-based method for fundoscopy training in neurology residency. *JAMA Neurol*. 2017;74:1223–1227.
25. Larsen P, Stoddart H, Griess M. Ophthalmoscopy using an eye simulator model. *Clin Teach*. 2014;11:99–103.
26. McMillan HJ, Writer H, Moreau KA, et al. Lumbar puncture simulation in pediatric residency training: improving procedural competence and decreasing anxiety. *BMC Med Educ*. 2016;16:198.
27. Richard S, Mione G, Varoqui C, et al. Simulation training for emergency teams to manage acute ischemic stroke by telemedicine. *Med Baltim*. 2016;95:e3924.
28. Lazzara EH, Benishek LE, Dietz AS, et al. Eight critical factors in creating and implementing a successful simulation program. *Jt Comm J Qual Patient Saf*. 2014;40:21–29.