Improvement and Evaluation of Emergency Trauma Management using Interactive Simulation

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***Abstract*—Trauma injuries are one of the main leading causes of death in the world. Therefore, specific trauma training using web-based technology presents a solid simulation modality to create and train realistic trauma scenarios. Medical students and residents were enrolled to train trauma management cases over a 2-weeks period with a web-based simulator. Sixteen different trauma scenarios were created, four of them were used as exams (pre-training) and the remaining twelve cases were used to train during the 2-weeks period. After the training period, the four exam cases were repeated (post-training) and different metrics are analyzed before and after the training to study the trauma management improvement. The actions taken by the participants along the initial four minutes, the minimum actions to perform and the whole simulation were analyzed. The results obtained show improvements on all the trauma scenarios showing significance (p-value < 0.05) after training. Statistical significance was achieved for the score indicating improvements on the correct actions executed by trainees, as well as for avoiding actions that do not contribute positively to patient recovery. Web-based simulation contributes to emergency trauma management learning, and it allows to objectively evaluate the learning process.**

Keywords—trauma; medical education; emergency medicine; simulation; hospital & prehospital.

I. Introduction

Clinical simulation is a method that offers realistic patient experiences to healthcare professionals, enabling them to practice and deal with scenarios as if they were real. Therefore, healthcare professionals can practice protocols and procedures before encountering a real situation, facilitating a practical training experience. Clinical simulation, since its inception, has been geared towards enhancing clinical training with a focus on ensuring patient safety [1]. However, it also presents other advantages such as including the ability to repeat simulations as many times as necessary, addressing uncommon medical scenarios, and providing training for different technical and non-technical skills [2]. Training trauma management requires acquiring both technical and non-technical skills. The technical skills refer to the application of correct techniques and treatments applied during the primary and secondary surveys [3], whereas the non-technical skills refer to communication, leadership, or management skills during a trauma scenario [4]. Several studies confirm that acquiring technical skills using a clinical simulator support an improvement on the technique learning curve [2]. Nevertheless, the impact that simulation has on improving the performance in trauma management is still limited as well as the impact on the long-term knowledge retention.

There are a variety of clinical simulation modalities. Among them, web-based simulators stand out because they enable simultaneous training for a substantial number of trainees while also reducing costs [5]. There are studies that present positive results after using web-based simulators in the clinical field, specially related to clinical reasoning skills [6]. Nevertheless, improvements in other fields such as problem solving and learning level acquired [7] are perceived after using web-based simulators. These tools allow to acquire new knowledge, by making connections between different concepts without having the pressure of real scenarios. Therefore, they promote learning, encouraging trainees to prioritize in the diagnoses to apply [8]. Additionally, web-based simulators allow to easily incorporate an objective evaluation method to measure the impact of simulation on the learning process. This objectivization would suppose an added value, considering the urgent need to develop evaluation methods [9]. This need fits with the purpose of clinical simulation, which can provide real-time objective information to allow better simulation evaluation [10].

Consequently, the aim of this paper is to verify if the use of the web-based trauma simulator (WBTS) developed in [11] supports trauma management learning.

II. Materials and Methods

The WBTS developed in [11] is used to create new trauma scenarios to investigate the impact that the use of simulators has on the learning process of trauma management. The first step is to test the trauma management knowledge of trainees prior to the training. Once this is done, the WBTS allows users to train with different trauma scenarios. For this study, there is a training

TABLE I. EXAMPLE OF FOUR OF THE SIXTEEN TRAUMA SCENARIOS CREATED

Trauma scenario	Age (years old)	SpO2	RR (breaths/min)	HR (beats/min)	SBP (mm Hg)	DBP (mm Hg)	Part of body affected	Mechanism of injury	Setting
1	25	98%	26	110	141	89	Pelvis	Pedestrian run over by a car	Hospital
2	33	90%	41	135	141	89	Pelvis	Car accident	Prehospital
3	50	92%	28	120	141	89	Right lower limb	Construction site accident with a high load machine	Hospital
4	82	95%	28	120	141	91	Left lower limb	Pedestrian run over by a car	Prehospital

period of two weeks. Finally, the same trauma scenarios, as the ones accessed before the training, are repeated to measure improvement behaviors. Ethical approval (code 2022.306) was obtained, and it was certified that the study was performed in accordance with the 1964 Declaration of Helsinki [12].

A. Trauma scenarios

Two different trauma lesions are considered: lower limb and pelvic injuries. Then, four different trauma cases are created per scenario, in which a different patient suffers a lesion. Therefore, there is a different mechanism of injury, age of the patient, vital signs and part of the body affected as shown in Table 1. Additionally, each trauma scenario could take place either on a hospital or on a prehospital setting. Therefore, all the trauma scenarios created within this study are sixteen.

B. Participants

Final-year medical students and first-year residents were invited to participate in this study. The final-year medical students had a previous training in trauma management and the first-year residents were working in the intensive care medicine specialty. They all voluntarily agreed to participate in the study. A manual for users along with a demonstration video with instructions on how to use the simulator were sent to the participants prior to the beginning of the study. A calendar was given in which the date in which the trainee should manage the first four different scenarios was stated. Then, for two weeks, they should perform one new simulation per day. Once this training period finishes, the trainees would be able to access again to the initial four trauma scenarios. In total, 157 simulations were analyzed: 91 simulations corresponded to the ones performed initially and 66 simulations were the ones repeated once the training period finished. As not all the trainees finished the training period as requested, they were excluded.

C. Data analysis

To quantify the simulation performance, eighteen medical experts on the trauma field were contacted. All the experts are consultants of the intensive care medicine department of different hospitals throughout Spain. All of them are members of the Spanish Society of Intensive Care Medicine and Coronary Units (SEMICYUC) and with, at least, 3 years' experience after residency education in Intensive Care Medicine. This panel of experts provided different solutions for the trauma scenarios defined based on the ATLS protocol [13]. The ATLS training was created by the American College of Surgeons Committee on Trauma on 1978 and it has become a worldwide trauma standard. Therefore, once all the possible solutions were defined, each simulation was analyzed to check which scenario, from the possible solutions, was more similar to the solution provided by the trainee. This would allow to analyze how well the simulation was performed focusing on the actions taken and when they were taken. To do so, the following scores are used: precision, recall, specificity, accuracy and F1. They are calculated as shown in Table 2.

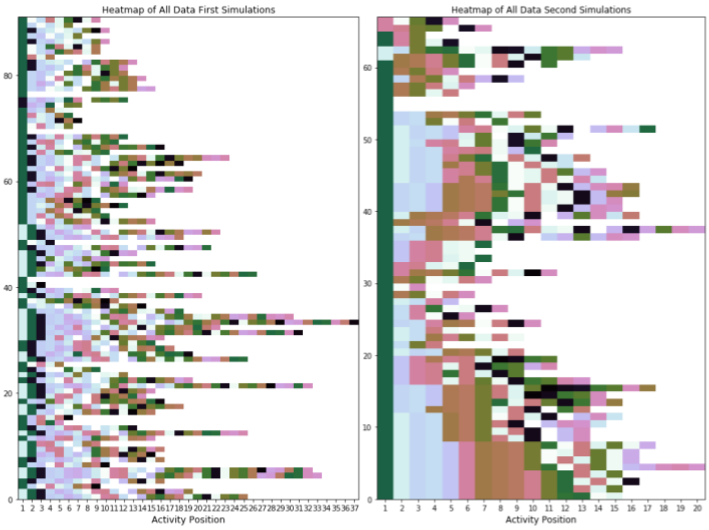
TABLE II. SCORES USED FOR THE ANALYSIS

	Positive	Negative
Positive	**True Positive (TP):** actions that should be done and were done	**False Negative (FN):** actions that should not be done and were done
Negative	**False Positive (FP):** actions that should be done and were not done	**True Negative (TN):** actions that should not be done and were not done
	Precision = $\left(\frac{\text{TP}}{\text{TP+FP}}\right)$	Specificity = $\left(\frac{\text{TN}}{\text{TN+FP}}\right)$
	Accuracy = $\left(\frac{\text{TP+TN}}{\text{TP+FP+FN+TN}}\right)$	Recall = $\left(\frac{\text{TP}}{\text{TP+FN}}\right)$
	F1= $2\left(\frac{\text{Precision}*\text{Recall}}{\text{Precision}+\textit{Recall}}\right)$	

Therefore, the analysis conducted was done according to the following three categories: i) the actions that should have been accomplished during the first four minutes of trauma management; ii) the minimum actions that should have been accomplished for each of the trauma scenarios and, iii) the complete sequence of actions taken along the simulation. The scores obtained on the first simulations were compared with the ones obtained for the same simulation scenario after the 2-weeks training. To compare these two sets of scores the Wilcoxon rank-sum test was used [20] and statistical significance is defined when the p-value is lower than 0.05.

III. RESULTS

Information about the sequences of actions accomplished were gathered to present, for the pre-training and post-training



(a) (b)

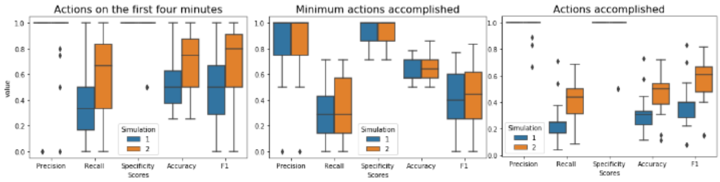
Fig. 1. Heatmap with the sequence of actions taken in all the simulations: (a) pre-training and (b) post-training.

simulations, the actions taken by all the trainees. Figure 1 shows all the information for all the trauma scenarios, (a) before and (b) after training, where different colors represent different actions. It is noted that a significant variety of actions are accomplished when a trauma scenario is managed. However, after the training period, the treatment provided by the trainees are more homogeneous. For example, the first mandatory step to take, which is anamnesis, represented by dark green in Figure 1, was performed in 63% of the simulations in pre-training whereas 94% in post-training. Moreover, the number of actions accomplished decreased after trainings (37 in pre-training and 20 post-training).

A. Prehospital Pelvic Trauma Management

First of all, the initial actions taken along the first four minutes of the trauma management treatment are studied. In Figure 2 (a), all the scores calculated for the pre- and post-training are displayed. All the scores increase, obtaining statistical significance on the recall and the F1 score (p-values of 0.025 and 0.036 respectively). Then, an analysis of the minimum actions is accomplished which shows that, for this trauma scenario, there is a small difference between pre and post training simulation, as shown in Figure 2(b), showing no statistical significance between simulations.

Finally, all the actions accomplished during the whole simulation are depicted in Figure 2 (c). Statistical significance is obtained for all the scores, except for the precision and specificity ones. This shows an enhancement on the post-training simulation.



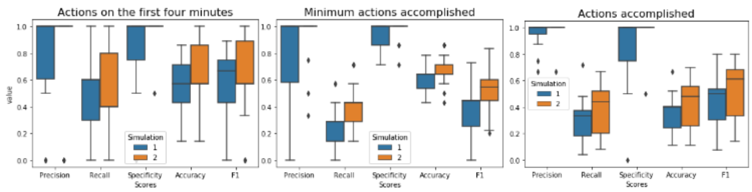
(a) (b) (c)

Fig. 2. All the scores calculated for the pre- and post-training simulation: (a) scores obtained for the initial four minutes; (b) scores when the minimum actions are anlyzed; (c) scores obtained when all the actions are analyzed.

B. Hospital Pelvic Trauma Management

When the pelvic trauma is treated within a hospital facility, the actions to take may be different from the ones at prehospital, as resources differ. For this trauma scenario, there is an improvement on the actions performed for the initial four minutes but no statistical significance is obtained (see Figure 3(a)). Nevertheless, for the minimum actions that should have been accomplished in the hospital setting, a clear increase is obtained in the median values. Additionally, Figure 3(b), shows significance on the accuracy score (p-value = 0.045).

Regarding all the actions taken during the whole simulation, there is also an improvement on the post training simulations as shown in Figure 3(c). Nevertheless, there is not statistically significance difference between both simulations.



(a) (b) (c)

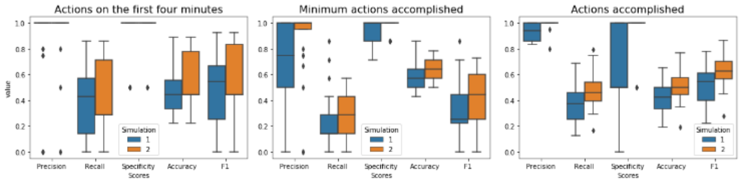
Fig. 3. All the scores calculated for the pre- and post-training simulation: (a) scores obtained for the initial four minutes; (b) scores when the minimum actions are anlyzed; (c) scores obtained when all the actions are analyzed.

C. Prehospital Lower Limb Trauma Management

In lower limb trauma management scenarios, the actions performed within the initial four minutes and the actions deemed as minimum to treat this trauma lesion remain consistent across both, prehospital and hospital settings. As a result, a single analysis will be presented to analyze all actions performed by the trainees throughout the simulations.

An improvement is obtained for the actions accomplished during the initial four minutes as shown in Figure 4(a). The median values of all the scores increase; nevertheless, no statistical significance is obtained. With respect to the minimum actions to accomplish for this trauma scenario, the analysis is shown in Figure 4(b). All the scores increase their median values obtaining statistical significance with the exception of the recall score.

When analyzing all the actions performed during whole the simulation, the actions accomplished by the trainees in the prehospital setting differ from the ones in the hospital one. In the prehospital setting, Figure 4 (c) shows an improvement for the post-training simulations obtaining statistical significance only for one score, the specifity one (p-value = 0.013).



(a) (b) (c)

Fig. 4. All the scores calculated for the pre- and post-training simulation: (a) scores obtained for the initial four minutes; (b) scores when the minimum actions are anlyzed; (c) scores obtained when all the actions are analyzed.

D. Hospital Lower Limb Trauma Management

Finally, when analyzing the hospital lower limb trauma scenarios, all the scores show a clear improvement as shown in Figure 5, obtaining significance on the specificity and accuracy scores. The recall score is close to show significance, with a p-value of 0.051.

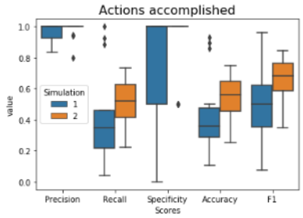


Fig. 5. Scores obtained from the pre- and post-training simulation, considering all the actions taken along the whole simulation.

IV. Conclusions

The goal of this study was to verify if the use of web-based trauma simulators supports trauma management learning by analyzing the behavior of trainees within the WBTS developed on [11]; the main contribution of this paper is to propose a set of scores that provides information about the performance of a simulation, considering that different actions should be implemented depending on the trauma scenario. After analyzing all the simulations accomplished by the trainees, a clear enhancement is perceived as a more homogeneous response is obtained once all the trainees performed the training with the WBTS. This is an important aspect, as the implementation of trauma management algorithms has grown with the objective to provide a more systematic and efficient treatment to patients and WBTS would contribute to that goal.

Regarding the prehospital pelvic trauma management, a clear improvement is perceived specially on the actions taken on the initial four minutes and on the total actions performed along the whole simulation. The initial first four minutes are extremely relevant as an important number of trauma patients pass away during the first minutes after the lesion [14]. As the recall and F1 scores increase, this means that trainees are getting better on taking the right actions to treat trauma patients. When all the actions accomplished are analyzed, the accuracy, F1 and recall scores show significance. This means that, there is not only an improvement on the correct actions taken but also, an improvement is perceived with respect to the actions that should not be taken to correctly manage a trauma lesion. Consequently, the training has a positive improvement with correct actions but also avoiding treating the patients with actions that do not have a positive impact on their evolution.

When a pelvic trauma lesion is managed on a hospital setting, the improvement is also perceived; nevertheless, almost no statistical difference is shown. The main enhancements are similar to the ones on the prehospital trauma management.

In the context of treating a lower limb trauma lesion in both, prehospital and hospital settings, the improvements are consistent as the initial actions accomplished within the first four minutes and the minimum actions to perform show no differences. All the scores, except for the recall score, show statistical significance for the minimum actions to perform. Furthermore, there is also an improvement on the actions accomplished during the initial four minutes. Consequently, training using the WBTS shows statistically significance improvements in all scores, providing trainees with a tool to improve trauma patient treatments. Analyzing the entire trauma management for the hospital lower limb lesions, an improvement is observed on the correct actions performed by the trainees and, additionally, on the avoidance of actions which have a negative impact on the patient. Consequently, this trauma scenario also improves after using the WBTS.

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