Incorporating Simulation Technology Into a Neurology Clerkship

David Matthew Ermak, DO; Douglas W. Bower, MD; Jody Wood, BS; Elizabeth H. Sinz, MD; and Milind J. Kothari, DO

From the Penn State Hershey Medical Center (Drs Ermak and Sinz), Anesthesia Associates of Lancaster, Ltd, in Pennsylvania (Dr Bower), the Penn State Hershey Clinical Simulation Center (Ms Wood), and the Penn State College of Medicine in Hershey (Dr Kothari).

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Address correspondence to David Matthew Ermak, DO, Penn State Hershey Medical Center, 30 Hope Dr, Hershey, PA 17033-2036.

E-mail: dermak@hmc.psu.edu

Simulation-based medical education is growing in use and popularity in various settings and specialties. A literature review yields scant information about the use of simulation-based medical education in neurology, however. The specialty of neurology presents an interesting challenge to the field of simulation-based medical education because of the inability of even the most advanced mannequins to mimic a focal neurologic deficit. The authors present simulator protocols for status epilepticus and acute stroke that use a high-fidelity mannequin despite its inability to mimic a focal neurologic deficit. These protocols are used in the training of third- and fourth-year medical students during their neurology clerkship at Penn State College of Medicine. The authors also provide a review of the pertinent literature.

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Simulation-based medical education (SBME) is an evolving method of training that allows medical practitioners to learn and perform clinical skills and interventions in a safe and controlled reproducible environment that replicates real-world situations.[1] The SBME method can involve a variety of aids including standardized patients, part-task mannequins (eg, a torso for cardiopulmonary resuscitation compression training), and whole-body advanced mannequins with high-fidelity capabilities.[2] Such high-fidelity mannequins, like the one used at Penn State College of Medicine, are able to run preprogrammed scenarios that can be manipulated in real time by a proctor. For example, a proctor can give the mannequin a "voice" by using a voice box and can manipulate the mannequin's vital signs including heart rate, blood pressure, and intracranial pressure. High-fidelity mannequins can also display clinical signs, including palpable pulses, pupil and eyelid reactivity, and visible respirations.

Medical educators are using SBME to teach communication skills, physical examination skills, identification of systemic problems, and clinical reasoning, as well as management of respiratory emergencies, advanced cardiac life support,[3,4] management of shock,[4] cardiac auscultation,[5] and various clinical procedures such as central line placement, thoracentesis, and paracentesis.[4] Simulators are also used to train medical professionals in rare clinical scenarios; for example, obstetrics and gynecology residents have used simulators to train for the management of magnesium toxicity and eclampsia.[6]

Although countless uses of SBME for teaching surgical and interventional procedures have been described,[3-6] published information regarding the use of simulation in neurology is scant, probably in large part because of the inability of high-fidelity mannequins to emulate focal neurologic deficits (eg, facial droop). This inability of high-fidelity mannequins is a substantial limiting factor in implementing SBME in neurology. At Penn State College of Medicine, however, we believe that SBME can be used for training in neurology despite the shortcomings of current simulator technology. In the present article, we describe Penn State College of Medicine's framework for using a high-fidelity mannequin to train medical students in 2 types of neurologic emergencies: status epilepticus and acute stroke (brain attack).

Simulation-Based Education at Penn State College of Medicine

At Penn State College of Medicine, we use SBME in the training of third- and fourth-year medical students during their neurology clerkship. We developed 2 main simulations for training our students: (1) evaluation and treatment of a patient with status epilepticus and (2) evaluation and treatment of a patient who has had an acute stroke. We use a high-fidelity mannequin programmed with particular vital signs and pupil responses; this mannequin is accompanied by a formal neurologic assessment available on request by the students. In the status epilepticus scenario, we augment the experience by having an actor play the role of a family member who is able to provide collateral information. Each session lasts approximately 1 hour: the simulation itself lasts approximately 15 minutes, and the remainder of the time is spent on debriefing.

In the status epilepticus simulation, students are provided general information about the case immediately before entering the simulation room. Once they enter, they are greeted by an actor playing the role of either the wife or son of the patient. The students are to question

the actor to gather a complete medical history (*Figure 1*). As the students proceed with their evaluation of the patient, they can see the vital signs on the monitor that accompanies the mannequin and can ask for the findings of the neurologic examination. They are also expected to ask for the results of individual laboratory and imaging tests (*Figure 1*). Students who successfully complete the scenario will diagnose status epilepticus and initiate a proper treatment protocol (*Figure 1*).

The acute stroke simulation has 2 scenarios (*Figure 2*). Students are provided basic patient history immediately prior to entering the simulation room. An actor can be available to provide collateral history, but it is not necessary; the physician facilitating the scenario can provide information regarding the patient's "last known normal" time. The students are provided formal neurologic examination findings on request. They are expected to ask for results of laboratory tests and computed tomography of the head, which are also available on request. Once the students are able to recognize the scenario as an acute stroke, they are asked to make decisions on management. In the setting of our first acute stroke scenario, the examination is consistent with brain herniation and the students are expected to withhold intravenous tissue plasminogen activator. In scenario 2, they are expected to administer the drug.

After the simulations, the students are able to review a video recording of their scenario for self-assessment. The physician facilitating the scenario provides further feedback and encourages discussion, focusing on the points listed in *Figure 1* and *Figure 2*. This step in the learning process allows for individualized instruction to address knowledge deficits that were identified during the simulation.

Comment

As previously mentioned, simulation of stroke and seizure is difficult because of the inability of current simulators to mimic a focal neurologic deficit. For this reason,

Figure 1.
Status epilepticus simulation protocol using a high-fidelity mannequin. This protocol is used by Penn State College of Medicine to train third- and fourth-year medical students during their neurology clerkships. [a] Liver function, toxicity screen, and blood alcohol content findings were available for select simulations. [b] The patient (ie, mannequin) is unable to talk initially, but after several minutes he is able to mumble. The patient appears disoriented and all history is obtained from his wife or son. *Abbreviations*: A, answer; Q, question; IV, intravenous; PE, phenytoin sodium equivalents.

Setup

An adult mannequin is on a stretcher with peripheral IV access in place (normal saline solution, 50 mL/h). Electrocardiography leads are off. Neurologic examination findings are available in a handout. The students wait in the hallway until video recording has started and then enter the room. The students are greeted by an actor portraying the patient's family member. The actor says, "You must be the neurology team. I'm so glad you're here." The simulation is completed with the actor providing patient information. The actor should try to redirect some of the questioning away from the mannequin. If the students continue to ask questions of the mannequin, the actor should redirect them by saying something like, "I'm having a lot of difficulty understanding him, too. He seems to be having trouble talking."

Overview

A 55-year-old man presents to the emergency department via ambulance with tonic-clonic seizure activity. The man is accompanied by his wife (or son), who called 911. The students are the neurology team and have been called to the emergency department to assess the patient 10 minutes after his arrival.

Findings

Vital Signs
Temperature, 38.5°C
Heart rate, 100 beats per minute
Blood pressure, 160/90 mm Hg
Respiratory rate, 16 breaths per minute
Oxygen saturation, 90%
Weight, 70 kg

Neurologic Examination
Generalized, rhythmic muscle twitching of upper and lower extremities, sweating, and salivating observed
Extraocular movements appeared intact without nystagmus; no facial droop noted (appears symmetric); tongue, uvula, and palate aligned with midline
Motor strength was difficult to assess, but the patient appeared to be moving all extremities equally
Reflexes, sensation, cerebellar functions, and gait were not assessed because patient was unable to comply with examination
Remainder of review of systems was unremarkable

Laboratory and Diagnostic Tests[a]
Serum glucose, 134 mg/dL
Arterial blood gas
  pH, 7.35
  P_{CO_2}, 41
  P_{O_2}, 68
Complete blood cell count and electrolyte levels within reference range
Prothrombin time, 12 s
Partial thromboplastin time, 36 s
International normalized ratio, 1.2

12-Lead Electrocardiogram
Normal sinus rhythm, 100 beats per minute

Standardized Actor's Knowledge

Course, Onset, and Duration
The patient was sitting on the couch when he started to have generalized rhythmic muscle contractions and relaxation. The patient was incontinent and possibly experienced a brief loss of consciousness. The incident occurred suddenly about 30 minutes ago. The duration was approximately 30 minutes.

Patient's Medical, Family, and Social History
Hypertension
Open cholecystectomy (1988)
A brother (aged 60 years) with hypertension and a son/daughter (alive and well at 30 years old)

Patient's Medical, Family, and Social History (continued)
Smokes 1 pack of cigarettes per day; drinks several beers per day (although none for past 1-2 days) (vague alcohol history from wife/son); no illicit drug use; lives with his wife; accountant
No known drug allergies
Medications include an antibiotic and past use of a "medication for seizures," which was stopped a few weeks ago

Answers to Questions the Students Should Ask[b]

Q: Any seizure disorder?
A: Well, he did have a few seizures in the past, but none recently.
Q: Any similar symptoms in the past?
A: Yes, a few times. I think the last one was a couple years ago. The seizures never lasted this long, though.
Q: Any family history of seizure disorder?
A: No.
Q: History of trauma?
A: No.

Q: History of stroke?
A: No.
Q: History of diabetes?
A: No.
Q: Any recent illnesses?
A: Yes—being treated for sinusitis.
Q: New medications?
A: Recently started on an unknown antibiotic for sinusitis (fluoroquinolones can decrease seizure threshold). Used to take a medication for seizures, but stopped because he didn't have any seizures for a while.

Expected Knowledge to Be Reviewed in Debriefing

Examination

Students should recognize the importance of ordering emergent noncontrast head computed tomography to rule out an acute stroke after the patient is stabilized.

Electroencephalogram findings revealing continuous seizure activity is diagnostic of status epilepticus.

Initial Management

Lorazepam (Ativan) (IV, 0.02 mg/kg)

Allow 1 minute to assess its effect. If seizures continue, administer additional lorazepam (up to a total of 0.1 mg/kg at a maximum rate of 2 mg per minute).

Initial Management (continued)

Phenytoin/fosphenytoin sodium (IV loading dose)

Administer using a second IV line (it will precipitate if given through same line as lorazepam).

Administer even if seizures stop with lorazepam to prevent recurrence.

Infusion of 20 mg/kg (or 20 mg/kg PE for fosphenytoin sodium) at maximum rate of 50 mg per minute (or 100 mg PE per minute).

Watch for signs of hypotension and cardiac arrhythmias.

Figure 1 *(continued).*
Status epilepticus simulation protocol using a high-fidelity mannequin. This protocol is used by Penn State College of Medicine to train third- and fourth-year medical students during their neurology clerkships.
[a] Liver function, toxicity screen, and blood alcohol content findings were available for select simulations.
[b] The patient (ie, mannequin) is unable to talk initially, but after several minutes he is able to mumble.
The patient appears disoriented and all history is obtained from his wife or son. *Abbreviations*: A, answer; Q, question; IV, intravenous; PE, phenytoin sodium equivalents.

we ask that our students use their imaginations during the SBME sessions. The localizing features of the examination play a small role in the care of such a patient, however; recognition of the diagnosis and decisions regarding acute therapy (ie, intravenous tissue plasminogen activator) are based largely on factors other than the fine details of the neurologic examination. In both the acute stroke and the status epilepticus scenarios, our students are assessed on their evaluation of the situation, their recognition of vital sign abnormalities (eg, Cushing triad), their time management in obtaining pertinent laboratory and imaging test results, and their decision-making skills. By stressing the recognition and management of a neurologic emergency rather than the recognition of localizing symptoms, we believe we have found an effective way to use SBME in a neurology clerkship that is not limited by current technology.

To our knowledge, few articles have been published regarding SBME in the field of neurology. The use of SBME for impending brain herniation with or without

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Setup

An adult mannequin is on a stretcher or bed, lying flat. The patient monitor is on, with oxygen saturation only running. Electrocardiogram is available. A noninvasive blood pressure cuff is hooked up but not reading. Oxygen source, nasal cannula, and non-rebreather are ready but not connected. A chair is available at the bedside for the standardized patient. Intravenous site is functional, and intravenous pump is ready but not connected. Three pages of results (12-lead electrocardiogram, neurologic examination, laboratory tests) are available upon request. A timer or other timekeeping method is ready (session lasts for 15 minutes).

Overview for Scenario 1

Figure 2.
Acute stroke (brain attack) simulation protocol using a high-fidelity mannequin. This protocol is used by Penn State College of Medicine to train third- and fourth-year medical students during their neurology clerkship. [a] Intensive care unit (ICU) status requires the patient to remain in the intensive care unit for 24 hours for close monitoring of neurologic status with frequent neurology checks, frequent vital sign checks, and stringent blood pressure goals, with a systolic blood pressure goal of less than 180 mm Hg.

A 70-year-old, right-handed man presented to the emergency department with right-sided weakness and slurred speech. He was initially lethargic but over the past hour has gradually become unresponsive. The patient's "last known normal" time was 90 minutes ago.

Findings for Simulation Scenario 1

Vital Signs
Blood pressure, 240/120 mm Hg
Pulse, 100 beats per minute (irregularly irregular)
Respiratory rate, 8 breaths per minute
Oxygen saturation, 90%
Neurologic Examination
Unresponsive to verbal and physical stimuli
Pupils: left 7 mm nonreactive, right 3 mm sluggishly
    reactive
Right facial weakness noted
No movement of extremities
Right side is flaccid
Toes are upgoing bilaterally

Laboratory Tests
Normal complete blood cell count, electrolytes,
    and coagulation profile
Electrocardiogram
Atrial fibrillation
Computed Tomography
Large hypodensity occupying the entire
    left hemisphere

Overview for Scenario 2

An 80-year-old man presented to the emergency department via ambulance with right-sided weakness (face, arm, and hand) and slurred speech. The patient's "last known normal" time was 45 minutes ago. The students are the neurology team and have been called to the emergency department to assess the patient.

Findings for Simulation Scenario 2

Vital Signs
Blood pressure, 160/80 mm Hg
Pulse, 104 beats per minute (irregularly irregular)
Respiratory rate, 15 breaths per minute
Oxygen saturation, 94%
Neurologic Examination
Extraocular movements intact without nystagmus or
    right visual field defect
Right facial droop
The patient was able to wrinkle forehead bilaterally
Tongue, uvula, and palate aligned with midline
Muscle strength
    Right upper extremity, 0/5 proximal and distal
    Right lower extremity, 4/5 proximal and distal
    Left upper and lower extremities, 5/5 proximal
        and distal
Reflexes
    Right upper extremity, 1+
    Right lower extremity and left upper and lower
        extremities, 2+
Sensation was difficult to assess, but it appears to be
    decreased in the right upper extremity and in the
    right side of face
Cerebellar functions and gait not assessed

Laboratory Findings
Serum glucose, 134 mg/dL
Arterial blood gas
    pH, 7.39
    P_{CO_2}, 41
    P_{O_2}, 68
    HCO_3, 24
International normalized ratio, 1.2
Complete blood cell count within reference range
Basic metabolic panel results within reference range
Liver function test results within reference range
Toxicity screen and blood alcohol content test negative
Electrocardiogram
Atrial fibrillation at 102 beats per minute
Computed Tomography
No acute intracranial abnormality

Expected Knowledge to Be Reviewed in Debriefing

Examination and Testing

Note the asymmetric pupil size

Increased blood pressure with blown pupil
  may be a sign of impending herniation

Electrocardiogram monitoring

Immediate noncontrast computed tomography
  of the head

Neurosurgical consult if needed

Initial Management

Monitor oxygen saturation; administer oxygen,
  initiate ventilator

Check pulses and blood pressure; administer
  antihypertensive medication to reduce mean
  arterial blood pressure to 120 mm Hg over
  a period of 2 to 6 hours

Acute Management of Ischemic Stroke
  (general guidelines)

Variables to consider

  Blood pressure

  Intravascular volume

  Serum glucose

  Temperature

  Oxygenation

  Head elevation (0°-15°)

Acute Management of Ischemic Stroke
  (general guidelines) *(continued)*

Indications for thrombolysis

  Clinical diagnosis of ischemic stroke with onset
    of symptoms within 3 hours of start of treatment

  Measurable neurologic deficits

Intravenous tissue plasminogen activator (0.9 mg/kg
  [maximum 90 mg] over a period of 60 minutes with
  10% given as bolus over 1 minute

After intravenous tissue plasminogen activator is
  given, initiate ICU status[a] with frequent neurology
  checks, monitor blood pressure, and maintain
  <180 mm Hg systolic

Contraindications for thrombolysis

  Recent trauma or surgery

  Recent myocardial infarction

  Pregnancy

  Persistent blood pressure >185 systolic

  Platelet count <100,000

  Serum glucose level <50 or >400 mg dL

  International normalized ratio >1.7

  Evidence of hemorrhage on computed
    tomography findings

  Very large area of infarction

Figure 2 *(continued).*
Acute stroke (brain attack) simulation protocol using a high-fidelity mannequin. This protocol is used by Penn State College of Medicine to train third- and fourth-year medical students during their neurology clerkship. [a] Intensive care unit (ICU) status requires the patient to remain in the intensive care unit for 24 hours for close monitoring of neurologic status with frequent neurology checks, frequent vital sign checks, and stringent blood pressure goals, with a systolic blood pressure goal of less than 180 mm Hg.

intracranial hypertension has been described in the literature, as this type of scenario does not necessitate the presence of a focal neurologic deficit other than an occasional pupillary asymmetry (which high-fidelity mannequins are currently capable of emulating).[7] Simulations using part-task mannequins have been shown to improve lumbar puncture skills in neurology residents.[8] Other uses of simulation in neurology have focused largely on critical care aspects including spinal shock, closed-head injury, and cerebral vasospasm. In these scenarios, a high-fidelity mannequin with real-time tracings of intracranial pressure and cerebral perfusion pressures was used. This mannequin was also equipped with a speaker box so that the proctor could speak for the simulated patient.[9]

The first (to our knowledge) described simulation of a stroke used accompanying video clips of real stroke patients with focal neurologic deficits to make up for the mannequin's incapacity to mimic such deficits.[10] It has been suggested that this type of work-around detracts from the believability of a scenario.[7] Because of the complexity and variety of focal neurologic deficits that exist, virtual patient simulations using computer-based technology have begun to emerge as potential mediums for enhancing education through simulation. In 2009, researchers created a computer-based virtual patient simulator called the Neurological Exam Rehearsal Virtual Environment, or NERVE, which has been used to teach the assessment and diagnosis of cranial nerve abnormalities.[11]

At Penn State College of Medicine, students are required to participate in the simulation scenarios as part of their curriculum. This requirement ensures that students gain experience in these scenarios, as the clinical variation during their rotation may not allow for adequate exposure. During the debriefing sessions, students participate in small groups in a lecture setting. A

1. **Feedback**
   Immediate assessment of a performance with discussion of educational material

2. **Repetitive practice**
   Skill repetition that allows for the student to correct errors and improve overall performance

3. **Curriculum integration**
   Simulation-based medical education that is part of a standard curriculum, not an extracurricular activity

4. **Range of difficulty level**
   Flexibility for the difficulty level to adjust based on the student's level of education

5. **Multiple learning strategies**
   Learning in multiple environments including large groups, small groups, and small group or independent learning without an instructor

6. **Capture clinical variation**
   Engaging the student in a wide variety of scenarios to which they may not otherwise be exposed

7. **Controlled environment**
   An environment in which there are no adverse outcomes to patients, which allows for the focus to be on the student and not on the patient

8. **Individualized learning**
   Active participation in a series of complex tasks that can be broken down into component parts, which allows for the mastery of each part at variable rates unique to each student

9. **Defined outcomes or benchmarks**
   Goals with tangible and objective measures

10. **Simulator validity**
    Degree of realism of the simulation

Figure 3.
Ten conditions that facilitate learning in simulation-based medical education.[13]

physician from the neurology faculty is present at each simulation to help guide the students through the scenario and to ensure a controlled environment. This faculty member also facilitates the postsimulation debriefing.

Simulation-based medical education has been shown to be most effective when paired with a debriefing session after the simulation to allow for self-reflection and identification of knowledge deficits.[6,12] A systematic review[13] revealed that 47% of all journal articles on the topic of the effectiveness of simulation-based education identified feedback as an important step in the learning process. This step was identified as the most important of 10 conditions that represent ideal circumstances for effective SBME (*Figure 3*).[13] Our students spend the majority of the 1-hour session on debriefing. This debriefing session is used to not only review what was done right and wrong, but also to integrate and affirm the newly learned information. Our program also has several of the other 10 conditions that are associated with effective learning in SBME, including integration into curriculum, controlled environment, clinical variation, and use of multiple learning strategies.[13] These strategies for learning were shown to be effective in a 2012 systematic review and meta-analysis by Cook et al.[14]

Simulation does not replace real patients, but it can help prepare students for real-life clinical scenarios.[1] As shown in a 2011 meta-analysis[15] by Cook et al of 609 studies on SBME, technology-enhanced education has been consistently associated with improved outcomes in knowledge, skills, behaviors, and even patient-related outcomes. In addition, SBME was endorsed as a method that is complementary to real patient-care experiences by the American College of Chest Physicians in their 2009 evidence-based guidelines on medical education.[16]

Conclusion

Without the backbone of traditional educational activities such as lectures, SBME could not be effective on its own; however, SBME can be used as an adjunct to train students in important clinical scenarios that they may not otherwise be exposed to in their clinical rotations. The scenarios described in the present article provide a framework for how SBME can be used in neurology despite the shortcomings of current technology. No outcome measures have been addressed, however. Further investigation is needed to determine the efficacy of our scenarios on educational outcomes.

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