Importance of Simulation in setting up ultrasound-guided vascular access

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Abstract

Background: Simulation is considered a major educational tool in medical practice as well as in the acquisition of technical and non-technical skills. Similarly, ultrasound takes an important place in the world of simulation, in particular for the realization of vascular access in emergencies and intensive care units. Ultrasound-guided vascular access is an invasive and precise gesture, hence the objective of evaluating the contribution of simulation in the success of ultrasound-guided vascular access and the stress management of the learners.

Materials and methods: This study aimed to assess the learning of the ultrasound-guided vascular access gesture and the stress management by simulation among medical residents, from emergency, medical and surgical resuscitation departments. We based on the Heart Rate (HR), the ENS score, the STAI score, and the PDI score measurement before and after simulation, during 03 simulation sessions, within a Tunisian university hospital. Sessions were animated by 02 monitors using a simulator vascular access and an ultrasound machine equipped with a high-frequency linear probe.

Results: 20 residents were included. During the evaluation, we found that (55%) of learners felt discomfort with vascular access in general, (75%) have already participated in a simulation session, and (90%) have already had a passage by intensive care units. We had 100% of satisfaction. A significant statistical relationship was found between the decrease in HR and in the time taken to perform the gesture after the simulation session ($p = 0.001$) and a significant decrease in the ENS score of each candidate ($p = 0.021$). A significant decrease also in HR was objectified for participants who completed the procedure for several passages ≤ 2. However, neither the length of medical studies nor the experience nor the variation of the PDI score interferes in any statistical analysis with the decrease of the HR or the time of realization of the gesture.

Conclusion: Today the real challenge of simulation in medicine is to link the technical and pedagogic quality of medical education. Our study made it possible to show a significant satisfaction of the learners during the simulation session, in the pose of ultrasound-guided vascular access, the reduction of the time of realization, and the positive effect of the simulation on the reduction of stress as being an omnipresent factor.HR=heart rate, STAI=Stat Trait Anxiety Inventory, PDI= Peritraumatic distress inventory ENS= numeric stress scale.

Keywords: Simulation, Ultrasound, Vascular access, Emergency Department, Critical Care, Peritraumatic distress inventory

INTRODUCTION

Medical simulation is a set of educational approaches, which highlights the importance of developing professional skills before, during, and after the interactions with patients encountered in professional practice. Simulation is now recognized as an essential part of evidence-based education. It allows the learner to acquire knowledge, and technical and soft skills such as team management, crisis management, and leadership, more quickly and without risk to the patient. It appears to be a tool for improving the quality and safety of care by offering the possibility of endlessly repeating common or rare situations (1,2). Ultrasound-guided vascular access has emerged as one of the technical skills that physicians need to master in intensive care and emergency settings. To initiate parenteral nutrition, osmotically active products (such as mannitol), infusions of products with low or high pH, vasopressin amines, prolonged venous access in patients without venous capital or very fragile venous capital (like in elderly, drug addicts, obese patients, and children) and requiring antibiotics, transfusions of blood products. Vascular access is a multidisciplinary need. Blind central venous access is complicated by 10% of failures, 8% of punctures, and 4%of pneumothorax (3). Meta-analyzes confirm the improvement in success rates at the first puncture, and the decrease in the rate of complicated ultrasound-guided central vascular access, this technique saves time and detects atypical venous anatomical position and thrombosis(4) A simple, but precise gesture which requires learning by simulation and which is often accompanied by a state of stress, especially in real-time. Stress is very subjective and varies from one person to another. Stressors must be well known to better control and understand them. (5)

The objective of our study is twofold:

- To evaluate the contribution of the simulation in the learning of ultrasound-guided vascular access placement (the success of vascular access placement, measurement of completion time, and satisfaction).
- To evaluate the effect of the simulation session on stress management when applying for ultrasound-guided vascular access.

METHODS

This Prospective cross-sectional descriptive study was carried out over 03 simulation sessions, at a University Hospital in Tunisia over 03 successive days. We included medical residents assigned to the emergency department, to medical resuscitation and surgical resuscitation services, with oral consent knowing the objectives of these sessions. Residents who have mastered ultrasound-guided vascular access have been excluded. It is a low-fidelity procedural simulation session with an estimated duration of 75 minutes. The context that we have chosen is the provision of vascular access in an intensive care room for an intubated patient ventilated outside an urgent situation. As learning objectives, we set ourselves to prepare the patient and the material necessary for the vascular access pose, know the rigorous asepsis

rules for the vascular access pose, recognize the aspect of the needle at the vascular site, recognize the two modes of vascular access, "in a plane" and "out of plane" and the realization of the gesture of vascular access correctly under ultrasound. At the end of the session, learners go through a final assessment test. The session took place in a simulation room with: a sick bed, good lighting, the possibility of dimming the light a good visualization of the ultrasound image, a round table to bring together the candidates, a PC and, a projection data show. The vascular access simulator that we made in advance on the bed (02 devices in reserve), a functional ultrasound device with a high-frequency linear probe from 10 to 15 MHz (6), a gel application adapted to the ultrasound probe and various equipment (sterile perforated fields, sterile gloves, hydroalcoholic solution for the hands, and 10ml syringes).

To start the Briefing, we set a maximum duration of 10 minutes for:

- Introducing for the interest of central vascular access and technical difficulties, the current place of ultrasound in vascular access
- Explaining the different stages of the session and the objectives to achieve
- Circulating the forms to be able to fill them out by the candidates.

The 40-minute session includes a demonstration of the 04 steps to learn the gesture to know with the ultrasound machine in front of the candidates, this demonstration stage lasts a maximum of 05 minutes. The 04 procedural learning times are as follows: A Time to make the gesture in silence / a Time to make the gesture commented on by the instructor / A Time to make the gesture while being commented on by the candidates / A Time when the candidates will voluntarily spend one by one making the gesture with the possibility during each visit to each candidate to ask the questions they want to ask.

The procedure consists of placing the ultrasound probe in position on the model with identification of the image of the vessel on the screen, the introduction of the needle, identification of the tip of the needle in the plane and outside the plane then the introduction of the needle at the level of the image of the vessel, take the artificial blood sample, and finally the reinjection of the liquid at the level of the vessel.

The gesture is said to be done or achieved if the tip of the needle is successfully identified from its introduction until it enters the lumen of the vessel and also by aspiration of the red liquid in the syringe and its reinjection without losing the ultrasound image or extravasation of fluid outside the vascular lumen.

The device used, called the Phantom device, is a box with echogenic content simulating a member where vessels pass. (4)

We explained to each candidate the possibility of doing the gesture another time if it is not reached or if the gesture is not understood or if its accomplishment is not satisfactory for the candidate.

On each pass, the candidate's Heart Rate is noted automatically and the time taken to complete the gesture on the first pass is also noted on their form.

At the end of the session, a form must be filled out and given to the instructor after the last test. At the final test, the candidate is asked to repeat the gesture of vascular access according to the standards acquired during the learning session while marking the duration of the gesture and his heart rate.

For each candidate, 2 stress scores that have already been used in the literature were collected: the PDI (the Peritraumatic Distress Inventory) score and the STAI (The state- Trait Anxiety Inventory score). They testify to a situation of stress if they are greater than or equal to 15. (7,8)

For the subjective assessment of satisfaction, we used a simple numerical scale (ENS) from 0 to 10: 0 is no stress, and 10 is a state of paralyzing stress.

The session was led by two monitors. We performed 03 procedural simulation sessions for ultrasound-guided vascular access under the same conditions for the 03 groups of residents.

All the forms were collected and carefully completed by the candidates anonymously. During the Debriefing, considered an important stage of our session respecting its three phases (8), we proposed to assess the technical and non-technical skills of the learners and the evaluation of the simulation session as much for the learners that for trainers by measuring satisfaction according to items already specified on the form, the acquisition of competence by ultrasound manipulation, the recognition of vascular access images in and out of the plane, the multiplication of passages from learners to better understand and master the gesture.

Did we judge the satisfaction of this session using 05 items:1-Are you generally satisfied with this simulation session?

2- The time designated for each participant seems correct to you? 3-Is the time designated for each session suitable? 4-Did you pass the vascular access gesture on the 02 flaps in-plane and out-of-plane? 5-Do you have a feeling of accomplishment at the end of the simulation session?

A PowerPoint presentation at the end of the session illustrated with images to explain the ultrasound technique of vascular access in the plan and outside the plan 05 minutes

Each candidate has received a certificate of participation in this simulation session in their email as an element of promotion.

Data analysis was performed by the SPSS 23.0 program.

The normal distribution of the quantitative variables was achieved by the Kolmogorov-Smirnov test.

The quantitative variables were expressed by their means ± standard deviation and compared by Student's “t” test.

The qualitative variables were expressed by their proportions and compared by the “chi-square” test. When conditions did not allow, Fisher's exact test was used. The different parameters were studied by univariate analysis. The materiality threshold used was set at 5%.

RESULTS

Twenty medical residents were included. We had 80% female. Our sample of residents has in 70% of the cases more than 06 years of medical

studies, 65% are from the medical school of Monastir, 45% are currently in training in the emergency department including 40% in the first year of residency.

We included medical residents who established their internship with an average age of 28.5 ± 3.8 years. The baseline characteristics of the learners are reported in table 1.

Table 1: Characteristics of the study population (n=20)

		number	percentage
AGE	≥ 30 years	5	23
	< 30 years	15	77
Male gender	Male	4	20
Current internship	Emergency department	9	45
	Intensive care unit	2	10
	Surgical resuscitation service	6	30
	Another department	3	15
Residency year	The first year of study	9	45
	The second year of study	2	10
	The third year of study	6	30
	The fourth year of study	3	15
Non-echo-guided vascular catheterization n(%)	Yes	Assisted by senior / major resident: 4(20)	11(55)
		Not assisted 16 (80)	
	No	9	45
Ultrasound practice	Yes	12	60
	No	8	40
Intensive care work	Yes	18	90
	No	2	10

In the study, we found that 15 (75%) of the learners had participated in a simulation session (Table 2).

The candidates report in 55% (11) of the cases a fear during the installation of vascular access and 65% (13) think that the use of simulation in learning about ultrasound-guided vascular access. The satisfaction was 100% positive with the various learners with the suggestion of other simulation sessions.

Table 2: Learners' previous experience with simulation:

		number	percentage
Participation in a simulation session	**Yes**	15	75
	No	5	25
Animation of the simulation session	**Yes**	5	25
	No	15	75

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The initial average of HR is 94.1 bpm ± 13. The average HR at the time of the final test is 82.1 bpm ± 17 with a single maximum HR more marked at the start of the session to 136 bpm, on the first pass on the simulator. There is a significant decrease in HR and the time to perform the gesture at the time of the test compared to HR and the time to complete the initial gesture (p = 0.001) (Table 3).

It was noted for the learners who have had several passages ≤2 a decrease in the time of realization of vascular access during the test at the end of the session but not significantly with

(p=0,071). We have noted a statistically significant relationship between the decrease in HR and the number of passages ≤2 with (p=0,052) but there was no significant relationship with a previous manipulation of ultrasound.

Table 3: Heart rate and time is taken to complete the procedure

	Minimum	Maximum	Average	P
Initial HR (bpm)	79	136	94	0,001
Test HR (bpm)	65	129	82	
Initial realization time (seconds)	70	294	146	0,001
Test realization time (seconds)	28	185	86	

Concerning the subjective evaluation of stress, the results showed a significant decrease in the mean value of the **ENS** after passing the simulation session (mean value of 3.8 initially and 2.2 at the time of the final test, p = 0.021).

We relied on two scores in the assessment of the candidates' stress state during our simulation session: the **STAI** score (6) and the **PDI** score(7). significant statistical difference between the two stress scores in our population.

We tried to establish a particular profile for which there is a significant decrease in the STAI or PDI Stress score but we did not find significant parameters in terms of age, the number of years of study, or the previous passage by the resuscitation services, or the previous manipulation of ultrasound or by the previous vascular access placement or even the previous participation in a simulation session (Table 4).

DISCUSSION

In our study, we included 20 medical residents with an average age of 28.5 ± 3,8 years old, 75% of them had previous participation in a simulation session and 60% of the learners had already used the ultrasound machine.

The rationale for the use of ultrasound is to provide fast, reliable, safe guidance for needle placement in a vessel, both for routine and difficult cases. (9)

Table 4: Descriptive table of the correlations between the STAI stress score and the parameters collected

	Score de STAI>=15 (p)
Age≥30 years	0,32
Gender (female)	0,53
Current intensive care internship	0,52
Number of years of medical study ≥6ans	1
Bn Number of years of residency	0,57
Haunt of the pose of vascular access	1
Previous intensive care internship	1
Previous participation in a simulation session	1
Previous ultrasound manipulation	0,34
Previous knowledge of ultrasound-guided vascular access basics	0,61
Number of passages <=2	1

During their passage for the pose of ultrasound-guided vascular access, we noted an initial HR at the first passage average of 94 bpm, with a maximum of 136 bpm, the HR at the final test was on average 82 bpm. The time of realization of initial ultrasound-guided vascular access was estimated on average by 146s but the time of realization of the gesture during the test was on average 86s. Initial ENS was 4 with an STAI scale of 13.5 on average and a maximum PDI scale was 11 which seems insignificant since this situation is generally considered nonstressful.

We noted that 75% of the learners consider it delicate, but this is not significantly correlated with the PDI stress scale. Some studies have shown that the success rate was higher, and the number of attempts, the time to successful cannulation, and complications were reduced significantly in the US-guided group to the traditional landmark (10–12).

A systematic protocolized approach for US-guided vascular access in elective clinical situations was proposed in the study of Shmidt and all, by the use of simulation sessions, to ensure procedural safety and high cannulation success rates, it was regrouping 06 steps: 1. Choose site, identify anatomy, select appropriately sized catheter 2. Confirm patency of the target vessel (compression) 3. Insert needle using real-time US guidance 4. Confirm the correct needle position 5. Ensure that the wire is in the desired vessel6. Verify catheter location (13)

The learning curve for US-guided IJV, CVC placement was evaluated in 30 novice intensivists, showing that optimal technical skill was obtained after 6–8 procedures (14).

In our study, the number of passages was on average 2. In one study of emergency medicine nurses and paramedics, the success rate using US guidance was 70% after 4 procedures, increasing to 88% after 15–26 (15). In another study, Duran et al, found in following initial training, emergency room technicians were successful on the first pass 86.8% of the time, the second pass another 11.6%, and the remaining 1.6% of subjects on the 3rd attempt (16)

Orientation of the ultrasound probe and needle is a skill that takes some practice, but the time spent understanding and practicing the technique will be repaid many times over when performing invasive procedures. (9)

In our study, there was also a significant decrease in HR after passing through the simulator and in the time taken to perform the gesture and the stress score assessed by the survey.

Several studies have focused on the place of simulation in the training of vascular access pose with increasingly sophisticated simulators called “Blue-Phantom” with a major concern to spare the patient from the risks of blind vascular access pose, by reducing the number of attempts, the completion time and even preferring the peripheral routes of good caliber but this apart from theoretical knowledge of vascular anatomy, manipulation, and knowledge of ultrasound anatomy. It seems necessary to increase the long-term simulation sessions with an average duration of 01 years (3,4).

We found 100% of satisfaction which is a point of strength in our study. Some studies try to understand this interaction study simulator, to better characterize the simulation sessions according to the target population, such as the study by Olson et al published in June 2019 (17). This study indicated that the incorporation of simulation experiences in the first year of medical school enhanced learning of basic science physiology concepts and promoted the development of self-confidence as future clinicians. Incorporating simulation into the

didactic coursework should be promoted in other medical schools' curricula.

Some studies have been based on a digital visual self-confidence scale to evaluate the performance evolution of emergency physicians throughout 03 years of training on different sessions for procedural simulation sessions such as thoracotomy, cricothyroidotomy, and other gestures. A questionnaire administered before and after each session assessed EM faculty physicians' self-perceived ability to perform these rare procedures. Participants self-reported confidence in their performance improved for all procedures (18).

The STAI score we used was in 1970 based on 40 items divided into 02 groups for the study of anxiety during stressful situations. A reduced form of the questionnaire was established and validated out of 10 items (7) (19).

Other studies were concerned with the evaluation of stress as a promising factor for success or failure with a significant correlation between the results and the performance of the professional (8).

Some consider that stress, as a ubiquitous factor during a simulation session even a paralyzing factor. We note in this regard the study made by Nunes et al. on interns in anesthesia and emergency medicine during critical situations such as the management of RCP or anaphylactic shock, stress was measured by a numerical scale simple (ENS), HR and STAI score for the situations for which they were previously trained or during the situations for which they were not trained with a significant difference due to the simulation session ($p \leq 0.05$). (20)

Another study made by Geerarerts et al in 2009, based on the study of stress by simple numerical stress scales (ENS) whose mean before the simulation was 5.03 ± 1.58 (median = 5 and extremes = 2 at 8), and that of the ENS after the simulation was 7.00 ± 1.98 (median = 7 and extremes = 2 to 10), with a significant difference between before and after the 13 sessions ($p = 0.0004$). The ENS scale after the session was always higher than those before the session except for 3 cases out of a total of 27 cases. Pre-session stress was significantly lower among interns who had already participated in a simulation session in their curriculum compared to those who had never participated 14 ($p = 0.04$). However, this difference was not found for stress after the session ($p = 0.68$) (8).

Vincent et al also conducted 2015 another prospective monocentric study on cardiorespiratory arrest (ACR) management with the transition to VF among resuscitation anesthesia technicians. The stress measurement was made by the peritraumatic distress score and was able to show the absence of a significant correlation between the learner's profile and demographic characteristics or seniority of experience, this is consistent with the results found in our study. Low stress could lead to a relative lack of interest in a situation that is nevertheless serious and thus leads to poor performance. Significant stress could have similar effects due to the anxiety and the inhibition it generates (inverted U curve) (8).

The evaluation of the session can be realized not only by the evaluation of the technical and non-technical skills of the participants but also of the trainers and this could be evaluated by the DASH grid (21), but we limited ourselves in our study to " assess technical skills by mastering the gesture and ultrasound objectives envisaged in the context of our procedural simulation and non-technical skills by achieving candidate satisfaction, meeting their expectations and managing stress. In this passage, we had 100% satisfaction as well as a verbal request from the candidates for evaluation and continuous learning by the multiplication of simulation sessions (22).

These findings are consistent with prior research reports that integrating simulation in a preclinical curriculum is beneficial for medical students, especially for emergency residents.

The limits of our work were: the small sample, and the availability of residents outside the guards and on-call teams, despite the insistent request from the learners to increase the number of sessions.

The strengths of our work, with the simplicity of the material, and the learning objectives were achieved in terms of success and reaching the criteria of quality of the vascular access gesture already described for all participants, on the one hand, satisfaction and also the effect of the simulation on the reduction of stress.

CONCLUSION

Medical simulation has succeeded in recent years as an essential training method for all health professionals by creating an environment where technology is at the service of education in particular the advancement of ultrasound vascular access without threatening patient safety.

we concluded that due to simulation sessions, there was a significant decrease in HR, the time it took to perform the procedure compared to the test time and we discussed the state of stress according to objective bases.

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