Low-Fidelity Haptic Simulation Increases the Transfer of Peripheral Blood Sampling Skills in Novice Medical Students

Thomas Rolf Erdmann[1], Getúlio Rodrigues de Oliveira Filho[1]

**Abstract**

**Background:** The transfer of skills into clinical practice is a major issue in medical education. This study compared the transfer of skills related to peripheral blood collection between naïve medical students simulation-trained or not before performing on real patients.

**Methods:** 30 novice medical students attended to a lecture addressing peripheral blood collection for laboratory tests. The intervention group trained procedural skills with low-fidelity haptic simulation and role-playing. Controls simulated basic life support. Each student performed six blood sampling attempts in real patients in another occasion. Performance was rated on a scoring checklist. Self-efficacy was measured after the lecture, immediately before and after blood collection procedures.

**Results:** Success rates were significantly higher in the intervention 82% than in the control group (68%; p = 0.037). Significantly lesser technical errors were observed in the intervention group. Self-efficacy scores increased significantly in both groups after blood collection procedures and correlated significantly with individual success rates (rho = 0.50).

**Conclusion:** An educational intervention consisting of low-fidelity simulation and role-playing added to a lecture-based teaching session on peripheral blood sampling was associated with increased transfer of procedural skills. Self-efficacy was positively associated with individual success rates.

**Keywords:** Medical education research; clinical skills; practical procedures; simulation; education environment.

**Introduction**

The attainment of proficiency in medical procedures requires training of cognitive (Shariff et al., 2015), technical,
and interpersonal skills (Nelson and Traub, 1993). Lectures can improve cognitive ability (Shariff et al., 2015), but the development of technical and attitudinal abilities requires practical training (Nelson and Traub, 1993). One of the goals of medical education is to provide the transfer of knowledge and skills acquired in the classroom and laboratories to the clinical practice. There is little evidence that theoretical training is associated with substantial transfer (Lim et al., 2016). However, it has been suggested that low fidelity simulation training may facilitate the transfer of aptitudes to the clinical practice (Friedman et al., 2009; Geoffrion et al., 2016; Adams et al., 2015). At the authors’ institution, the horizontally integrated curriculum includes early exposition of medical students to procedures, like peripheral blood sampling in the ambulatory setting, from the start of the medical course. This requires early training, which is usually provided as lectures, followed by training in real patients. It has been demonstrated that the success rates at venous puncture performed by untrained medical students may be as low as 33% (Costantino et al., 2005), suggesting the need for more effective training strategies.

The hypothesis of this study was that a low fidelity haptic simulation training supplementing a lecture-based teaching of peripheral vein puncture (PVP) for blood sampling would be associated with greater transfer of aptitude and better perceptions about self-efficacy of first- and second-year medical students when performing the procedures in real patients. The objective of this study was to test this hypothesis.

**Methods**

With IRB approval, 30 first- and second-year medical students with no experience in peripheral venous access were allocated in two study groups according to electronically generated random numbers: control (n = 15) and intervention (n = 15) groups. Students of both groups were instructed during a slide-illustrated lecture about the anatomical, technical and non-technical aspects of peripheral venous access for blood collection. Subjects pertaining to the intervention group participated in an instructor-lead practical training that included low-fidelity haptic simulation on home-made ballistic gel phantoms with embedded small-diameter, 8-10 cm long latex balloons filled with grape juice. Commercially available anatomical mannequins designed for training in peripheral venous access (Multi-Venous IV Training Arms, Laerdal Medical, Wappingers Falls) were also used. Communication and other non-technical skills were trained as role-playing sessions in which students acted as patients or physicians. The lecture and the workshop followed a pre-established and rehearsed script that included a step-by-step approach to the technical and non-technical aspects of the procedure and the respective theoretical background. In parallel, the control group received an attention intervention consisting of a practical training session on basic life support manoeuvres, which did not include venous access. For the skills transfer assessment, the students were scheduled to supervised blood collection on patients of the institution’s clinical laboratory, according to subjects’ and facility availabilities. Before collecting blood from real patients, one same laboratory technician blinded to the study group of the student demonstrated the technical aspects of the procedure according to the content of the previous training sessions. Each student performed six peripheral venous blood samplings in one or more sessions, depending on scheduling availability. Each blood collection was performed on a different patient who accepted to participate in the study and signed written informed consent. 23-Gauge BD Vacutainer Push Button Blood Collection Set® attached to BD Vacutainer blood collection tubes® (Becton, Dickinson and Company, Franklin Lakes) were used for blood sampling. One trained investigator blinded to students’ groups assessed performance using a 21-item checklist that addressed the expected actions and behaviours associated with each main step of the procedure: approach to the patient, self-protective equipment and behaviours, preparation of blood sampling devices, examination of patient’s upper limb venous system, cleaning and antisepsis of the puncture site, compression, dressing of the puncture site and instructions to the patient at the completion of the procedure. Items were rated on categorical scales.

All students responded to a four-item self-efficacy questionnaire scored on five-point Likert scales addressing the level of anxiety, the perceptions about self-preparedness and self-confidence in performing successfully the
procedure in real patients at the following occasions: (1) immediately after the lecture; (2) immediately before collecting blood from patients; and (3) after completing the assigned blood sampling. Global scores were estimated by averaging individual item scores.

The outcome variables were (1) the individual success rates at blood collection procedures; (2) the total number of technical errors committed by each student during procedures; and (3) the global self-efficacy scores. Factor analysis and Cronbach's alpha coefficients tested the factorial structure and the internal consistency of the measurement instruments. Inter-rater agreement was tested in a pilot study in which the observer investigator and two other independent raters scored technicians' performances during 40 blood collections on the study checklist, each independent rater scoring 20 performances. Cohen's kappa coefficients were estimated for pairs of ratings including those of the observer investigator and those of each of the independent raters.

The number of six attempts per student was estimated based on a difference between the baseline probability of success equal to 33% (Costantino et al., 2005) and the final probability of success equal to 83% (de Oliveira Filho, 2002), considering the binomial distribution of success probabilities and type error failure I (α) of 5% and of error type II (1-β) of 10%.

Student's t and chi-square tests were applied to demographic data for inter-group comparisons. Success rates and the number of technical errors were compared between groups by Mann-Whitney tests. Friedman's test followed by Mann-Whitney and paired-Wilcoxon tests were used to explore inter- and intra-group differences in self-efficacy scores across the measurement occasions. Stepwise backward logistic regression was used to identify independent predictors of success at blood collection procedures. Independent variables included demographic data, study group, patient's anatomical variables and perceptions about self-efficacy, when significant differences were identified when comparing failures and successes at the procedures at p less than 0.2. The Hosmer-Lemeshow test and the estimated area under the ROC curve assessed model fit and discrimination capacity. Spearman's rho coefficients and the respective bootstrap 95% confidence intervals with 1000 replications were calculated between success rates and self-efficacy scores. The sample size calculations were based on the probabilities of success equal to 33% (Costantino et al., 2005) in students in the control group and equal to 83% in students in the intervention group (de Oliveira Filho, 2002). Accordingly, 11 subjects were needed in each study group for inter-group comparisons of the success rates. Fifteen students were enrolled considering possible losses. The probabilities of type I and type II errors were set at 5% and 20%. P values less than 0.05 were considered statistically significant. Data are presented as (median; 25th – 75th percentiles), except when otherwise indicated.

**Results/Analysis**

Tables 1 and 2 provide demographic data observed.

**Table 1. Demographic data of students**

|                     | Group 1 | Group 2 |
|---------------------|---------|---------|
| Age (years)*        | 22 (21 – 27) | 20,5 (19 – 21) |
| Gender (M / F)      | 4 / 7 | 2 / 12 |

*Data are presented as (median; 25th – 75th percentiles)*

**Table 2. Demographic data of patients**

| Age (years)* | 47 (27,75 – 58) |
Eleven students of group 1 (73.3%) and 14 students of group 2 (93.3%) completed the all phases of the study. The time elapsed between training sessions and blood collection procedures ranged from 12 to 93 days (44; 30 - 74). Factor analysis identified a single component in the self-efficacy questionnaire that explained 80.74% of score variance; Cronbach’s alpha coefficient was 0.92. The scoring checklist showed moderate internal consistency as the Cronbach’s alpha coefficient was 0.44. Cohen’s kappa coefficient based on 1681 independent paired scores from the pilot study was 0.84 (95% CI = 0.81 - 0.87).

The number of technical errors per procedure was significantly lower in the intervention (1; 0 - 2.75) as compared to the control group (2; 1 - 3; p = 0.005). The success rate in PVP was significantly higher in the intervention (82%; 95% CI = 62% - 100%) than in the control group (68%; 95% CI = 40% - 95%; p = 0.037). The independent predictors of success were: exposure to haptic simulation (OR = 2.46; 95% CI = 1.06 - 5.69; p = 0.035) and large-diameter veins (OR= 8.12; 95% CI = 3.10 - 21.22; p < 0.01). The logistic model fitted the data ($\chi^2$(2df) = 0.778; p = 0.678). The area under the ROC curve was estimated as 73.8% (95% CI = 64.1 - 83.5%; p < 0.001). Self-efficacy scores in control group increased significantly only at occasion 3 (4.25; 4 - 4.25) compared to occasions 2 (2.75; 2.25 – 3.25; p < 0.001) and 1 (2.25; 2 - 3.25; p < 0.001). No significant change was observed between occasions 1 and 2. In the intervention group, self-efficacy scores were significantly higher at occasion 3 (4; 3.93 - 4.5) compared to occasions 2 (2.25; 2.25 – 3.25; p < 0.001) and 1 (2.25; 2 - 3.25; p < 0.001). No significant change was observed between occasions 1 and 2. Group comparisons showed no significant difference between the self-efficacy scores at all measurement occasions. The success rates correlated significantly with self-efficacy scores only at occasion 3 (Spearman’s rho = 0.495; 95% CI bs = 0.163 - 0.776; p < 0.05). The number of days elapsed between training sessions and performance in real patients did not differ between groups (group 1: 33; 26 – 64; group 2: 45; 24.5 – 76 days; p = 0.687), and did not correlate with success rates (Spearman’s rho = 0.11; p = 0.17).

**Discussion**

We have shown that exposure of first-and second-year medical students to low-fidelity haptic simulation facilitate the transfer into clinical practice of abilities in peripheral blood sampling, as suggest the higher success rates and smaller numbers of technical errors found among students exposed to haptic simulation support in comparison to controls.

This is in agreement with Siddiqui et al. (2014), who found that residents and fellows improve learning processes on mastering the sterile technique during placement of epidural catheters when trained in a low-fidelity simulator complementing conventional teaching. This is in agreement with Panait et al. (2009), who found that medical students trained in a haptic enhanced laparoscopic simulator environment demonstrated superior precision, faster completion of tasks and a trend toward fewer technical errors in more advanced tasks in comparison to medical students trained in a non-haptic enhanced laparoscopic simulator.

This study also shows that perceptions about self-efficacy of students exposed to simulation training did not differ
from those of their counterparts who did not participate in the simulation workshop and did not correlate significantly with the success rates at blood collection.

Sauter et al. (2016) found a significant increase in the perception about self-efficacy in physicians and nurses exposed to simulation of sedation for emergency care. Similar results have been described by Watters et al. (2015). Supporting our results, Maschuw et al. (2008) found that high self-efficacy does not predict success in advanced and novice surgical residents laparoscopic abilities measured in simulation environment. In novice residents, it negatively correlates with laparoscopic skills, and in advanced residents, it was independent of laparoscopic performance (Maschuw et al., 2008).

Our study shows that supervised practical training in real patients increases the perceptions of self-efficacy. This is in disagreement with Aper et al. (2012), who found that supervised medical student consultations did not improve self-efficacy, although improves self-efficacy in real patients consultations without supervision (Aper et al., 2012).

This study must be interpreted in the context of its limitations. The relatively small sample size was adequate for the purposes of the study, which included the presumption of a great effect size (odds ratio = 9.9). Such effect size was not confirmed, as the odds ratio associated with the intervention group relative to the control was 2.14. Although a high inter-rater reliability was documented in the pilot study, intra-rater biases cannot be ruled out as a single investigator assessed all procedures.

**Conclusion**

Low fidelity haptic simulation facilitated the transfer of aptitudes of peripheral blood sampling to the clinical practice as suggested by the significantly higher success rates of medical students exposed to the simulation training.

**Take Home Messages**

- One of the goals of medical education is to provide the transfer of knowledge and skills acquired in the classroom and laboratories to the clinical practice.
- Success rates at venous puncture performed by untrained medical students may be low.
- Blood sampling predictors of success were exposure to haptic simulation and large-diameter veins.
- Low-fidelity haptic simulation facilitate the transfer into clinical practice of abilities in peripheral blood sampling, as suggest the success rates and numbers of technical errors found among students exposed to haptic simulation support in comparison to controls.
- Supervised practical training in real patients increases the perceptions of self-efficacy.

**Notes On Contributors**

Thomas Rolf Erdmann is a PhD student in Medical Sciences at the Universidade Federal de Santa Catarina, Brazil.

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**Appendices**

**Declarations**

The author has declared that there are no conflicts of interest.

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**Ethics Statement**

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