Original Article

Simulation of intraosseous access is effective for resident training

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Abstract

Intraosseous (IO) access can be used for the resuscitation of patients with severe traumatic injuries. However, opportunities to learn how to insert IO devices are limited for residents. The aim of this study was to perform simulated IO device placement by residents and evaluate the effectiveness of training. Residents placed IO needles into a porcine sternum under general anesthesia with guidance from an instructor. Comprehension tests and questionnaires about satisfaction and self-efficacy were conducted before and after the study. The objective evaluation was based on IO access success rate and comprehension test scores, and a subjective evaluation was obtained from questionnaire scores. Participants included 36 residents. One resident had successful clinical experience with IO access. The success rate for establishing IO access in the simulation was 100%. The rate of test completion was 100%, and that the questionnaire response rate was 61%. Mean (±standard deviation) comprehension test results improved from 9.2±0.94 to 9.6±0.79 (maximum 10; P=0.017). The questionnaire score for subjective understanding increased from 7.4±2.9 to 14±1.3 (maximum 15; P<0.0001). The score for questions specifically concerning self-efficacy increased from 1.8±0.91 to 4.1±0.64 (out of 5; P<0.0001). This simulation training improved the knowledge, subjective understanding, and self-efficacy of residents performing IO access. The success rate for confirmed IO access in this study was 100%. Simulation training may positively affect clinical performance in trauma care and requires further study.
(Key words: Intraosseous infusion, Medical education, Simulation training,)

Introduction

Intraosseous (IO) infusion is an essential skill in emergency care. IO infusion is recommended if obtaining a venous line proves too difficult in emergency or trauma practice(1-3). It was reported that the success rate of establishing IO access is 90% (3, 4), and establishing IO access is easier than a central venous catheter. An IO route can be obtained within 30-60 seconds regardless of the patient's age, and the ability to deliver fluid and medications is comparable to that of routine venous access(5). However, opportunities to learn IO device insertion are limited for residents, despite the importance of this technique in emergency situations. It is difficult to perform IO infusions without specific knowledge about IO infusions. In fact, only 11% of Danish emergency departments consistently used IO infusion(6). Simulation training to administer IO infusions is required(3), but a systematic program for education regarding IO infusion has not generally been conducted in medical school curricula(3). Opportunities for learning IO infusion depend on the training programs at each facility or individual participation in training sessions. Few studies have been performed to demonstrate the effectiveness

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of simulation training for learning IO infusion, although simulation training has been conducted to teach these skills[7, 8]. The availability of simulation programs in IO infusion to train residents is not ubiquitous.

The aim of this study was to conduct a simulation of IO device insertion for residents and to evaluate the effectiveness of this training based on comprehension tests and questionnaires.

Methods

Simulation of IO infusion was performed for second (PGY-2) and third (PGY-3) year residents at Jichi Medical University Hospital in 2008. Institutional Animal Experiment Committee approval was obtained before beginning this study (approval number: 08 183). This study was conducted in the Center for Development of Advanced Medical Technology (CDAMTec) at Jichi Medical University. Comprehension tests and questionnaires about understanding of technical skills and self-efficacy were conducted before the simulation, and similar tests were conducted after the simulation.

After Pre-simulation comprehension tests and questionnaires (Tables 1, 2) were completed, an instructor explained the correct answers to objective questions including indications and contraindications for IO infusion, where to insert an IO needle, how to hold the IO needle, types of infusions and drugs for the IO route, confirmation of the IO route and precautions for insertion.

In this simulation, each resident inserted IO needles (Dieckmann Intraosseous Infusion Needle®; Cook Medical, Bloomington, IN) into a porcine sternum and confirmed access to the bone marrow under general anesthesia or after euthanasia under the guidance of an instructor. The instructor is a specialist in surgical emergency medicine with more than ten years' experience. The instructor provided each resident with instruction regarding practical skills of IO infusion, indications and contraindications, complications, and the types of infusions for IO routes. The

Table1 Comprehension test administered before the study

Please mark ○ for correct statements and × for incorrect statements.

Statement	Answer
Intraosseous infusion can be used in adults as well as children.	
Central venous line access is preferred over intraosseous infusion when peripheral lines are difficult.	
The insertion site is the distal part of the femur or anterior part of the proximal tibia.	
Do not insert intraosseous devices if a fracture, vascular injury, or infection is present near the insert site.	
Blood products and blood transfusions cannot be administered by intraosseous infusion.	
Intraosseous infusion does not cause osteomyelitis, even after long-term placement.	
Needle fixation is used to assess whether an intraosseous device has been inserted successfully.	
Even if the tip of the bone marrow needle is properly placed in the medullary cavity, aspiration of bone marrow by applying negative pressure is not always possible.	
Intraosseous devices should be removed promptly if there is another infusion route.	
A risk of epiphyseal line injury exists due to insertion of the intraosseous device in front of the proximal tibia.	

Table 2 Questionnaire administered before the study

Please answer the following questions.

Question	Answer
Have you ever performed intraosseous device insertion by yourself?	Yes or No
How many times have you performed intraosseous device insertion?	( ) times
Please answer the following questions using a 5-point scale: (5: I agree with that opinion; 1: I disagree with that opinion)	
To what extent do you know the indications for intraosseous device insertion on a 5-point scale?	5 4 3 2 1
To what extent do you know how to insert an intraosseous device and how to check its placement on a 5-point scale?	5 4 3 2 1
To what extent are you confident that you can insert an intraosseous device alone with a 5-point rating?	5 4 3 2 1

instructor confirmed that the IO needle was fixed, that the transfusion did not leak into the subcutaneous layer, and whether the resident successfully inserted the IO device. Post-simulation comprehension tests and questionnaires (Tables 3, 4) were completed after training on the same day as the simulation.

The objective evaluation included the IO access success rate and scores on comprehension tests. A subjective evaluation was obtained from responses on the questionnaires.

Data are presented as mean ± standard deviation (SD). Wilcoxon matched-pairs signed-rank testing was performed for the analysis of data. Analyses were performed using GraphPad Prism for Windows version 6.07 (GraphPad Software, La Jolla, CA). A significant difference was defined as a value of $P<0.05$. Post hoc analysis was performed, and that revealed power was 1.00 for outcomes of questionnaires about self-efficacy, analyzed by GPower, Heinrich Heine Universität, Dusseldörf, Germany.

Results

Thirty-six residents participated in this study (PGY-2, n=35; PGY-3, n=1). Just one resident had successfully clinically performed IO access prior to this study. The success rate for establishing IO access in the simulation was 100%. The rate of test completion was 100%, and the survey response rate for the questionnaire was 61%. Comprehension test results improved from 9.2 ± 0.94 to 9.6 ± 0.79 (out of 10; P=0.01739) (Figure 1). Questionnaire scores concerning the subjective level of understanding changed from 7.4 ± 2.9 to 14 ± 1.3 (out of 15; $P<0.0001$) (Figure 2). Scores on questions specifically related to self-efficacy increased dramatically from 1.8 ± 0.91 to 4.1 ± 0.64 (out of 5; $P<0.0001$) after the simulation (Figure 3).

Table 3 Comprehension test administered after the study

Please provide ○ for correct statements and × for incorrect statements.

Statement	Answer
Intraosseous infusion cannot be used in adults.	
Central venous line is prioritized over intraosseous infusion when peripheral lines are difficult.	
The insertion site is only the distal part of the femur.	
You can insert intraosseous devices even if a fracture, vascular injury or infection is present around the insert site.	
Blood products and blood transfusions can be administered by intraosseous infusion.	
Intraosseous infusion may cause osteomyelitis, even with long-term placement.	
Needle fixation is not used to assess whether an intraosseous device has been inserted successfully.	
Even if the tip of the bone marrow needle is properly placed in the medullary cavity, aspiration of bone marrow by applying negative pressure is always possible.	
Intraosseous devices should not be removed promptly if there is another infusion route.	
There is no risk of epiphyseal injury because the intraosseous device is inserted in front of the proximal tibia.	

Table 4 Questionnaire administered after the study

Please answer the following questions.

Question	Answer
Have you ever performed intraosseous device insertion by yourself?	Yes or No
How many times have you performed intraosseous device insertion?	( )times
Please answer the following questions using a 5-point scale: (5: I agree with that opinion; 1: I disagree with that opinion)	
To what extent do you know the indications for intraosseous device insertion on a 5-point scale?	5 4 3 2 1
To what extent do you know how to insert an intraosseous device and how to check the placement of an intraosseous device on a 5-point scale?	5 4 3 2 1
To what extent are you confident that you can insert an intraosseous device alone with a 5-point rating?	5 4 3 2 1

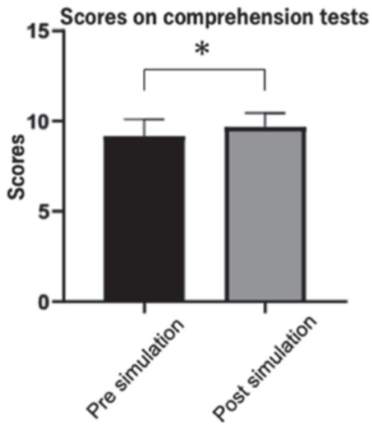

Figure 1 Scores on comprehension tests
Mean (±standard deviation) comprehension test scores improved from 9.2±0.94 to 9.6±0.79 (out of 10; P=0.01739). *indicates a significant difference ($p<.05$).

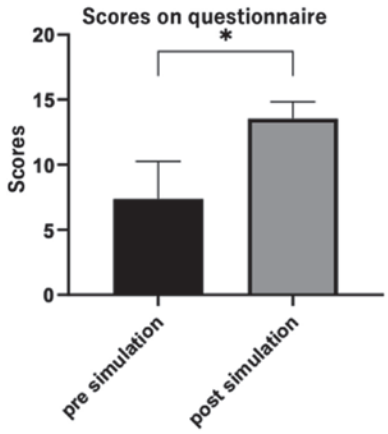

Figure 2 Scores for questionnaire
Questionnaire scores concerning subjective understanding changed from 7.4±2.9 to 14±1.3 (out of 15; P<0.0001). *indicates a significant difference ($p<.05$).

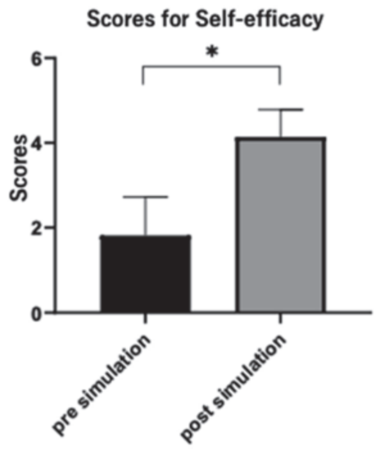

Figure 3 Self-efficacy scores
Questions specifically concerning self-efficacy dramatically increased from 1.8±0.91 to 4.1±0.64 (out of 5; P<0.0001) after the simulation. *indicates a significant difference ($p<.05$).

Discussion

Simulation training of IO access was conducted for 36 second and third-year residents, and the success rate for establishing access by an IO device was 100%. Scores on the comprehension test improved from pre- to post-simulation. Questionnaires about the subjective understanding of technical skills and self-efficacy also improved. IO insertion has a high success rate even for inexperienced physicians[3], and comprehension testing before the training and guidance from an instructor increase the rate of success.

The comprehension test, which evaluated knowledge about IO device insertion, indications, and contraindications, improved significantly comparing pre- and post-simulation results. Adequate knowledge of the procedure is important in addition to technical skills because sufficient knowledge should lead to performing the procedure when indicated. Molin et al. reported that 47% of ER departments in Denmark learned how to establish IO access, and IO infusion was established in only 11% of patients who met the indications for IO device insertion. However, 74% of ER departments had IO needles[6]. That supports the idea that obtaining sufficient knowledge is central to performing medical procedures. In this simulation, prior learning was conducted through the comprehension test and explanation of the answers before conducting the simulation training. Guidance by an instructor increases practical knowledge for the simulation.

Scores on the questionnaire for subjective understanding and self-efficacy improved after the training compared to before the training. Scores regarding the subjective knowledge of technical skills for the procedure doubled on the post-simulation scores, which suggests that residents had positive evaluations of this simulation. Indeed, positive evaluations would motivate providing this training regularly for residents in the future. Scores for self-efficacy doubled after the simulation. Self-efficacy refers to "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances"[9]. This is an important factor influencing motivation for behavior, and similar factors apply in clinical situations[10]. In particular, adequate self-efficacy is required in emergency clinical practice[11, 12].

Simulation with live animals is feasible and enables us to practice hemostatic skills with reality. The reality of a live animal procedure motivates the students well. However, it can be problematic due to cost, special equipment, personnel required, ethical concerns, and anatomical differences[14].

The advantages and disadvantages of IO simulation are unknown because no specific comparison was made between live animals, cadavers, and phantoms in this study. We believe that simulation of IO infusion in cadavers and phantoms are similar to live animals in terms of effectiveness. There is little difference in the feeling of penetrating the bone cortex and fixation of the needle comparing the three models. We conducted this simulation in a live porcine model, because the animals used for this IO simulation were also used in training for trauma procedures, and securing an IO route was a part of the overall program.

The skills for IO infusion in a porcine model are similar to what is done in the human. It is common to insert the IO needle into the tibial tuberosity in humans while the insertion of an IO needle into the sternum in a porcine model feels like penetrating the cortex with the same pressure as insertion into the tibial tuberosity of a human.

The use of experimental animals involves important ethical issues. For animal ethics, Burch and Russel recommend the 3Rs: reduction, replacement, and refinement [13]. In this simulation, we used experimental animals. Simulation using real bones is essential when teaching IO access. Before the simulation, we taught residents about the background of IO, and every resident was carefully instructed during the simulation. The experimental animals were used after other trauma surgery simulations or studies to reduce the number of animals used and respect the principles of the 3Rs.

Some limitations of this study must be considered. First, cognitive bias could have been present, because this was not a blinded study and the instructor and the evaluator are the same person. Second, the subjective evaluation did not directly reflect the quality of the simulation. Third, post-simulation comprehension tests and questionnaires were completed on the same day as the simulation. Fourth, this study does not have a control group. Fifth, there is a possibility that sufficient effectiveness would be obtained only using the didactic teaching and pre-simulation comprehension tests, without the simulation. However, we think that the simulation with a porcine model is useful for residents and provides confirmation of learning the desired skills.

Conclusion

Simulation training with a porcine model in this study may have improved the knowledge, subjective understanding, and self-efficacy of residents for performing IO access. The success rate for confirmed IO access in this study was 100%. Although this study has some limitations, this simulation appears useful for improving skills and self-efficacy for IO access procedure by residents. Further studies are needed to develop more effective training for technical and non-technical skills regarding IO device insertion. This experience may positively affect clinical performance.

Conflict (s) of Interest: We declare no conflict of interest.

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アンケート調査を用いた骨髄路確保シミュレーショントレーニングの有用性についての検討

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要　　約

骨髄路確保は重度患者に対する処置として重要だが，研修医が学習する機会は少ない。今回，当院救急科で研修した36人の研修医を対象にブタの胸骨に骨髄針を挿入するシミュレーションを行い，その前後にテストとアンケートを実施してその結果を評価した。シミュレーションでの骨髄路確保の成功率は100％だった。理解度テストの結果は，9.2±0.94（平均±標準偏差）から9.6±0.79に改善された（満点10，P＝0.017）。骨髄針に関するアンケートの点数は7.4±2.9から14±1.3に増加した（満点15；P <0.0001）。特に自己効力感に関するスコアは1.8±0.91から4.1±0.64に増加した（満点5，P <0.0001）。このシミュレーションで骨髄路確保に関する知識・理解・自己効力感が向上した。本トレーニングにより，骨髄路確保がより良くできる可能性がある。

（キーワード：骨髄針，医学教育，シミュレーショントレーニング）

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