Original Article

Effects of a simulation-based workshop on nursing students' competence in arterial puncture

Efeitos de um *workshop* de simulação sobre a competência em punção arterial de estudantes de enfermagem

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Abstract

Objective: To evaluate whether a short simulation-based workshop in radial artery puncture would improve nursing students' competence to a level in which they could practise the procedure on a live patient without compromising his safety.

Methods: Quasi-experimental one-group pretest-posttest study with 111 third-year nursing students. A 1.5-hour simulation-based workshop was implemented. This included a video-lecture, live demonstrations, self-directed simulated practice in dyads and individual intermittent feedback. Participants' skills, knowledge and self-efficacy in arterial puncture were measured before and after attending the workshop.

Results: After the intervention, a total of 61.1% of the participants showed the level of competence required to safely practice radial artery puncture on a live patient under supervision.

Conclusion: Effective simulation-based training in arterial puncture for nursing students does not necessarily need to be resource-intensive. Well-planned, evidence-based training sessions using low-tech simulators could help educators to achieve good educational outcomes and promote patient safety.

Resumo

Objetivo: Avaliar se um workshop de simulação e curta duração sobre punção da artéria radial melhoraria a competência de alunos de enfermagem em um nível em que pudessem praticar o procedimento em um paciente vivo sem comprometer sua segurança.

Métodos: Estudo quase-experimental do tipo pré-teste e pós-teste com um grupo de 111 estudantes do terceiro ano de enfermagem. Foi implementado um *workshop* de simulação e 1,5 horas de duração. Isso incluiu uma vídeo-palestra, demonstrações ao vivo, prática simulada autodirigida em díades e *feedback* intermitente individual. As habilidades, conhecimentos e autoeficácia dos participantes em punção arterial foram medidos antes e depois da participação no *workshop*.

Resultados: Após a intervenção, 61,1% dos participantes demonstraram o nível de competência necessário para a prática segura da punção da artéria radial em um paciente vivo sob supervisão.

Conclusão: O treinamento efetivo em punção arterial baseado em simulação para estudantes de enfermagem não necessariamente precisa ser intensivo em recursos. Sessões de treinamento bem planejadas e baseadas em evidências, com uso de simuladores de baixa tecnologia podem ajudar os educadores a alcançarem bons resultados educacionais e promover a segurança do paciente.

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Introduction

As part of the respiratory assessment of acutely ill patients, arterial blood gases (ABG) analysis has become one of the most common laboratory investigations in modern medicine.[1] Consequently, radial artery puncture has emerged as a regularly-performed invasive procedure in clinical settings.[1,2] The puncture of the radial artery is often described as a very painful and challenging invasive procedure that is not exempt of risks.[2,3] In fact, case report studies suggest that errors during the performance of arterial puncture for ABG analysis could lead to serious complications such as nerve injuries, acute compartment syndrome, thrombosis and pseudoaneurysm.[3,4] Therefore, it is important that those healthcare professionals responsible for collecting arterial blood samples are adequately trained and their competence rigorously assessed before they attempt radial artery puncture on live patients.[5] More studies specifically focusing on designing, implementing and evaluating the effects of different educational interventions in healthcare professionals' competence in radial artery puncture for ABG analysis are needed.

In Spain and many other countries, nurses are responsible for collecting arterial blood samples for ABG analysis through the puncture of the radial artery.[1] In many of these countries, the licensing examination does not exist and nurses are expected to be safe and fully competent practitioners upon completing their undergraduate nursing programme.[6] However, literature suggests that opportunities to practise invasive procedures on live patients are usually scarce during undergraduate programmes.[7] This reality could have a negative impact on the development of competence of future newly-qualified healthcare professionals, increasing the occurrence of mistakes and compromising patients' safety.[5,8] Consequently, with regard to arterial puncture and other invasive procedures, nursing educators are expected to: [1] find more effective educational strategies that facilitate the acquisition of competence amongst nursing students;[7] and

[2] rigorously assess learners' competence before they are allowed to perform on live patients.[5,6] Adopting a person-centred approach based on the holistic definition of competence may help nursing educators to effectively address these challenges.[6-9]

Firstly, nursing educators should take into consideration that successful educational strategies must focus on the equal development of the cognitive, psychomotor and attitudinal domains of competence. Therefore, an effective training strategy should always include elements that not only facilitate the acquisition of knowledge and skills, but also promote individuals' self-efficacy.[5,10-12] Secondly, valid and reliable tools should be used to individually assess these three domains of competence. Rigorous and comprehensive assessment of knowledge, skills and self-efficacy can help to determine individuals' competence in invasive procedures such as arterial puncture.[5,9,13,14] The use of simulation-based training supports this person-centred approach and promotes safe practice.[10,15]

To different extents, many studies have shown that the use of simulation is effective in both improving and assessing participants' knowledge, performance and/or confidence in a wide range of skills and procedures.[8,11,16,17] However, effective simulation-based training can be resource-intensive and this may pose a threat to its implementation in faculties with a limited budget.[12,17,18] In these cases, video demonstration, modelling examples, dyad learning and intermittent feedback have demonstrated that, when used in conjunction with self-directed simulated practice, can be beneficial for the acquisition of competence in procedural skills whilst limiting the amount of resources needed.[8,18-23] In spite of this, our literature review showed that there is a dearth of published studies aiming to develop, implement and evaluate the effects of educational interventions that facilitate the acquisition of competence in arterial puncture amongst healthcare professionals in general and nursing students in particular. Using low-tech equipment and an evidence-based educational intervention, this

study aimed to evaluate whether a short simulation-based workshop in radial artery puncture would improve nursing students' competence to a level in which they could practise the procedure on a live patient without compromising his safety.

Methods

Study setting and context

The study took place in a southeastern Spanish university between October 2014 and January 2015. In the national context of this study, radial artery puncture for ABG analysis is taught as part of the undergraduate nursing degree programme. In many faculties around the country -and around the world-, budgets for innovation in teaching and learning are limited. This does not only apply to the acquisition of new equipment, but also to the amount of human resources dedicated to educate nursing students. For example, in the context of this study the ratio lecturer to student for procedural skills training is 1:16. Traditionally in this context, arterial puncture for ABG analysis is taught as part of a 2-hour lecture on "critical care procedures". This is often done in a lecture theatre, with large groups of students (up to 60 at the time) and using either PowerPoint® presentations, video demonstrations, live demonstrations performed by the lecturer in a low-fidelity venepuncture arm, or a combination of them. It is expected that nursing students have the opportunity to practice the procedure once they are in clinical placements, under the direct supervision of their mentors and on live patients.

Study design

In this study, a quasi-experimental, one-group pretest-posttest design was used to test whether a single, short simulation-based workshop using low-tech equipment would allow nursing students to achieve a safe level of competence in arterial puncture for ABG analysis before practising the procedure on live patients. In order to rigorously assess the effectiveness of the educational intervention,[11] we compared the proportion of students achieving the pre-defined competence pass-mark before and after attending the simulation-based workshop in arterial puncture for ABG analysis.

Ethical considerations

The Institutional Research and Ethics Committee granted ethical approval before a member of the research team contacted the potential participants. Written detailed information about the study's aims and procedures was provided to all eligible subjects, who were both asked to voluntarily sign an informed consent document before participating and notified of their right to withdraw at any time. Assessment and demographic data were anonymous, and information was handled and stored confidentially.

Study participants and sample size

Participants' eligibility criteria were: [1] to be enrolled in the critical care module of the undergraduate nursing programme, and [2] not to have received any training in arterial puncture. Sample size was calculated a priori using a conservative approach.[24] Assuming a true proportion of 0.5, a type-I error of 5% and 95% power to detect significant statistical differences (p<0.05, two-sided), it was estimated that a total sample of 82 participants was needed. To compensate for possible attrition, an extra 30% was added to the sample size estimate. A total of 111 nursing students participated in the study. Information about whether participants had observed a qualified healthcare professional performing an arterial puncture on a live patient was collected in conjunction with demographic data (age, gender and education level).

Educational intervention

Participants were randomly divided in groups of 16 students and attended a 1.5-hour simulation-based workshop in arterial puncture for ABG analysis. Two members of the research team and two independent experts designed the workshop. The educational intervention started with a 5-minute introduction

on the session's aims, learning outcomes and structure. Then, all attendees were shown a 10-minute video lecture on arterial puncture for ABG analysis,[25] which was followed by two flawless modelling examples performed by the facilitator. Whilst the first one of these modelling examples was carried out silently, the second one included a simultaneous description of the procedure. Furthermore, a flawed modelling example was performed and participants were asked to identify the mistakes, describe them and explain the correct way of doing it. All these modelling examples were run in 25 minutes using a hybrid-simulated approach that comprised an arterial puncture simulator (Arterial Puncture Wrist from Kyoto Kagaku Co., Japan®) and a role-player who acted as the patient. This allowed the facilitator to demonstrate not only the technical skills involved in the procedure, but also the communication skills needed to guarantee an effective nurse-patient interaction. Finally, students were paired up in dyads and the last 50 minutes of the workshop were dedicated to self-directed simulated practice. A member of the dyad acted as a simulated patient, which allowed the other one to practise the nurse-patient interaction while performing arterial puncture on the simulator. The ratio student to simulator was 4:1, meaning that while one dyad practised using the simulator, the other dyad observed them doing so. The facilitator provided individual intermittent feedback to all participants. Although students were encouraged to provide feedback to each other, the use of concurrent feedback was forbidden. In order to minimise bias, the same facilitator delivered all the training workshops and the ratio lecturer to student was 1:16.

Data collection, instruments and outcome measures

Procedural skills, knowledge and self-efficacy in arterial puncture for ABG analysis were individually assessed for all participants before (pre-test) and immediately after (post-test) receiving the intervention.

In order to assess participants' skills in arterial puncture, they were given a hybrid-simulated scenario with a role-player acting as the patient and the arterial puncture simulator to perform the invasive procedure

on. Participants' performances were observed and assessed using the *'Arterial Puncture Skills Assessment Tool'* (APSAT). Participants' knowledge was assessed using a 20-item multiple-choice-questionnaire (AP-MCQ). Both assessment tools were developed based on international guidelines on best practices in arterial blood sampling and other authors' tool. Psychometric evaluation of the AP-MCQ and APSAT included a critical review from a panel of 10 experts and an experimental study with 58 students. The psychometric properties of both tools are presented in table 1. Lastly, participants' self-efficacy was measured using the *'Arterial Puncture Self-Efficacy Scale'* (APSES).[5]

Table 1. Psychometric properties of the AP-MCQ* and APSAT**

Psychometric properties	Instrument	
	AP-MCQ*	APSAT**
Reliability properties		
Internal consistency Cronbach alpha coefficient	0.90	0.96
Temporal stability - tested at 4 weeks Spearman correlation coefficient between test and re-test	0.85	0.78
Validity properties		
Content validity Average Content Validity Index	0.92	0.97
Criterion validity Correlation with other tools measuring similar concepts	0.63	0.70
Construct validity		
Number of structural factors + percentage of variance explained by factors	1 (62.1)	5 (79.8)
Ability to differentiate between known-groups = p-value <0.05	<0.05	<0.05

[1] AP-MCQ is the multiple-choice-questionnaire used to assess knowledge in arterial puncture;
[2] APSAT is the checklist used to assess skills in arterial puncture.

Participants' results on the assessments of knowledge, skills and self-confidence could range from 0-100. Following similar studies' benchmarks, participants were considered to have demonstrated a safe level of competence in arterial puncture for ABG analysis when they achieved the following average results: APSAT≥70%, AP-MCQ≥80% and APSES≥70%.[11,22] Due to the multidimensional structure of the APSAT and APSES, it was stipulated that, in order to compute an average final score, participants must have achieved more than 70% in all the dimensions of these instruments.

Data analysis

Statistical analysis of data was performed using IBM® SPSS® version 21 for Mac®. Firstly, the counts and proportion of students achieving the benchmarks for skills, knowledge and self-effica-

cy in arterial puncture at pre-test and post-test were compared using McNemar's test. Then, participants' competence was dichotomised and the proportion of students demonstrating competence at pre-test and post-test was also compared using McNemar's test.

Results

Participants' demographic characteristics and data about previous direct observation of an arterial puncture for ABG analysis are presented in table 2. Students who had observed qualified

nurses performing the procedure (n=16) completed the workshop but their data were not included in the analysis, as this could be considered a form of training. Furthermore, a total of 9 participants did not complete all the self-administered assessment tools correctly and they were also excluded from the analysis. A total of 86 datasets were finally analysed.

The final sample (N=86) had not received any form of training in arterial puncture before the educational intervention and was comprised of approximately 77% (n=66) female participants. The average age of the participants included in the analysis was 22 years (SD=5.48; range=19-50). In terms of education level, 77% (n=66) of these participants had entered the undergraduate nursing degree programme after completing upper secondary education.

Table 3 presents the counts and proportion of students who achieved the safety benchmarks for the following variables: skills, knowledge, self-efficacy and competence in arterial puncture. In summary, the proportion of students who achieved the safety benchmarks at post-test was significantly higher than at pre-test for all the study variables (p<0.05).

Table 2. Demographic characteristics of the total workshop participants (n=111) and the final study sample (n=86)

Characteristic	Workshop participants (n=111) n(%) M ± S.D.	Final study sample (n=86) n(%) M ± S.D.
Age (years)	22.36 ± 5.49	22.01 ± 5.48
Gender		
Female	82 (73.9)	66 (76.7)
Male	29 (26.1)	20 (23.3)
Education Level (completed)		
Upper secondary education	79 (71.2)	66 (76.7)
Others	32 (28.8)	20 (23.3)
Observed arterial puncture on a live patient	16 (14.4)	0 (0)

Table 3. Counts (proportions) of participants who achieved the benchmark for all variables measuring competence in arterial puncture. Comparisons are based on McNemar's test[1]

Variables	Simulation-based workshop		
	Pre-test n=86 n(%)	Post-test n=86 n(%)	p-value
Knowledge in arterial puncture			
≥80% of AP-MCQ[a] answered correctly	1(1.2)	64(75.3)	<0.05
Self-efficacy in arterial puncture			
≥70% achieved in Total APSES[b]	18(20.9)	81(94.2)	<0.05
≥70% achieved in APSES' subscale 'Preparation of patient and material'	33(38.4)	86(100)	<0.05
≥70% achieved in APSES' subscale 'Arterial puncture and sample management'	22(25.6)	81(94.2)	<0.05
Skills in arterial puncture			
≥70% achieved in Total APSAT[c]	4(4.7)	74(86)	<0.05
≥70% achieved in APSAT's subscale 'Patient communication'	15(17.4)	84(97.7)	<0.05
≥70% achieved in APSAT's subscale 'Preparation of material'	7(8.1)	80(93)	<0.05
≥70% achieved in APSAT's subscale 'Infection control and anaesthesia'	8(9.3)	82(95.4)	<0.05
≥70% achieved in APSAT's subscale 'Arterial puncture procedure'	17(19.8)	85(98.8)	<0.05
≥70% achieved in APSAT's subscale 'Sample management'	14(16.3)	84(97.7)	<0.05
Competence in arterial puncture			
Overall competence[d] achieved	0(0)	56(61.1)	<0.05

[a] AP-MCQ is the multiple-choice-questionnaire used to assess knowledge in arterial puncture; [b] APSES is the scale used to assess self-efficacy in arterial puncture; [c] APSAT is the checklist used to assess skills in arterial puncture; [d] Overall competence = ≥80% of the AP-MCQ answered correctly and ≥70% in all subscales of the APSES achieved and ≥70% in all subscales of the APSAT achieved

Discussion

This study aimed to design and implement a simulation-based workshop in radial artery puncture for ABG analysis and explore its effects on nursing students' competence. In summary, participation in a 1.5-hour simulation-based workshop resulted in a significantly higher proportion of students achieving and demonstrating adequate levels of knowledge, skills, self-efficacy and overall competence that would allow them to safely practise radial artery puncture for ABG analysis on live patients. However, almost 40% of the participants did not achieve the pre-established level of competence required to be allowed to practise radial artery puncture on a live patient. Far from interpreting this finding as a failure of the educational intervention implemented in this study, we see this result as a success in so far as it demonstrates that the simulation-based workshop not only allowed more than 60% of the students to achieve a safe level of competence in arterial puncture for ABG analysis, but also allowed the educators to identify those who may have not been safe performing the procedure on live patients. Nonetheless, more research on how to support these students and how to improve the educational intervention used in this study is needed.

In the study setting, as in many other faculties with limited resources, creating realistic and effective simulation training can be challenging.[12,17,18] Consequently, the researchers focused on designing and implementing an innovative educational intervention that, being potentially effective in improving nursing students' competence in arterial puncture, would only require the extra expense of acquiring low-tech simulators. In this context, evidence suggested that the use of video and live demonstrations,[19-22] self-directed hybrid-simulated practice,[8,19] dyads learning,[18,23] and intermittent feedback[21] could improve learners' competence in invasive procedures. Corroborating these studies' findings, our results have shown that the integration of self-directed hybrid-simulated practice with video and facilitator demonstration, peer-observation and intermittent feedback can also significantly improve nursing students' knowledge, skills and self-efficacy in invasive procedures such as radial artery puncture.

Previously published results suggest that the use of low-tech simulators may not be effective in improving nursing students' acquisition of venepuncture skills if they are not combined with high-tech simulators.[16] However, concurring with Reinhardt et al.,[28] our study has demonstrated that using low-tech simulators does not necessarily prevent students from acquiring confidence and competence in arterial puncture. In fact, when combined with simulated patients, the low-fidelity simulators served to create an accurate representation of real-life scenarios,[29] which may have contributed to the observed improvement in the proportion of participants who achieved the benchmarks for psychomotor and communication skills.[19] This improvement in participants' skills may have also been positively influenced by other factors. For example, the video and facilitator demonstrations of the procedure on a simulator could have reduced the cognitive demands that learning such skills impose on students;[22] the self-directed practice may have increased participants' motivation to learn and given them the opportunity to repeat the procedure until the skills were mastered;[8,11] the dyad learning might have fostered peer-teaching and peer-observation, reduced the time needed for hands-on practice and increased participants' motivation to learn;[18,23] and lastly, intermittent feedback from peers and facilitator may have contributed to correct mistakes and consolidate learning gains while minimising distractions.[21]

Although skills are a paramount element of the competence, students should also be expected to gain certain level of knowledge and self-efficacy before being allowed to practise invasive procedures on live patients.[10-12] In this regard, the present study has shown that attending a simulation-based workshop can improve nursing students' knowledge and self-efficacy in arterial puncture.

The improvement in the proportion of participants achieving the knowledge benchmark could have been influenced by all the different educational methodologies used. On the one hand, the initial video-lecture and the two flawless modelling examples could have contributed to disseminate the knowledge involved in the procedure.[25] On the other hand, the flawed modelling example, self-directed practice in dyads and individual feedback may have facilitated its consolidation through fostering individual reflection, group discussion, practical implementation and self-evaluation of such knowledge.[20] Likewise and concurring with previous studies' results, the implementation of modelling examples, self-directed simulated practice and dyad learning seems to have fostered an increase in the proportion of students reporting a high level of self-efficacy in arterial puncture.[8,18] This increase in participants' self-efficacy could have contributed to the final acquisition of competence in so far as it could have boosted their motivation to learn and positively influenced their perseverance and willingness to work.[17,30]

To the best of our knowledge, this is not only the first study that focuses on the design, implementation and evaluation of the effects of a simulation-based workshop in arterial puncture for nursing students, but also the first one that measures the competence in terms of knowledge, skills and self-efficacy. However, there are some limitations that may restrict the generalizability and interpretation of our results. Firstly, the study sample was conveniently recruited, which means that our results cannot be generalised to populations with different characteristics. Secondly, due to organisational constraints we could only design a one-group pretest-posttest study. Lacking results from a comparison group means that it is very difficult to ascertain whether the improvements on the participants' competence are directly caused by our educational intervention. Thirdly, although we could say that the simulation-based workshop has contributed to an increase in the proportion of participants achieving competence in arterial puncture, we are unable to identify what is the actual effect of each educational methodology on the learners' competence. Lastly, in this study, we could not measure students' retention of competence and their ability to transfer it into clinical practice. Therefore, we are unable to guarantee whether participants' educational gains after the simulation-based workshop will be maintained in time and whether they would be able to show similar levels of competence when performing the procedure on live patients.

Conclusion

Radial artery puncture for ABG analysis is a risky and challenging procedure. Consequently, nurses and nursing students should be trained and assessed before they are allowed to practise arterial puncture on live patients. The design and implementation of a 1.5-hour workshop using video demonstration, modelling examples, dyad learning, intermittent feedback and self-directed hybrid simulated practice using low-tech equipment can improve nursing students' competence in radial artery puncture for ABG analysis. Future studies should use experimental designs and aim to compare the effects of different educational strategies on nurses' and nursing students' acquisition, retention and transferability of competence in arterial puncture. Equally, more research needs to be conducted on how to support those who do not achieve the level of competence required to practise on live patients after simulation-based training in arterial puncture.

Collaborations

Hernández-Padilla JM, Granero-Molina J, Márquez-Hernández Verónica V., Cortés-Rodríguez AE and Fernández-Sola C state that they collaborated in the conception of the study, analysis, data interpretation,writing of the article, relevant critical review of its intellectual content and final approval of the version to be published.

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