Neuro-Critical Care Skills Training Using a Human Patient Simulator

Michael J. Musacchio Jr. · Adam P. Smith · Christopher A. McNeal · Lorenzo Munoz · David M. Rothenberg · Kelvin A. von Roenn · Richard W. Byrne

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Abstract

Background Neurosurgical trainees regularly encounter critical care situations. Traditionally, education was accomplished through lecture and experience. Increasingly, human patient simulators (HPS) are employed, allowing trainees to sharpen skills in a safe and realistic environment. We describe our experience using HPS in neurosurgical training.

Methods We developed a critical care training program for residents and medical students using HPS. We used a high-fidelity, lifelike Human Patient Simulator™ (HPS™) produced by Medical Education Technologies, Inc.™ to simulate realistic scenarios for trainee education. Topics included spinal shock, closed head injury, and cerebral vasospasm. A three-way evaluation model was employed to test validity, including pre- and post-exercise testing, survey feedback, and videotaped replay. The simulation exercises were conducted by a neuro-critical care attending, a senior neurosurgical resident, and a HPS technician.

Results We currently have 29 participants. On a 20-point critical care multiple-choice exam for these participants, average improvement has been 4.5 points or 25%. In subgroup analysis, average improvement was 4.75 points (24%) amongst neurosurgery residents, 3.07 points (18%) amongst neurology residents, 7 points (38%) amongst general surgery residents, and 7 points (38%) amongst senior medical students. Post-exercise evaluations were overwhelmingly positive.

Conclusions Neurosurgical critical care education is important for safe and effective care for patients. Clinical experience and didactic lectures help trainees obtain a solid knowledge base, but do not provide the benefit for learning in a fail-safe environment. Through the use of HPS, we have enhanced the critical care education of our trainees.

Keywords Neurocritical care · Human patient simulator · Neurosurgical training

Introduction

The clinical neuroscience field presents unique and complex critical care problems to residents and students. Traditionally, neuro-critical care education has been accomplished through didactic lectures and direct patient experience, with little repetitive training exercises otherwise. Residents and students, therefore, are commonly exposed to neuro-critical care emergencies as first responders with little to no practical training and thus are poorly equipped to handle such problems.

Patient simulators are being widely employed in educational models throughout all fields of medicine. In particular, they have been used to a great extent in anesthesia and critical care education [1–5]. Early incarnations of these simulators are the lifeless mannequins used for ACLS/BCS training as well as other rudimentary skill training models.

Today’s patient simulators are far more advanced and applicable to widespread medical specialties. Among the
The highest fidelity simulators are full-sized, computer-model driven mannequins that accurately mimic human responses to procedures, medications, and other treatment modalities. They respond to real-time, real-life clinical maneuvers, and allow trainees to experience critical care scenarios in a fail-safe environment.

Recently, we have incorporated the Human Patient Simulator (HPS™) made by Medical Education Technology, Inc.™ (METI™, Sarasota, FL) into our neuro-critical care education model. We have identified particularly common and troublesome areas of neuro-critical care, such as spinal shock, closed head injury, and vasospasm, and designed and implemented computer-based programs that expose residents and students to these topics. With this program, participants are provided with an environment that enhances neuro-critical care skills training while also gaining experience working as a team in stressful situations.

We describe our experience using the HPS™ to enhance neuro-critical care education for neurosurgical, general surgery, and neurological residents and students. We evaluate the efficacy and content validity of implementing this model, and report our results.

**Methods**

The Human Patient Simulator

In conjunction with the Rush University Simulation Laboratory (RUSL), we developed a neuro-critical care skills training program using a HPS made by METI™. The particular model used in our facility is a 5’11”, 167 lb computer-model driven, full-sized mannequin. Figure 1 shows a similar mannequin.

The HPS™ is capable of running pre-programmed clinical scenarios capable of real-time manipulation by the proctor in response to the current clinical actions. The mannequin responds to drug injections, endotracheal intubation and mechanical ventilation, electrocardioversion, and CPR among various other clinical maneuvers. It is capable of displaying clinical signs such as pupil and eyelid reactivity, palpable pulse, visible respirations, and measurable blood pressure. Specific to neurologic applications, the mannequin displays intracranial pressure and cerebral perfusion pressure recordings. The mannequin is also equipped with a speaker box in its mouth so that it may have a “voice” controlled by the proctor. Figure 2 shows the mannequin in the simulation setting.

RUSL

The RUSL houses the METI™ HPS™, among other interactive simulation devices. The lab set-up includes the HPS™ connected to a multi-functional terminal displaying vital signs such as pulse, blood pressure, oxygenation, intracranial pressure, and cerebral perfusion pressure. A fully functioning anesthesia machine is present to deliver mechanical ventilation and general anesthesia. A variety of simulated medications and a defibrillator are also available.

Adjacent to the HPS™ room is a command center consisting of the processors and software controlling the simulator. This center is controlled by the lab operator and proctor who can manipulate and amend the computer-driven program to adjust for real-time applications. From here, the exercise is driven according to the particular clinical specialty utilizing the space.

A classroom is attached to the center with multi-media capabilities. Students are able to watch live exercises taking place in the simulation lab via closed circuit television or watch their own exercises retrospectively. Computer and web-based presentations along with clinical lectures may be given in the classroom.
Study Design

We began using the RUSL and HPS™ to enhance our neuro-critical care education in 2004. We originally designed three general clinical models, which have been programmed into the HPS™ computer system. These models include spinal shock, closed head injury, and cerebral vasospasm. An example of our spinal shock clinical scenario is provided in Fig. 3. The purpose of these HPS-assisted critical care exercises is to enhance resident and medical student education, while providing an opportunity to practice performing as a team in stressful environments.

To test the efficacy of this education tool, we enrolled 29 volunteer participants into the study. The participants were comprised of junior level neurosurgical residents, general surgery residents rotating on the neurosurgical service, neurology residents, and senior level medical students interested in neurosurgery. We used a three-way evaluation model to evaluate the efficacy of HPS™, including pre- and post-exercise testing, student satisfaction survey, and self-evaluation.

Reliability, measured by the assessment of repeated performance over the different exercises and rating of performance, was not performed. Each participant went through two out of the three exercises only once. However, validity, measured by the post-exercise score comparisons between different levels of training, was performed. Lastly, no comparison of simulation to didactic training was performed; all participants underwent both training methods. No control groups were used.

Simulation Exercise

Students were first introduced to the RUSL setting via a tour and explanation of the capabilities of the facility. A 20-question multiple-choice pre-exercise test was then administered consisting of questions relevant to the neuro-critical care scenarios to be presented (Table 1). Next, the participants are separated into groups of three to four for...
Each of the neuro-critical care scenarios lasts approximately 10–15 min. The actual performance was not objectively evaluated through scoring by the proctor during or after the simulation. However, overall critiques were given to the participants by the proctor after the simulation as feedback.

Once the scenarios have been completed, the participants and proctor return to the classroom to discuss the exercises. Approximately half of these sessions were video-taped and the tape was reviewed with the participants during this time solely for learning and not for evaluation. Lastly, the participants are administered a post-exercise test consisting of the same 20 multiple-choice questions seen in the pre-exercise test to assess learning and improvement. They also are given a satisfaction and feedback survey to fill out confidentially. Specifically, participants are asked if they subjectively believed their critical care knowledge and skills improved during the simulation and didactic teaching and to freely elaborate on their overall experience.

Statistical Analysis

A paired Student’s t-test was performed to compare pre- and post-test scores for each sub-group of participants. Statistical significance was defined as \( P < 0.05 \).

Results

To date, we have enrolled 29 participants in our HPS™ neuro-critical care teaching exercise and evaluation model. These participants were comprised of eight neurosurgery residents (5 Post-Graduation-Year [PGY] 2 and 3 PGY1), 4 PGY1 general surgery residents rotating on the neurosurgery service, 14 neurology residents (6 PGY4, 4 PGY3, and 4 PGY2), and 3 senior year medical students interested in neurosurgery. Demographic information and test scores are provided in Table 2.

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The average pre-exercise test score for all participants was 13.8 out of a possible 20 (range 9–19, SD 2.73). This was compared to an average post-exercise test score of 17.9 out of a possible 20 (range 13–20, SD 1.95). This constituted an average improvement of 4.5 points or 25%. All but one participant’s score improved from their pre- to post-exercise test score.

In a sub-analysis of the groups, the average pre-exercise test score was 15.1 (range 12–19, SD 2.85) amongst neurosurgery residents, 13.6 (range 11–15, SD 1.28) amongst neurology residents, 11.5 (range 9–15, SD 3.0) amongst general surgery residents, and 11.7 (range 11–15, SD 1.53) amongst senior year medical students. The average post-exercise test score was 19.9 (range 19–20, SD 0.33), 16.6
Simulation is a widely used educational tool to enhance critical care education. In an attempt to test the efficacy of our educational model, we wrote a 20-question multiple-choice test directly related to the HPS™ sessions. In our study, twenty-eight of the 29 participants showed improved scores from pre- to post-exercise testing with the average score improvement of 4.5 points. Despite slight differences in average percent improvement between sub-groups, all demonstrated statistically significance. It should be noted that the participants with the least or no improvement tended to be the neurology residents who had little to no critical care experience before this exercise. Of equal or possibly greater importance is that all subjects provided overwhelmingly positive feedback on surveys regarding the utility of this exercise. All groups rated the simulation evaluation as realistic and helpful.

The reliability of our results was not tested in this study through repetitive analysis. Each participant only went through each simulation exercise once and was tested only after that performance. However, our simulation lab is open for student and resident practice outside of testing times, and many of our participants have subsequently used care simulation categories, the most difficult case presented was cerebral hemorrhage–herniation. This is likely due to the complexity of cerebral emergencies combined with a general unfamiliarity of intracranial issues. This is precisely why we incorporated simulation into our educational program.

Our experience with the HPS™ has been very positive. Junior residents and students on our neurosurgical service encounter complex and unique clinical problems in which correct immediate recognition and response is crucial to the safety of our patients. It is not uncommon to have these residents as first responders to intensive care unit and on-call emergencies. Simulation offers these students experience in a fail-safe environment that can be replicated as many times as needed to ensure clear understanding and execution of basic concepts. Furthermore, it serves as a teaching tool where didactic lectures and standardized patients have limitations. Practice, direction, and repetition are important to solidifying the knowledge base and confidence to act appropriately in real-life situations. This is the first application of HPS to neuro-critical care to the author’s knowledge.

In addition, all participants returned overwhelmingly positive satisfaction surveys with all 29 participants reporting that their neuro-critical care education was enhanced by this exercise and that the simulation was realistic.

### Discussion

Simulation is a widely used educational tool to enhance resident and medical student training across all fields of medicine. Simulators can range from very basic functions to hi-fidelity. Amongst hi-fidelity simulators, the HPS™ from METI™ can simulate complex physiologic conditions and respond to real-time interventions, making it uniquely suited for critical care education.

Critical care issues are not only intellectually challenging for most, but also extremely difficult to teach in didactic lectures or replicate in standardized patient scenarios. Traditionally, these teaching methods were the only means of attaining critical care knowledge. With the advent of higher technology, simulators such as the HPS™ allow students to learn in fail-safe environments, attain unlimited exposure to rare events, provide immediate feedback, and experience team approaches to care [2, 6]. Furthermore, Chopra et al. [7], illustrated that certain simulation exercises result in faster and more accurate responses up to 4 months after training compared to standard didactic teaching.

Amongst all critical care topics, those involving the nervous system tend to be most troublesome for young aspiring physicians to learn and for their pedagogue’s to teach. In a study by Boulet et al. [8], in which students were graded on their performance in 10 different critical care simulation categories, the most difficult case presented was cerebral hemorrhage–herniation. This is likely due to the complexity of cerebral emergencies combined with a general unfamiliarity of intracranial issues. This is precisely why we incorporated simulation into our educational program.

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### Table 2 Demographic information and test scores

<table>
<thead>
<tr>
<th></th>
<th>Avg training year</th>
<th>Avg pre-test score</th>
<th>Avg post-test score</th>
<th>Avg improvement (%)</th>
<th>*P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurosurgery residents</td>
<td>1.6 (range 1–2)</td>
<td>15.1 (range 12–19)</td>
<td>19.9 (range 19–20)</td>
<td>4.75 (24)</td>
<td>0.0017</td>
</tr>
<tr>
<td>General surgery residents</td>
<td>1</td>
<td>11.5 (range 9–15)</td>
<td>18.3 (range 17–20)</td>
<td>7 (38)</td>
<td>0.0374</td>
</tr>
<tr>
<td>Medical students</td>
<td>M4</td>
<td>11.7 (range 11–15)</td>
<td>18.7 (range 18–19)</td>
<td>7 (38)</td>
<td>0.0067</td>
</tr>
<tr>
<td>Neurology residents</td>
<td>3.14 (range 2–4)</td>
<td>13.6 (range 11–15)</td>
<td>16.6 (range 13–19)</td>
<td>3.07 (18)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*P-value < 0.05 considered statistically significant
the facility to repeat the exercises numerous times with subjectively reported positive feedback. The lack of objective reliability analysis is a limitation to the study.

In a similar manner, the validity of our results was only indirectly tested. While no objective numeric scoring of performance by the proctor’s occurred, a comparison of post-exercise test scores between levels of experience was made. This follows the indications of construct validity as described by Devitt et al. [9]. We demonstrated that post-exercise scores were highest among neurosurgery residents, which is expected as these physicians are most familiar with treating and studying the concepts tested. The validity is questioned by the fact that both the general surgery residents and medical students did perform better on the post-exercise test than the neurology residents. However, one explanatory hypothesis is that the general surgery residents and medical students were currently on the neurosurgery service and familiar with many of the tested concepts while the neurology residents were not and often have less critical care experience. Regardless, all groups showed a positive average improvement in pre- to post-test scoring which were statistically significant. Of note, the author’s cannot exclude the possibility that post-test improvement is attributable to didactic session teachings and not to the simulation exercises. However, the proctors were specifically trained not focus on concepts highlighted in individual test questions and all participants experienced unbiased didactic sessions equally.

Another limitation is that no control group was used and no direct comparison of teaching method (simulation versus didactic teaching) was performed in this study. Therefore, no assumptions can be made regarding any superiority of simulation over didactic teaching. This is an important unanswered issue needing attention in future studies.

Prior studies have verified the validity in using HPS through detailed analysis of case performance compared to level of training and experience [8]. Scores on a global evaluation system rated independently by several evaluators are both reliable and valid. In particular, the validity has repeatedly been shown for use of a patient simulator as a performance evaluation tool [3, 6, 8, 10–13]. This highlights the appropriateness and worth of simulation training to critical care training in general. Therefore, another obvious criticism of our study is the lack of performance evaluation through numeric objective scoring of performance by proctors to test the validity of our model. While each participant’s knowledge is enhanced by the sessions, knowledge alone does not ensure the capability of the participants to actually provide treatment quickly and correctly. Our next steps therefore will be not only to develop more neuro-critical care scenarios, but to also begin objective performance evaluation by the proctors to prove the full validity of these exercises.

Clearly, the greatest limitation to incorporating high-fidelity patient simulation into any educational program is availability and cost. These simulators can be quite expensive, and typically requires a great commitment by the academic center to purchase a HPS, develop programs, and maintain them. However, Grenvik et al. [2] highlight that simulators may be cost-saving through decreased use of operating room training and fewer malpractice suits. Specific to neuro-critical care training, limitations include the time and effort of designing and implementing the program, as well as taking away clinical time from residents to perform the exercises. However, these are small obstacles to overcome when considering the importance and necessity for improved neuro-critical care education.

Conclusions

Neurosurgical critical care education is important to the safe and effective care for patients experiencing neurosurgical complications. Clinical training and didactic lectures help residents and students obtain a solid knowledge base, but do not provide the benefit for learning in a fail-safe environment where tasks can be repeated. Through the use of a HPS, we have enhanced the critical care education of neurosurgical residents and medical students. We will continue to train these concepts in the future with simulation, incorporating additional scenarios and adapting the exercise for improved validity assessment.

Conflict of interest statement  None.

References