Behavior Change and Skills Retention With an Action Record After Ultrasonography Training

Toru Yamada (toru.y.fmed@tmd.ac.jp)
Department of Family Medicine, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University

Jun Ehara
Department of Internal Medicine, Tokyo Bay Urayasu Ichikawa Medical Center

Hiraku Funakoshi
Department of Emergency and Critical Care Medicine, Tokyo Bay Urayasu Ichikawa Medical Center

Keita Endo
Department of Nephrology, Endocrinology and Diabetes, Tokyo Bay Urayasu Ichikawa Medical Center

Yuka Kitano
Department of Emergency and Critical Care Medicine, St. Marianna University School of Medicine

Yousuke Takemura
Department of Family Medicine, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University

Research Article

Keywords: simulation training, action record, behavior change, skills retention, point-of-care ultrasonography

DOI: https://doi.org/10.21203/rs.3.rs-154531/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background

In simulation training, behavior change (Kirkpatrick’s level 3) is more important than learning improvement (Kirkpatrick’s level 2). However, few studies have evaluated behavior change because it is difficult to assess objectively. Skills retention is another challenge. We evaluated whether keeping a record of the number of ultrasound (US) examinations performed after a simulation course led to positive behavior changes and improved skills retention.

Methods

A 2-day point-of-care ultrasound (POCUS) course in cardiac US, lung US, lower extremity deep vein thrombosis (DVT) US, and abdominal US was held for Japanese nurse practitioners and trainees in 2018 and 2019. Participants kept a record of the number of US examinations they performed for 3 months before and 3 months after the course. The number of US exams performed was grouped into six categories. All participants underwent pre-course, immediate post-course, and 4-month post-course testing to assess image interpretation skills, image acquisition skills, and confidence.

Results

Thirty-three participants from 21 facilities completed the program. The median number of US exams performed during the 3-month period after the course increased significantly from before the course ($P < 0.001$). The median number of each US examination type (cardiac, lung, lower extremity DVT, and abdominal) after the course statistically significantly increased compared with before the course ($P < 0.001$). The immediate post-course and 4-month follow-up test scores for image interpretation skills, image acquisition skills, and confidence were statistically significantly higher than the pre-course test scores ($P < 0.001$). The results of the 4-month follow-up test showed no decline compared with immediate post-course scores.

Conclusions

Keeping a record after a POCUS simulation course increased the number of US examinations and improved knowledge, skills, and confidence. Keeping a record after simulation training led to positive behavior change and improved skills retention.

Background

Point-of-care ultrasonography (POCUS) has become widespread in various fields, including emergency departments, wards, and intensive care units. POCUS is used for echo-guided procedures as well as
diagnosis, and contributes to reducing complications.\textsuperscript{1,2} POCUS is also part of under-graduate and post-graduate medical education.\textsuperscript{3–5} Numerous POCUS simulation courses with variable content and duration are available.\textsuperscript{6,7} Generally, simulation courses such as the Advanced Cardiovascular Life Support course have been shown to increase knowledge or skills.\textsuperscript{8} POCUS simulation courses for medical students and doctors have shown similar results.\textsuperscript{1,5,7,9} Few studies have evaluated the educational effect of POCUS courses for nurse practitioners; however, some studies reported that this training improved skills.\textsuperscript{10–12}

In evaluating the educational effect of training, the four levels of learning evaluation advocated by Kirkpatrick and Kirkpatrick showed that “What did participants apply in practice?” (level 3; behavior) is more important than “What have participants learned?” (level 2; learning) (Fig. 1).\textsuperscript{13} Few studies have shown that simulation training can change both behavior and the learning level, especially regarding POCUS.\textsuperscript{14} In addition, simulation courses can increase knowledge and skills immediately after the course; however, these gains tend to decline a few months after the training.\textsuperscript{4,8,9,15,16} To resolve this problem, follow-up lectures or hands-on training after the initial course may be effective for maintaining knowledge.\textsuperscript{17–19} POCUS simulation courses are similar; however it is unclear whether both knowledge and clinical skills (e.g., image acquisition) can be maintained.\textsuperscript{4,5,9,15,16,20,21}

In this study, we held a 2-day POCUS simulation course for Japanese nurse practitioners (JNP) and JNP trainees. These practitioners were instructed to record the number of ultrasound (US) examinations they performed before and after the course. This study had two aims. First, we aimed to determine whether keeping a record of the number of US examinations performed after the simulation course improved both knowledge and skills (level 2; learning) and led to behavior change (level 3; behavior). Second, we aimed to determine whether keeping a record of the number of US examinations helped to maintain US knowledge and skills. Behavior change was evaluated by comparing the number of US exams performed before and after the course. To evaluate maintenance of the learning level, we evaluated image interpretation skills, image acquisition skills, and confidence in performing POCUS before and immediately after the course, and again 4 months after the course.

**Methods**

**Study design and setting**

We held one POCUS training program in 2018 and one in 2019. The program involved four parts: 1) recording the number of US exams performed during the 3 months before participating in the POCUS course, 2) participating in the 2-day POCUS course, 3) recording the number of US exams performed during the 3 months after participating in the course, and 4) follow-up evaluation 4 months after the course. All participants recorded the number of cardiac US, lung US, deep vein thrombosis (DVT) US for the lower extremities, and abdominal US they performed in the 3 months before the course. We chose these four US examinations because the 2-day POCUS course focused on these examinations A standardized POCUS course with a proven educational effect was adopted for our 2-day POCUS course.\textsuperscript{7}
The educational effects of this course for medical students and doctors have been demonstrated; however, this was the first such training for JNPs. Participants’ image interpretation skills, image acquisition skills, and confidence in performing POCUS were evaluated before and after the course. Image interpretation skills were evaluated by a written examination using POCUS case study videos and multiple-choice questions. Image acquisition skills were evaluated in hands-on situations by the POCUS instructors using live models and evaluation sheets. Confidence was evaluated by a self-evaluation survey with a five-point Likert scale using previously validated multiple-choice questions and a self-evaluation survey. Participants then recorded the number of US examinations they performed for the 3 months after the course. Four months after completing the course, participants completed a follow-up test covering image interpretation skills, image acquisition skills, and confidence. This test was the same as that performed immediately after the course (Figure 2). There were no interventions, including didactic lectures, between the end of the course and the 4-month follow-up test.

Nine instructors were involved in the course and evaluated participants. All instructors were certified POCUS instructors. Before the course, the instructors received a lecture presenting the evaluation method and online discussions to standardize the evaluation method.

This study was approved by the Institutional Review Board of the Tokyo Bay Urayasu Ichikawa Medical Center. Before participation, participants were informed that the results of this study would not affect evaluation of their work or future training. Written informed consent was obtained from all participants.

Participants

Japan has an original nurse practitioner system (JNP system), which began in 2008 and was partially revised in 2015. There are several certified JNP training programs in Japan. In the present study, JNPs and JNP trainees were recruited through the JNP training program delivered by the Japan Association for the Development of Community Medicine from 2018 to 2019. During the study period, JNPs worked in hospitals or clinics, and JNP trainees worked in hospitals and were engaged in on-the-job training under the supervision of attending doctors; therefore, all participants could access portable US machines and perform US examinations.

Data collection

All participants recorded the number of US exams they performed on their own for 3 months before participating in the 2-day POCUS course. This information was recorded on a Microsoft Excel spreadsheet distributed by the study secretariat. These sheets were collected before participants began the POCUS course. The number of US examinations performed during the 3 months was categorized: category 1: 0 cases, category 2: 1–9 cases, category 3: 10–29 cases, category 4: 30–49 cases, category 5: 50–99 cases, and category 6: ≥100 cases. Image interpretation skills, image acquisition skills, and confidence in performing POCUS were evaluated pre- and immediately post-course. Participants recorded the number of US examinations they performed for 3 months after the course, using the same system as
for the 3-month period before the course. These records were collected by the study secretariat. Four months after the course, participants completed follow-up testing to evaluate their image interpretation skills, image acquisition skills, and confidence. This test was the same as that used for the pre- and immediate post-course testing.

**Statistical analysis**

Comparisons of the difference between the US examination categories before and after the course were analyzed using Wilcoxon's signed-rank test. Written examinations, evaluation sheets, and self-evaluation survey scores were analyzed with the Friedman test with Bonferroni adjustment. Data analyses were performed using EZR statistical software (version 1.52), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria).

**Results**

**Participants**

Thirty-five participants completed the POCUS training program in 2018 or 2019. Two participants were excluded because they could not complete the program. Nine JNPs and 24 JNP trainees from 21 facilities completed the program. These facilities were geographically distributed across Japan from Hokkaido in the north to Nagasaki prefecture in the south. Some participants were from the same facilities, and most (94%) worked in community hospitals; no participants worked in university hospitals. The mean number of post-graduate years was 13.2 years (range: 6–22 years). All participants were novice POCUS trainees (Table 1).
Table 1 Participants’ characteristics (n = 33)

| Characteristic          | Total (%) | JNP* (%) | JNP trainee (%) |
|-------------------------|-----------|----------|-----------------|
| Number of participants  | 33        | 9        | 24              |
| Sex                     |           |          |                 |
| Male                    | 10 (30)   | 3 (33)   | 7 (29)          |
| Female                  | 23 (70)   | 6 (66)   | 17 (71)         |
| Work environment        |           |          |                 |
| Clinic                  | 2 (6)     | 0 (0)    | 2 (8)           |
| Community hospital      | 31 (94)   | 9 (100)  | 22 (92)         |
| University hospital     | 0 (0)     | 0 (0)    | 0 (0)           |
| Post-graduate year      |           |          |                 |
| 1–5                     | 0 (0)     | 0 (0)    | 0 (0)           |
| 6–10                    | 10 (30)   | 3 (33)   | 7 (29)          |
| 11–15                   | 10 (30)   | 4 (45)   | 6 (25)          |
| ≥16                     | 13 (40)   | 2 (22)   | 11 (46)         |
| Novice POCUS** trainee*** | 33 (100) | 9 (100)  | 24 (100)        |

*JNP: Japanese nurse practitioner  
**POCUS: point-of-care ultrasound  
***Participants who had never participated in a POCUS simulation course.

Number of US examinations performed before and after the course

The median category for the number of US examinations performed 3 months before the course was category 1 (standard deviation [SD]: 1.0) and that for US performed 3 months after the course was category 3 (SD: 0.9). The median category after the course had statistically significantly increased compared with before the course (\(P < 0.001\)). The median categories for the 3 months before the course for cardiac US, lung US, lower extremities DVT US, and abdominal US examinations were 1 (SD: 0.7), 1 (SD: 0.5), 1 (SD: 0.4), and 1 (SD: 0.7), respectively. The median categories 3 months after the course for cardiac US, lung US, lower extremity DVT US, and abdominal US examinations were 3 (SD: 0.6), 2 (SD: 0.4), 2 (SD: 0.5), and 2 (SD: 0.6), respectively. The median category for each US examination type 3 months after the course had statistically significantly increased compared with before the course (\(P < 0.001\)) (Figure 3).
Image interpretation skills, image acquisition skills, and confidence scores

The mean scores for the image interpretation skills test pre-course, and immediately post-course, and at the 4-month follow-up evaluation were 37.1 (SD: 16.0), 72.6 (SD 11.1), and 71.8 (SD 9.9) (out of 100 points), respectively. Both the immediate post-course test and the 4-month follow-up test scores were statistically significantly higher than the pre-course scores ($P < 0.001$). However, the difference between the immediate post-course and the 4-month follow-up test scores was not statistically significant ($P = 1.00$). The mean scores for the image acquisition skills test pre-course, immediate post-course, and at the 4-month follow-up were 13.7 (SD: 10.7), 53.6 (SD: 8.9), and 52.9 (SD: 9.3) (out of 71 points), respectively. Both the immediate post-course and 4-month follow-up test scores were statistically significantly higher than the pre-course test scores ($P < 0.001$). The difference between the immediate post-course and the 4-month follow-up test scores was not statistically significant ($P = 1.00$). The mean scores for confidence pre-course, immediate post-course, and at the 4-month follow-up survey were 15.8 (SD: 3.6), 35.7 (SD: 10.5), and 33.0 (SD: 11.6) (out of 70 points), respectively. Both the immediate post-course survey and 4-month follow-up test scores were statistically significantly higher than the pre-course survey scores ($P < 0.001$). The difference between the immediate post-course and the 4-month follow-up test scores was not statistically significant ($P = 0.34$) (Figure 4).

Discussion

This study aimed to determine whether recording the number of US examinations performed after taking a POCUS simulation course led to a behavior change, and whether keeping a record of the number of US examinations performed maintained US knowledge and skills. Our results showed that keeping a record significantly increased the number of US examinations performed. In addition, keeping a record after the simulation training led to a behavior change in the field of simulation education. Keeping a record also contributed to maintaining POCUS knowledge, skills, and confidence. Our study suggests that keeping a record may be useful to improve skills retention in the field of simulation education.

In educational methods, including in simulation training, it is important and most effective to cause both a reaction or learning improvement (Kirkpatrick's levels 1 and 2, respectively), and behavior change or improvement (Kirkpatrick's levels 3 and 4, respectively). However, it is often difficult to evaluate levels 3 and 4 because this evaluation is time consuming and requires effort and cost to train evaluators and prepare tools and facilities. Therefore, few studies have evaluated behavior change, and effective methods to change behavior have not been established in the field of simulation training. In our study, recording the number of clinical US examinations increased the number of these examinations that participants performed after the simulation course. Our results also showed that keeping a record after the simulation course led to a behavior change.

This study showed that the quality of the examinations was maintained after the course. The 4-month follow-up test results showed that the image interpretation skills, image acquisition skills, and confidence scores were statistically significantly improved compared with the pre-course test scores, and that these
scores did not decline compared with the immediate post-course test scores. The problem of skills retention is an most important problem in the field of simulation training.\(^4,5,16,17\) Knowledge, skills, and confidence decline in a few months to 1 year after a simulation course with no interventions.\(^4,5,9,16,19\) Several methods have been proposed to help participants retain knowledge and skills; for example, providing didactic or online lectures, and holding hands-on training sessions or simulation training courses regularly or several months after the course.\(^15,18-21\) The method that we used in this study (keeping a record) was useful to maintain knowledge, skills, and confidence 4 months after the simulation course. This method involves less effort and cost than conventional methods and is feasible and can be implemented at most facilities.

This study had several limitations. First, we recruited only JNPs; however, participants were from 21 facilities in numerous regions across Japan. The number of post-graduate years also varied; repeating this research with attending doctors, residents, and medical students is needed to clarify the usefulness of this method for these cohorts. Second, this study involved a follow-up test 4 months after the course. Participants were aware of this follow-up test in advance, which might have influenced their behavior. However, all participants were informed that the results of this study would not affect their future work or training. Therefore, the impact of the follow-up test was not considered large. Third, the number of US examinations was self-reported. Additionally, nine instructors participated as evaluators. All instructors were certified and trained regarding how to evaluate participants before this study. However, it cannot be denied that there might have been measurement error. This study was not a crossover study, and we did not compare study participants with a group who did not keep a record. However, research has shown that skills and knowledge decrease after a simulation course without intervention. Therefore, our method appeared to be effective to improve the educational effectiveness of simulation courses.

Although there were several limitations, our study indicated that keeping a record after taking a simulation course can lead to behavior change. This method also effectively maintained knowledge, skills, and confidence and is inexpensive, with good feasibility. This method is therefore useful to induce behavior change (Kirkpatrick's level 3) and improve skills retention in the field of simulation training.

**Conclusion**

Keeping a record after a POCUS simulation course increases the number of clinical US examinations performed after the course. Image interpretation skills, image acquisition skills, and confidence also improve and are maintained. This method not only improves the learning effect, but also leads to changes in behavior (Kirkpatrick's level 2 and 3, respectively) in the field of simulation training. Skills retention is also improved. The method is inexpensive and feasible. Combining simulation training with keeping a record may improve the educational effect in the field of simulation training.

**List Of Abbreviations**
Declarations

Ethics approval and consent to participate: The study protocol was approved by the Institutional Review Board of the Tokyo Bay Urayasu Ichikawa Medical Center. Written informed consent was obtained from all study subjects before participation. All methods were carried out in accordance with regulations of Institutional Review Board of the Tokyo Bay Urayasu Ichikawa Medical Center.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: None.

Authors’ contributions: All authors were involved in study design, data interpretation, and manuscript preparation. TY was the principal investigator and was responsible for regulatory compliance, participant recruitment, data collection, data analysis, and manuscript preparation. JE, HF, KE, YK, and YT contributed to the study coordination and data collection, entry, and analysis. All authors read and approved the final manuscript.

Acknowledgments: The authors wish to thank Eiji Hiraoka, Hatsuyo Ebisu, Haruka Toda, Hiroyuki Ide, Kenji Motohashi, Naoyuki Sato, Nanako Tsukui, Natsumi Isechi, Nilam J Soni, Osamu Takahashi, Shigeki Fujitani, Shintaro Kosaka, Taro Minami, Yasuko Suzuki, Yosuke Matsuzaki, Yuiko Nagamine, Yuito Okada, and Yukio Muramatsu for serving as course faculty or helping with the course, data collection, and analysis. We thank Jane Charbonneau, DVM, and Audrey Holmes, MA, from Edanz Group (https://en-author-services.edanz.com/ac) for editing drafts of this manuscript.

References

1. Duncan DR, Morgenthaler TI, Ryu JH, Daniels CE. Reducing iatrogenic risk in thoracentesis: establishing best practice via experiential training in a zero-risk environment. Chest. 2009;135(5):1315-20.
2. Wrightson JM, Fysh E, Maskell NA, Lee YC. Risk reduction in pleural procedures: sonography, simulation and supervision. Curr Opin Pulm Med. 2010;16(4):340-50.

3. Schnobrich DJ, Gladding S, Olson AP, Duran-Nelson A. Point-of-care ultrasound in internal medicine: A national survey of educational leadership. J Grad Med Educ. 2013;5(3):498-502.

4. Fisher J, Viscusi R, Ratesic A, Johnstone C, Kelley R, Tegethoff AM, et al. Clinical skills temporal degradation assessment in undergraduate medical education. J Adv Med Educ Prof. 2018;6(1):1-5.

5. Yamamoto R, Clanton D, Willis RE, Jonas RB, Cestero RF. Rapid decay of transthoracic echocardiography skills at 1 month: A prospective observational study. J Surg Educ. 2018;75(2):503-509.

6. Greenstein YY, Littauer R, Narasimhan M, Mayo PH, Koenig SJ. Effectiveness of a critical care ultrasonography course. Chest. 2017;151(1):34-40.

7. Yamada T, Minami T, Soni NJ, Hiraoka E, Takahashi H, Okubo T, et al. Skills acquisition for novice learners after a point-of-care ultrasound course: does clinical rank matter? BMC Med Educ. 2018;18(1):202.

8. Semeraro F, Signore L, Cerchiari EL. Retention of CPR performance in anaesthetists. Resuscitation. 2006;68(1):101-8.

9. Dulohery MM, Stoven S, Kurklinsky AK, Halvorsen A, McDonald FS, Bhagra A. Ultrasound for internal medicine physicians: the future of the physical examination. J Ultrasound Med. 2014;33(6):1005-11.

10. Weiner SG, Sarff AR, Esener DE, Shroff SD, Budhram GR, Switkowski KM, et al. Single-operator ultrasound-guided intravenous line placement by emergency nurses reduces the need for physician intervention in patients with difficult-to-establish intravenous access. J Emerg Med. 2013;44(3):653-60.

11. Gundersen GH, Norekval TM, Haug HH, Skjetne K, Kleinau JO, Graven T, et al. Adding point of care ultrasound to assess volume status in heart failure patients in a nurse-led outpatient clinic. A randomised study. Heart (British Cardiac Society). 2016;102(1):29-34.

12. Gustafsson M, Alehagen U, Johansson P. Pocket-sized ultrasound examination of fluid imbalance in patients with heart failure: a pilot and feasibility study of heart failure nurses without prior experience of ultrasonography. Eur J Cardiovasc Nurs. 2015;14(4):294-302.

13. Kirkpatrick DL, Kirkpatrick JD. Implementing the four levels. 1st ed. Oakland, CA: Berrett-Koehler Publishers, Inc.; 2007.

14. Delisle M, Ward MAR, Pradarelli JC, Panda N, Howard JD, Hannenberg AA. Comparing the learning effectiveness of healthcare simulation in the observer versus active role: Systematic review and meta-analysis. Simul Healthc. 2019;14(5):318-32.

15. Kelm DJ, Ratelle JT, Azeem N, Bonnes SL, Halvorsen AJ, Oxentenko AS, et al. Longitudinal ultrasound curriculum improves long-term retention among internal medicine residents. J Grad Med Educ. 2015;7(3):454-7.

16. Kimura BJ, Sliman SM, Waalen J, Amundson SA, Shaw DJ. Retention of ultrasound skills and training in “point-of-care” cardiac ultrasound. J Am Soc Echocardiogr. 2016;29(10):992-7.
17. Cecilio-Fernandes D, Cnossen F, Jaarsma D, Tio RA. Avoiding surgical skill decay: A systematic review on the spacing of training sessions. J Surg Educ. 2018;75(2):471-480

18. Wayne DB, Butter J, Siddall VJ, Fudala MJ, Linquist LA, Feinglass J, et al. Simulation-based training of internal medicine residents in advanced cardiac life support protocols: a randomized trial. Teach Learn Med. 2005;17(3):210-6.

19. Wayne DB, Siddall VJ, Butter J, Fudala MJ, Wade LD, Feinglass J, et al. A longitudinal study of internal medicine residents' retention of advanced cardiac life support skills. Acad Med. 2006;81(10 Suppl):S9-S12.

20. Noble VE, Nelson BP, Sutingco AN, Marill KA, Cranmer H. Assessment of knowledge retention and the value of proctored ultrasound exams after the introduction of an emergency ultrasound curriculum. BMC Med Educ. 2007;7:40.

21. Henwood PC, Mackenzie DC, Rempell JS, Douglass E, Dukundane D, Liteplo AS, et al. Intensive point-of-care ultrasound training with long-term follow-up in a cohort of Rwandan physicians. Trop Med Int Health. 2016;21(12):1531-8.

22. Sugiyama S, Asakura K, Takada N. Japanese nurse practitioners’ legal liability ambiguity regarding their medical practice: a qualitative study. BMC Nurs. 2020;19:62.

23. Kanda Y. Investigation of the freely available easy-to-use software ‘EZR’ for medical statistics. Bone Marrow Transplant. 2013;48(3):452-8.

24. Boet S, Bould MD, Fung L, Qosa H, Perrier L, Tavares W, et al. Transfer of learning and patient outcome in simulated crisis resource management: a systematic review. Can J Anaesth. 2014;61(6):571-82.

25. Dudas RA, Colbert-Getz JM, Balighian E, Cooke D, Golden WC, Khan S, et al. Evaluation of a simulation-based pediatric clinical skills curriculum for medical students. Simul Healthc. 2014;9(1):21-32.