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Development and evaluation of simulation based neurosurgery curriculum. Pilot study at the Poznan University of Medical Sciences

Bartosz Sokół[1], Roman Jankowski[1], Barbara Więckowska[2], Łukasz Gąsiorowski[3], Michael Czekajlo[4]

[1] Department of Neurosurgery, Poznan University of Medical Sciences, Poznan, Poland
[2] Department of Computer Science and Statistics, Poznan University of Medical Sciences, Poznan, Poland
[3] Medical Simulation Center, Poznan University of Medical Sciences, Poznan, Poland
[4] Simulation Center, Virginia Commonwealth University Health System, Richmond VA, USA

ABSTRACT

Introduction. Neurosurgical emergencies are complex tasks. The current learning environment limits students' ability to manage acute neurosurgical emergencies due to legal and safety concerns. Simulation provides an opportunity to participate in the care of neurosurgical emergencies and develop clinical decision making skills.
Aim. We aim to determine whether neuroscience simulation curriculum improves student ability to: manage a critically ill patient, recognize neurosurgical emergencies, to assess how stress tolerance affects experience during simulations and effectiveness of students performance. The third objective is to develop a tool for student assessment.
Material and Methods. The simulation was performed on SimMan 3G Human Patient Simulator (Laerdal Medical). Scenarios included common neurosurgical emergencies. Students were assessed before and after the course by completing a Likert type questionnaire. Response data was analysed using Cronbach's reliability for Likert-type response data and Spearman's monotonic correlation.
Results. 60 students of fifth and sixth year of medical studies attended the course. 39 students of them replied to the questionnaire. The simulated clinical experience was positive and it improved their knowledge about neurosurgical emergencies. There was an improvement in their confidence. Improvement in individual and team performance was also observed.
Conclusions. Neurosurgical simulations improve students` ability to recognize neurosurgical emergencies. The level of stress related to simulation is important factor of the education process and should be reduced to improve students' development. Our questionnaire is an effective tool for assessment of students experience during clinical simulations.

Keywords: Neurosurgery, Simulation, Education, Medical students.

Introduction

Many neurosurgical emergencies are complex tasks which require considerable repertoire of knowledge and skill for effective performance. The early diagnostics are performed in Accident and Emergency Departments. Those tasks are rapid and occur in turmoil and stressful environment and can result with serious consequences. It reflects the complexity of patient care in these clinical environments as well as the challenging demand for high-quality teamwork. Important objective of simulation based medical education is to contribute to the reduction of error occurrences during medical

treatment. Preventable medical errors result in more than 400,000 deaths each year in the United States and are the third cause of death in this country, followed by cardiovascular diseases and cancer [1] Simulation based medical education in its widest sense can be defined as any educational activity that utilizes simulative aids to replicate clinical scenarios [2]. Simulation mistakes in order to enhance patient safety and improve medical care are a central goal of simulation based medical education [3]. It provides a safe, controlled environment in which problem-based learning is developed and competences are practiced in high-standards [1]. It is especially important for neurosurgical patients where urgent operations performed within few hours of onset have much better prognosis compared to mortality if surgery is delayed [4]. High-performance environments which are characteristic of neurosurgical emergencies involve complex, multicomponent decisions; rapidly evolving, ambiguous cases; information overload; severe time pressure; severe consequences for error; adverse physical conditions; sustained fatigue; and extensive team interactions. Therefore there exist demands on medical education to prepare young professionals to practice in the 21st century emergency medicine paradigm. It is also important to focus attention on what constitutes effective scenario-based training so that medical professionals can practice and receive feedback on crucial skills. For example the current standard of surgical evacuation of all haematomas within 4 hours is not being met in Europe. Most of the time it is not related to the inability to diagnose a haematoma but to the problems with patient transfer. The efficiency of management of all other neurosurgical emergencies also requires improvement in emergency departments. Delays were identified at every stage of the management of these patients and no single step was identified as the major cause. The mean time to surgical decompression was 5.0 h and 32% performed with in 4h. Patients who initially presented to a district hospital and required transfer for neurosurgery were decompressed in 5.4 h vs 3.7 hr for those admitted directly. There may be time savings from improvement of initial treatment in district hospitals [5, 6]. This is the field where more thematic programmes of simulation based medical education are needed. In the Simulation Centre at Poznan University of Medical Sciences we developed a neuroscience simulation curriculum which is used to improve the student's ability to recognize neurosurgical emergencies. This is the first paper describing neurosurgical themed simulation scenarios for medical students [7–9].

Material and Methods

The study was approved by the Poznan University of Medical Sciences' bioethics committee. All students provided written informed consent. 60 students of fifth and sixth year of medical studies attended the course. Those students were exposed to scenarios which were created at the Simulation Centre at Poznan University of Medical Sciences. The groups consisted of twelve students who were divided on three subgroups with four students each. The Simulation was performed on SimMan 3G Human Patient Simulator at the Center for Medical Simulation in Poznan. Students had to manage scenarios of patients with subarachnoid haemorrhage, acute subdural haematoma, acute epidural haematoma, polytrauma patient, gunshot head injury, status epilepticus, ventriculoperitoneal shunt infection, vasospasm secondary to subarachnoid haemorrhage, ischemic stroke and spinal cord injury. Although those cases are relatively rare in emergency departments they constitute core of neurosurgical emergencies. The scenarios were designed by our team and undergo continuous quality improvement. We used deidentified data of real clinical cases from our Emergency Department. Prior to the simulation program each group was sent a set of questions concerning their self-confidence (**Table 1**). The questionnaire was prepared using Likert-type scale [10] and send using Google Forms tool. Participants were asked to indicate their level of agreement with an item by choosing one of four categories ranging from: 1 – strongly agree, 2 – somewhat agree, 3 – do not agree to 4 – not applicable. Each group of students consisted of 12 students who were divided into three subgroups. While one group was managing the neurosurgical case, the remaining two groups were watching the scenario live in a separate room. Each scenario lasted approximately 10–11 minutes and then was followed by the debriefing. All

Table 1. Questions sent before the course

Do you think that the negative emotions associated with failure during the simulation improve memorizing a particular material?
I can deal with people who are arrogant at work
I easily get nervous and confused and lose confidence in stressful situations
I don`t mind when someone points out my mistakes

sessions were videotaped to review during the debrief and for QI and research. Following those simulations all students were send a questionnaire which is based on the Simulation Effectiveness Tool [11] Questions were subdivided in three groups: simulated clinical experience (**Table 2),** learning subscale (**Table 3**) and confidence subscale (**Table 4**) [11]. Response data was analysed using Cronbach's reliability for Likert-type response data [12]. PQStat software version 1.4.8 for statistical analysis was used. Analysis of correlation with questions asked before the course was performed using Spearman's monotonic correlation.

Results and statistical analysis

We received 41 complete responses. From 28 to 112 points could be obtained in the scale The higher score indicate higher level of disagreement with asked question. Mean of scale was 39.27, standard deviation of scale was 7.79. Scale reliability was measured by Cronbach Alpha and was as high as 0,896 (**Table 5**). Scores in the individual questions and the individual subscales: (SCE – simulated clinical experience, L – learning and C – confidence) are shown in **Figure 1**. The lowest values equal to one indicated that students agreed with asked question predominated in the respondents obtained subscale SCE indicating that students enjoyed working with the simulator and that time and size of the group were right. On a scale of learning, the median of the results also was 1, although there were also some higher values. The greatest diversity of the results presented subscale C concerning students` confidence. Spearman`s monotonic correlation analysis of questions asked before the course demonstrated that negative emotions are positively correlated with confidence scale, whereas simulation clinical experience ques-

Table 2. Questions concerning simulated clinical experience in post course questionnaire

I enjoyed working with the simulator
The group was the right size to facilitate my learning
The time allotted for this activity was adequate
I had fun while I was learning

Table 3. Questions concerning learning in post course questionnaire

The instructor's questions helped me to think critically
Completing the simulation helped me understand classroom information better
I feel better prepared to care for real patients
I developed a better understanding of the pathophysiology of the conditions in the simulation
I developed a better understanding of the medications that were in the simulation
My assessment skills improved
I am able to better predict what changes may occur with my real patients
I was challenged in my thinking and decision-making skills
I learned as much from observing my peers as I did when I was actively involved in caring for the simulated patient
Debriefing and group discussion were valuable
I would attend simulation again

Table 4. Questions concerning confidence in post course questionnaire

I felt like it was ok to make a mistake
I felt stressed when the simulator's condition worsened
I feel more confident in my decision-making skills
My communication skills have improved a lot
My ability to deal with arrogant people have improved a lot
Do you think that the stress associated with simulation improves remembering the material?
Do you think that negative emotions are associated with the failure to remember the material?
During the simulation I experienced feelings of nervousness, confusion and I lost confidence.
Classes of medical simulation helped me to control the feeling of nervousness, confusion, and improved self-confidence
I feel more confident that I will be able to recognize changes in my real patient's condition
The simulator and the environment were realistic
Did you have sense that the atmosphere of trust and transparency was created during error analysis?
Have medical simulations taught you a more constructive approach to your own mistakes?

tions were negatively correlated among those who felt stressed in difficult situations (**Table 6**). Significantly negative and only one positive correlations of the question: "I easily get nervous and confused and lose confidence in stressful situations" with post simulations questions are demonstrated in **Table 7**.

Table 5. Statistical Analysis

Mean of scale	39.272727
Standard deviation of scale	7.79933
Cronbach Alpha for scale	0.896098
Standard error of measurement	2.514018
Average correlation between pairs of items	0.266078

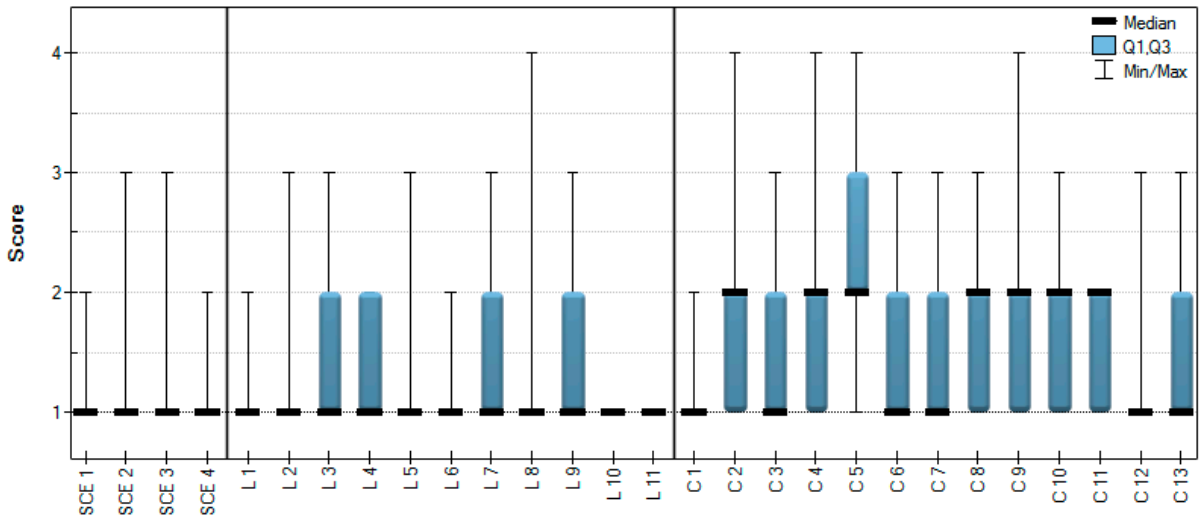

Figure 1. Responses obtained using simulation effectiveness tool. SCE 1, 2, 3, 4 – simulated clinical experience questions (details in **Table 2**), L 1–11 learning subscale questions (details in **Table 3**), C1–13 – confidence subscale questions (details in **Table 4**). Figure demonstrates obtained score for each question. 1 – strongly agree, 2 – somewhat agree, 3 – do not agree, 4 – not applicable

Table 6. Spearman's monotonic correlation of questions asked before the course with subscales in questionnaire sent after simulation. SCE – simulated clinical experience, L – learning subscale, C – confidence subscale

Scale	Do you think that the negative emotions associated with failure during the simulation improve memorizing a particular material? vs Scales		I can deal with people who are arrogant at work vs Scale		I easily get nervous and confused and lose confidence in stressful situations vs Scales		I don`t mind when someone points out my mistakes	
	p-value	r	p-value	r	p-value	r	p-value	r
SCE	0.2904	0.18	0.4628	-0.13	0.0337*	-0.35	0.9192	0.02
L	0.0653	0.32	0.0806	-0.30	0.6598	-0.08	0.8662	-0.03
C	0.0343*	0.38	0.7519	-0.06	0.1409	-0.27	0.6892	-0.07

Table 7. Statistical significance of Spearman's monotonic correlation of question: "I easily get nervous and confused and lose confidence in stressful situations" asked before the course with questions sent after simulation

Question	p-value	r
I enjoyed working with the simulator	0.0223*	-0.38
The group was the right size to facilitate my learning	0.0036*	-0.47
I learned as much from observing my peers as I did when I was actively involved in caring for the simulated patient	0.0058*	-0.45
I felt like it was ok to make a mistake	0.0055*	-0.45
I felt stressed when the simulator's condition worsened	0.0104*	0.42
Do you think that stress associated with the simulation helps to remember important information?	0.0237*	-0.38
The simulator and the environment were realistic	0.0362*	-0.35
Have you learned to take advantage of your mistakes?	0.0390*	-0.35

Discussion

The process by which experts make decisions tends to be based on experience and an increased ability to assess risk. In emergency situations the tendency is for people to want to do things faster, making them more error prone. More experienced and technically competent individuals make more effective and quicker decisions introducing the greater structure to their behavior. It has been argued that intuition alone is not sufficient to lead to a decision but rather requires a cognitive continuum which is a series of decision strategies dependent on the situation and expertise [13, 14]. A recognition primed decision model describes how people use their experience based on a repertoire of patterns. It blends intuition and analysis. A purely intuitive strategy relying only on pattern recognition would be too risky and could generate flawed options whereas a completely analytical strategy would be to slow. Weighing options generally makes sense for novices, who need a decision-making framework to help them think their way through a problem. But the way to get people past the novice stage is to accelerate their experiences so that they can rapidly accumulate the memories and cues that will enable them to make better decisions faster [13]. It is extremely important at Emergency Department where neurological emergency has to be managed in the time and efficient manner. Simulation, and the use of simulators to educate healthcare practitioners, has been shown to be effective in transferring knowledge to both trainees and practicing healthcare professionals [15].

We designed simulation course which covers purely neurosurgical emergencies. We assessed participants` experiences regarding learning, confidence improvement and clinical scenarios reality. The information obtained from the participants indicates that the course was well received and the groups of 4 students are an appropriate size [16]. The ability to not only participate in the simulation but to observe colleagues performance in simulation scenarios also proved to be of educational benefit. It was considered by students as an effective tool to learn how to manage a critically ill patient and recognize neurosurgical emergencies. We also analysed the influence of self-confidence assessed before the simulation with answers obtained in the post simulation questionnaire. Obtained answers suggest that student who have positive approach towards stress felt that simulations helped them to remember material, control emotions and easier recognize changes in patients condition. Students who felt that they easily get nervous had much less positive clinical experience during simulation. Those observations are confirmed by the fact that there was only one positive correlation with the question: "I felt stressed when the simulator's condition worsened" and students who felt they get easily nervous had negative rho correlation with the remaining questions. The literature indicates that stress is a factor in learning and performance [17, 18]. The Inverted U graph was initially presented by Robert Yerkes and John Dodson in 1908. They indicated that the performance at any task varies with stress in a predictable parabolic curve [19]. A study by Demaria demonstrated that emotional stress in simulated cardiac arrest simulation scenarios improved performance [20]. The evaluation of stress on performance was not a primary endpoint of this study but should be evaluated further in the future to improve simulation scenarios and longitudinal education for medical students. Simulation scenarios allows students to obtain a better understanding of how to utilize the complex neurological knowledge and pathophysiology from their neurosurgical rotation. Simulation also provided them an opportunity to manage patients they typically would not be allowed to manage in an acute setting during their studies. During this pilot curriculum the faculty also assessed the longitudinal progression of the students during the course. Notes and interviews with the faculty demonstrated a perception of improved individual and team performance over the course of the 5 days. Other studies support the use of deliberate practice and use of simulation to improve team performance [21, 22]. It was apparent to all the instructors that over the course of the 5 days the general approach to the critically ill patient became more structured and the speed in assessment, ordering tests and requesting neurosurgery consult improved. This improvement in performance followed constructive feedback provided in the debriefings [23, 24]. This study demonstrated that the deliberate practice model is an important property of simulation based medical education as is immediate informative feedback. In the future we intend to incorporate a Global Rating Scale in addition to checklist evaluation as part of the student evaluation process. We also plan to evaluate the retention of performance after simulated training which was not addressed in our current study.

Conclusions

1. Neurosurgical simulations curriculum improves student ability to manage a critically ill patient and recognize neurosurgical emergencies.
2. Neurosurgical simulations expose and accustom students to stress associated with clinical practice therefore improving students stress tolerance.
3. Our questionnaire is an effective tool for assessment of students experience during clinical simulations.

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Authors' contributions
Study design: BS, LG; data collection and analysis: BS, BW, RJ, MC, LG, manuscript preparation BS, RJ, MC, LG. All authors read and approved the final manuscript.

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Availability of data and material
All data generated or analysed during this study are included in this published article.

Conflict of interest statement
The authors declare no conflict of interest.

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Correspondence address:
Bartosz Sokół MD, PhD
Department and Clinic of Neurosurgery and Neurotraumatology, Poznan University of Medical Sciences
Heliodor Swiecicki Clinical Hospital
49 Przybyszewskiego Street, 60–355 Poznan, Poland
phone: +48 61 8691423, fax: +48 61 8691430
email: bartosz.sokol@ump.edu.pl