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EDUCATION & TRAINING

Acquisition of Competencies by Medical Students in Neurological Emergency Simulation Environments Using High Fidelity Patient Simulators

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Abstract The training of medical students demands practice of skills in scenarios as close as possible to real ones that on one hand ensure acquisition of competencies, and on the other, avoid putting patients at risk. This study shows the practicality of using high definition mannequins (SimMan 3G) in scenarios of first attention in neurological emergencies so that medical students at the Faculty of Medicine of the University of Salamanca could acquire specific and transversal competencies. The repetition of activities in simulation environments significantly facilitates the acquisition of competencies by groups of students ($p < 00.5$). The greatest achievements refer to skills whereas the competencies that demand greater integration of knowledge seem to need more time or new sessions. This is what happens with the competencies related to the initial diagnosis, the requesting of tests and therapeutic approaches, which demand greater theoretical knowledge.

Keywords Simulation · High fidelity patient simulator · Mannequin · Medical education · Learning setting

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Introduction

The teaching of medicine in universities has undergone huge changes over the last 15 years. On one hand, the vertical integration of the basic and clinical disciplines has affected the teaching-learning process, which is now student-focused [1, 2]. On the other, it has changed from a type of teaching linked to the accumulation of theoretical knowledge as a basis for subsequent practical learning to immersion in practice as the essential basis for acquiring any competency [3]. However, clinical practice within the patient environment in our medical surgeries and hospitals is quite limited given the increase in the number of students and because, although students have always been present, considerations about the safety and well-being of patients, as well as the ethical implications, have become increasingly more important [3, 4]. This mainly affects critical patients, who require the best possible combination of knowledge and skills acquisition for their care. As a result, it is usually the emergency clinical situations, and therefore the most difficult ones the students have to face, that are the ones most jeopardized in teaching medical students in training [2, 3]). In short, it is necessary to rethink the traditional methods of skills acquisition and seek to implement new teaching aids [6]. Thus the need to replicate clinical situations by taking advantage of the possibilities for simulation in skills laboratories [2, 5, 6].

Simulation encompasses a set of techniques aimed at recreating aspects of the real world, typically to replace or enhance real-life experiences. From the teaching point of view, these simulated experiences are meant to help students attain their educational goals [6]. The use of simulators in instruction can be traced back to the training of pilots in the 1920s [7]. They have been used in medicine over the last two decades in the field of Anaesthesiology and Reanimation, which was the first speciality to use mannequins extensively for residents to practice endotracheal intubation, mask ventilation and cricothyrotomy [7, 8]. Emergency medicine quickly adopted this kind of teaching technique [9, 10], which has now spread gradually to other areas with the support of technological development and the creation of high fidelity scenarios and mannequins that can reproduce physiological and pathological situations [11–13]. In addition, it is a field with good prospects for research and multidisciplinary integration.

However, most studies to date address the use of simulation in the training of residents, not medical students. The purpose of the present study is to evaluate the use of a high fidelity simulator, the SimMan 3G model, in the acquisition of competencies in situations of clinical neurological emergencies by fourth year medical students at the University of Salamanca.

Materials and methods

The simulation carried out in this study was done using the SimMan 3G (Laerdal R) mannequin. This is a high fidelity simulator of an adult patient that includes many possibilities, among them an integrated system of fluids and bleeding, automatic drug recognition, vital sign recording, feedback on the quality of cardiopulmonary resuscitation (CPR), convulsions, light-sensitive pupils, and Wi-Fi portability, among others. The wireless technology facilitates training in complete rescue, provides an intuitive graphic user interface that makes it possible to enact effective simulation scenarios and records notes prepared for debriefing. It interacts with SimView to permit total video capture.

The mannequin is connected to a patient monitor that records the vital signs coming from the simulator (heart rate, blood pressure, arterial gases, respiratory rate, and central venous pressure, among others). It takes orders from the instructor monitor which incorporates the software of the simulation scenarios.

Training can be carried out in automatic mode for rapid configuration and automated functioning, or in manual mode to allow instructors to use their own experience. The software does this through a combination of physiological models, preprogrammed patient cases and an innovative method for managing model-based simulation.

For this study we selected two simulation scenarios representing two clinical cases in two different patients that have suffered a traumatic brain injury. In the first case the injury caused an acute subdural haematoma and in the second, a cerebral contusion, both of which required initial attention in A&E. The general and specific learning objectives were similar for the two scenarios.

The instructors of the practical activity had previously successfully completed a training course for instructors in the handling of the mannequin and simulation environments for SimMan 3G.

The activity was carried out during two successive academic years, 2014–2015 and 2015–2016, with a total of 300 fourth year medical students (150 students per year). In 2014–2015, the 150 students were distributed into groups of 10, whereas in 2015–2016, they were distributed into groups of 5, owing to needs of academic organization. Thus, we obtained a total of 45 groups of students, 15 groups with 10 students each and 30 groups with 5.

After 15 min of presentation and training in the handling of the mannequin, each of the groups was randomly assigned a simulation scenario (A or B), and began to work on the simulated patient as soon as they arrived at the scene, under the observation and control of the instructor. The students interacted with the mannequin during a period of 30 min. At the end of the practice session the instructor filled in a questionnaire that included the following items corresponding to the competencies to be acquired.

Specific competencies

1. Reception of the patient
2. General exploration
3. Management of airways
4. Control of breathing
5. Control of circulation
6. Evaluation of vital signs
7. Glasgow Coma Scale
8. Initial diagnostic evaluation
9. Appropriate pharmacological treatment
10. Request for tests and planning of possible therapeutic approaches

Transverse competencies

1. Team work
2. Communications skills
3. Coping in an emergency situation
4. Sequencing of actions to be taken in emergency situations
5. Care of materials and mannequin

The items were assessed taking into consideration whether or not the group had acquired the 15 specific and transversal competencies.

Once the 30 min were over, the group's performance was reviewed over the next 20 min, during which details were discussed with the students and any problems in assisting the simulated patient were identified. The student group then had to confront the second simulation scenario so that their acquisition of the same competencies in the same time frame (30 min) could be newly assessed taking into account the same criteria.

The data were entered into the SPSS v23 statistical programme for analysis. The results were expressed as frequencies and percentages for categorical variables and as the median and percentiles (*25th percentile and 75th percentile*) for continuous variables. A chi-square test was used to compare the association between categorical variables and the measured outcome was expressed as the odds ratio (OR) together with the 95 % CI for OR.

Results

Data were analysed by comparing the results obtained among the groups in relation to the assessments made in the simulation scenarios before (pretest) and after the discussion of the group's performance in the first scenario (posttest). The acquisition of competencies was studied in 45 groups (15 groups of 10 students each and 30 groups of 5 students each) in the two practical simulation sessions (Table 1).

Statistically significant differences ($p < 0.05$) were found between the pretest and posttest in each of the academic years (see Tables 2 and 3), but no significant differences ($p > 0.05$) appeared when the distribution of proportions in the two academic years was compared (see Table 4). Figure 1 shows the data collected from the pretest and posttest for academic years 2014–15 and 2015–16.

It was found that in the groups comprising 10 students in academic year 2014–2015 the specific competencies with the worst results in the first simulation were appropriate pharmacological treatment, initial diagnostic evaluation, and request for tests and planning of possible therapeutic approaches. The repeated simulation allowed 60 % of the groups to acquire these three competencies. However, these three competencies continued to garner the least favourable results, given that 80 % of the groups attained the rest of the competencies.

In the groups with 5 students set up in academic year 2015–2016, the specific competencies with the worst results in the first simulation were the exploration of the Glasgow Coma Scale (GCS), pharmacological management and initial diagnostic evaluation. The repeated simulation allowed 60 % of the groups to attain these competencies, although they were still the ones with the least favourable results, since 83 % of the groups acquired the rest of the competencies. The competency relating to the request for tests and therapeutic planning was acquired by 33.3 % of the groups in the first simulation, and by 83 % of the groups in the posttest simulation.

It was observed that in the first simulation only 46.6 % of the groups received a favourable assessment in each of the specific competencies, the ones most acquired being management of airways in academic year 2014–2015 and control of breathing in academic year 2015–2016. After the second simulation the maximum reached 86.6 % of the groups with 10 students in reception of patients and 100 % in groups with 5 students in regard to management of airways.

In relation to the transversal competencies, even though the care of the materials and the mannequin was constant as from the first simulation, the rest of the transversal competencies were only acquired in more than 50 % of the groups in the second simulation, improving considerably in the groups with 5 students as opposed to the groups with 10 students, although the differences were not statistically significant.

Table 1 Descriptive statistics for continuous variables

	Academic year 2014–2015		Academic year 2015–2016	
	$N = 15$		$N = 30$	
	PRETEST	POSTTEST	PRETEST	POSTTEST
Median	5	12	10	28
Minimum	2	8	8	18
Maximum	15	15	30	30
Percentile				
25th	3	9	9	26
75th	6	13	12	30

Discussion

Over the last few years, the impressive development of simulation research and technology is now leading to the design of forms of simulation with increasing fidelity to reality for learning and training in the health sciences [2–5, 9, 11, 12].

It has been shown that the use of simulation shortens the time needed to learn clinical skills, especially because the training can be repeated as many times as necessary until the skills are correctly acquired. In addition, the learning curves based on the simulations are better than the curves based on classic training [2, 3, 5, 6, 13, 16]. The immediate feedback users receive from their actions allows them to perceive their errors as soon as they take place and to try out different responses. In addition, their ability to learn from their mistakes is multiplied by observing those of other students [4, 6, 11, 13, 14].

Among the advantages attributed by different studies to simulation with mannequins, and which has been corroborated in this study, is that the same clinical scenarios can be used for many groups of students, offering similar opportunities for learning, and thus allowing the development of clinical cases based on the needs of the students instead of on the availability of patients [11, 14–18].

From the teaching perspective, the instructor can download repetitive tasks and create educational applications in a short amount of time. The use of these simulation environments, when well-orientated and combined with other resources, can favour both group and individual teaching-learning processes [19–21]. It should be underscored that students are usually highly motivated when using these materials. Motivation is one of the drivers

Table 2 Academic year 2014/2015 (15 groups of 10 students each group, $N = 15$)

Competence		PRETEST n (%)	POSTTEST n (%)	Chi-squared test	*p*-value*	OR[a]	95 % CI
Specific competencies							
1	Yes	5 (33.3)	13 (86.6)	8.88	0.002*	13.00	[2.07–81.47]
	No	10 (66.6)	2 (13.3)				
2	Yes	5 (33.3)	12 (80.0)	6.65	0.009*	8.00	[1.52–42.04]
	No	10 (66.6)	3 (20.0)				
3	Yes	7 (46.6)	13 (86.6)	5.40	0.020*	7.42	[1.22–45.00]
	No	8 (53.3)	2 (13.3)				
4	Yes	5 (33.3)	12 (80.0)	6.65	0.009*	8.00	[1.52–42.04]
	No	10 (66.6)	3 (20.0)				
5	Yes	7 (46.6)	12 (80.0)	3.58	0.058	4.57	[0.90–23.13]
	No	8 (53.3)	3 (20.0)				
6	Yes	5 (33.3)	12 (80.0)	6.65	0.009*	8.00	[1.52–42.04]
	No	10 (66.6)	3 (20.0)				
7	Yes	6 (40.0)	12 (80.0)	5.00	0.025*	6.00	[1.17–30.72]
	No	9 (60.0)	3 (20.0)				
8	Yes	3 (20.0)	9 (60.0)	5.00	0.025*	6.00	[1.17–30.72]
	No	12 (80.0)	6 (40.0)				
9	Yes	2 (13.3)	9 (60.0)	7.03	0.008*	9.75	[1.59–59.69]
	No	13 (86.6)	6 (40.0)				
10	Yes	4 (26.6)	10 (66.6)	4.82	0.028*	5.50	[1.14–26.41]
	No	11 (73.3)	5 (33.3)				
Transversal competencies							
1	Yes	3 (20.0)	8 (53.3)	3.58	0.058	4.57	[0.90–23.13]
	No	12 (80.0)	7 (46.6)				
2	Yes	3 (20.0)	8 (53.3)	3.58	0.058	4.57	[0.90–23.13]
	No	12 (80.0)	7 (46.6)				
3	Yes	4 (26.6)	10 (66.6)	4.82	0.028*	5.50	[1.14–26.41]
	No	11 (73.3)	5 (33.3)				
4	Yes	5 (33.3)	14 (93.3)	11.62	0.000*	28.0	[2.82–277.96]
	No	10 (66.6)	1 (6.6)				
5	Yes	15 (100.0)	15 (100.0)	–	–	–	–
	No	0 (0.0)	0 (0.0)				

*Statistical significance level of 5 % ($p < 0.05$)

[a] OR: How many times outcomes improved in the post relative to pretest

of learning because it stimulates activity and thought, thus increasing dedication to work, as can be seen from the results [15, 19, 22].

In our study it was found how the specific and transversal competencies were acquired in the second simulation session with learning based on skill repetition. Medical training based on simulations allows the students to receive feedback in real time and to reflect on their actions, thus providing instructional assessment. Furthermore, by providing a standardized, reproducible and objective scenario, it also permits summative assessment [4, 6, 19]. Thus, the clinical skills acquired through simulation are transferable to reality [11, 15, 20] and the importance of students being able to practice invasive procedures without putting patients at additional risk cannot be exaggerated [3, 6, 17, 21].

What is striking in our results, something also found in previous studies by our group [23], is how the greatest achievements refer to skills whereas the competencies that demand greater integration of knowledge seem to need more time or new sessions. This is what happens with the competencies related to the initial diagnosis, the requesting of tests and therapeutic approaches, which demand greater theoretical knowledge. The same occurs with the transversal competencies. Learning team work and communication skills requires a succession of practical activities of one type or another for students to attain complete acquisition of the competencies. However, as indicated in other research [15], the opportunity to exercise these types of abilities should be underscored. Simulation through the use of mannequins provides a magnificent opportunity to approach the reality of clinical emergencies and to train in teamwork, communication skills, leadership, stress management and decision-making under pressure [19–22]. Some authors are of the opinion that the circumstances surrounding activity in the skills laboratory in relation to the mannequin improve students' acquisition and retention

Table 3 Academic year 2015/2016 (30 groups of 5 students each group, $N = 30$)

Competence		PRETEST n (%)	POSTTEST n (%)	Chi-squared test	*p*-value*	OR[a]	95 % CI
Specific competencies							
1	Yes	10 (33.3)	30 (100.0)	30.00	0.000*	–	–
	No	20 (66.6)	0 (0.0)				
2	Yes	12 (40.0)	28 (93.3)	19.20	0.000*	21.00	[4.19–105.03]
	No	18 (60.0)	2 (6.6)				
3	Yes	9 (30.0)	30 (100.0)	32.30	0.000*	–	–
	No	21 (70.0)	0 (0.0)				
4	Yes	16 (53.3)	27 (90.0)	9.93	0.001*	7.87	[1.95–31.67]
	No	14 (46.6)	3 (10.0)				
5	Yes	12 (40.0)	26 (86.6)	14.06	0.000*	9.75	[2.70–35.11]
	No	18 (60.0)	4 (13.3)				
6	Yes	13 (43.3)	26 (86.6)	12.38	0.000*	8.50	[2.37–30.46]
	No	17 (56.6)	4 (13.3)				
7	Yes	8 (26.6)	28 (93.3)	27.77	0.000*	38.50	[7.41–199.87]
	No	22 (73.3)	2 (6.6)				
8	Yes	8 (26.6)	20 (66.6)	9.64	0.001*	5.50	[1.81–16.68]
	No	22 (73.3)	10 (33.3)				
9	Yes	8 (26.6)	18 (60.0)	6.78	0.009*	4.12	[1.38–12.27]
	No	22 (73.3)	12 (40.0)				
10	Yes	10 (33.3)	25 (83.3)	15.42	0.000*	10.00	[2.94–34.00]
	No	20 (66.6)	5 (16.6)				
Transversal competencies							
1	Yes	10 (33.3)	28 (93.3)	23.25	0.000*	28.00	[5.52–141.91]
	No	20 (66.6)	2 (6.6)				
2	Yes	11 (36.6)	30 (100.0)	27.80	0.000*	–	–
	No	19 (63.3)	0 (0.0)				
3	Yes	11 (36.6)	29 (96.6)	24.30	0.000*	50.09	[5.96–420.36]
	No	19 (63.3)	(3.3)				
4	Yes	10 (33.3)	28 (93.3)	23.25	0.000*	28.00	[5.52–141.91]
	No	20 (66.6)	2 (6.6)				
5	Yes	30 (100.0)	30 (100.0)	–	–	–	–
	No	0 (0.0)	0 (0.0)				

*Statistical significance level of 5 % ($p < 0.05$)

[a] OR: How many times outcomes improved in the post relative to pretest

of knowledge as compared to traditional methodologies [13, 18, 19], and there is evidence that it helps to improve patient care [11, 12, 17, 18]. Although one of the limitations of these teaching methods is the cost of the equipment, one should also take into account that the cost of training in real clinical scenarios and the costs of mistakes are even greater [24].

Moreover, these technologies help to form a new kind of student, one prepared to make decisions and engage in autonomous learning. This opens up a challenge for an educational system concerned with the acquisition, memorization and reproduction of information according to more traditional established patterns.

Another observation based on our results has to do with the fact that more groups acquired the competencies after the second simulation in academic year 2015–2016, coinciding with the groups of 5 students, as compared to the groups with 10 students in academic year 2014–2015, the same as in other studies [12–14, 16]. However, the difference was not statistically significant. This may be due to the fact that, the groups of 10 students, the same 4–5 students practice their skills during the simulation while the rest of the students help and assess their actions. It would therefore be advisable, in order to determine the ideal number of students per group, to assess students individually in addition to the group assessment, even though it is a matter of training and skill acquisition that inexorably requires teamwork.

Finally, although simulation serves to fine tune the acquisition of clinical skills and the attainment of the competencies that inevitably come into play in each real clinical situation, it cannot replace clinical teaching in real scenarios [24]. Nonetheless, the use of simulation should be employed more widely and new experiences should be proposed that will allow medical students to improve in their acquisition of competencies through these methods as compared to other teaching methods, particularly during undergraduate teaching in the health

Table 4 Comparative data between the two academic years

Competence	Academic course 2014/2015		Academic course 2015/2016		p-value*
	N = 15		N = 30		
	PRETEST n (%)	POSTTEST n (%)	PRETEST n (%)	POSTTEST n (%)	
Specific competencies					
1. Reception of the patient	5 (33.3)	13 (86.6)	10 (33.3)	30 (100.0)	0.823
2. General exploration	5 (33.3)	12 (80.0)	12 (40.0)	28 (93.3)	0.964
3. Management of airways	7 (46.6)	13 (86.6)	9 (30.0)	30 (100.0)	0.329
4. Control of breathing	5 (33.3)	12 (80.0)	16 (53.3)	27 (90.0)	0.568
5. Control of circulation	7 (46.6)	12 (80.0)	12 (40.0)	26 (86.6)	0.691
6. Evaluation of vital signs	5 (33.3)	12 (80.0)	13 (43.3)	26 (86.6)	0.772
7. Glasgow Coma Scale	6 (40.0)	12 (80.0)	8 (26.6)	28 (93.3)	0.379
8. Initial diagnostic evaluation	3 (20.0)	9 (60.0)	8 (26.6)	20 (66.6)	0.816
9. Appropriate pharmacological treatment	2 (13.3)	9 (60.0)	8 (26.6)	18 (60.0)	0.430
10. Request for tests and planning of possible therapeutic approaches	4 (26.6)	10 (66.6)	10 (33.3)	25 (83.3)	1.000
Transversal competencies					
1. Team work	3 (20.0)	8 (53.3)	10 (33.3)	28 (93.3)	0.949
2. Communications skills	3 (20.0)	8 (53.3)	11 (36.6)	30 (100.0)	0.976
3. Coping in an emergency situation	4 (26.6)	10 (66.6)	11 (36.6)	29 (96.6)	0.938
4. Sequencing of actions to be taken in emergency situations	5 (33.3)	14 (93.3)	10 (33.3)	28 (93.3)	1.000
5. Care of materials and mannequin	15 (100.0)	15 (100.0)	30 (100.0)	30 (100.0)	1.000

*Statistical significance level of 5 % ($p < 0.05$)

sciences, where the possibilities of future development are even greater [11, 16, 18, 19].

Conclusion

In our experience, the use of high-fidelity patient simulators is a good alternative for complementing teaching, facilitating learning and helping medical students to acquire clinical, communicative, teamwork and response skills in neurological emergency situations. The repetition of actions in simulation scenarios facilitates the attainment of specific and transversal competencies in the initial handing of brain trauma, thus justifying the implementation of simulation in learning, with the certainty that it will improve teaching quality in the field of medicine.

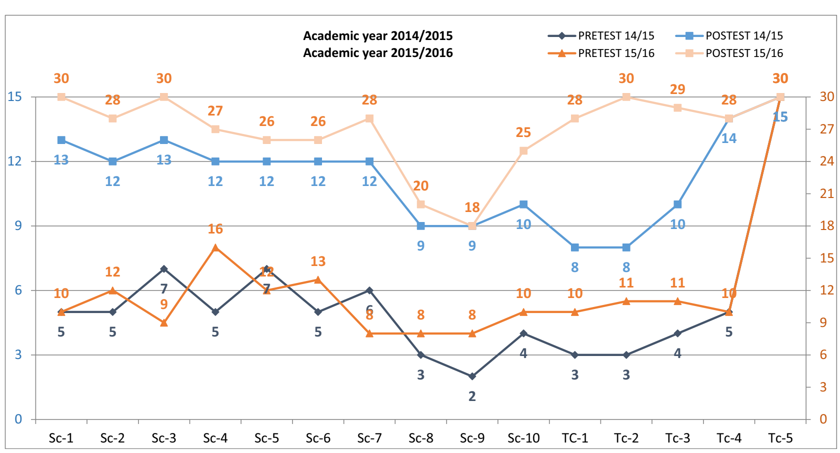

Fig. 1 Plot of the data collected in the first simulation (pretest) and in the second simulation (posttest) in academic years 2014–2015 and 2015–2016

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