Medical Education Tool: Central Line Insertion Task Trainer Kit

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Abstract

Background: Simulation is an effective tool for teaching technical procedural skills to medical residents, yet barriers such as limited space, faculty availability, and conflicting schedules can hinder its use in family medicine residency. To address these barriers, we developed a central line insertion task trainer kit designed to provide resources and guidance for residents to independently simulate ultrasound-guided internal jugular central venous catheterization. The objective of this tool is to allow family medicine residents to engage in self-regulated procedural simulations, enhancing their skills and confidence in performing central line insertions.

Methods: The development of this medical education tool was informed by Experiential Learning Theory, along with the principles of self-regulated learning and spaced repetition learning.

Results: The central line insertion task trainer kit is available in the Colchester East Hants Health Center simulation lab. A dedicated website outlines how to access the simulation space and required equipment locations. The website also provides essential resources such as a procedural video, ultrasound guides, written procedural manual, images, a self-testing checklist, and references. These resources integrate self-regulated learning and spaced repetition learning to optimize learner experience.

Interpretation: We developed a medical education tool to facilitate independent resident simulation of ultrasound-guided central line insertion. Future research opportunities include comparing self-regulated versus facilitator-led procedural simulation, exploring optimal intervals

for spaced repetition simulation, and examining the perceived benefits and barriers of this tool from the learners' perspective.

Keywords: Medical education, simulation, central venous access, procedural skills training

Background

The acquisition of procedural skills during residency is largely dependent on how frequently learners have exposure to relevant clinical encounters (1). This is impacted by many factors, including residency site, serviced patient population, and preceptor comfort with teaching clinical skills at the bedside (1). Bedside teaching of procedural skills can also be a stressful experience for the unprepared and inexperienced learner (1). The College of Family Physicians of Canada is considering extending the duration of Canadian family medicine residency programs due to concerns that the current educational and clinical experiences may not consistently provide new practitioners with the confidence they need across all clinical areas (2). The final report and recommendations from the Outcomes of Training Program highlighted that "while most residents and early-career physicians feel prepared to deliver comprehensive office-based primary care, they report limited exposure during residency to key areas such as in-hospital procedures, home and long-term care, and underserved populations, including Indigenous communities" (2). Simulation enhanced education is a possible solution to this gap, offering a hands-on experience that uses a situation or environment to allow learners to experience a realistic representation of an event (3). Simulation provides learners with a space to safely practice many different components of clinical care, including procedural skills, interprofessional collaboration, and crisis resource management (4). In simulation, participants are able gain and hone skills deliberately in a controlled environment, without risk to patient safety (1).

Central venous catheter insertion is a skill required by many family physicians working in acute care settings. It is also a medical competency associated with potentially critical complications (5). The use of ultrasound to guide central venous catheter insertion is associated with reduced rates of carotid artery puncture, hematoma, cannulation failure, and hemothorax. (6). Studies have demonstrated that resident simulation programs targeting ultrasound-guided central line insertion resulted in improved resident venous access success, decreased adverse outcomes, and increased adherence to safety protocols (7,8). Despite research suggesting the benefits of simulation-based training for central venous catheter insertion in residency training programs, there remain barriers to implementation. These barriers include, but are not limited to, availability of space, faculty time, cost of equipment and schedule management (5).

To address these gaps and challenges, we developed a medical education tool in the form of a central line insertion task trainer kit, designed to provide family medicine residents with the resources and guidance to independently perform ultrasound-guided internal jugular central venous catheterization simulations. The objective of this tool is to provide family medicine residents with the opportunity to engage in independent, self-regulated, hands-on procedural simulations to enhance their skills and confidence in performing central line insertions. Our central line insertion task trainer kit aims to overcome barriers to resident simulation by minimizing faculty involvement, enabling residents to self-schedule training sessions, and providing easily accessible, user-friendly resources.

Method

Methodology

The development of this medical education tool was guided by Experiential Learning Theory, along with the principles of self-regulated learning and spaced repetition learning.

Experiential Learning Theory emphasizes the integration of experience and education, proposing that learners acquire knowledge through active participation and reflection on those experiences (9,10). This hands-on approach encourages learners to engage directly with the material and reflect on their actions, fostering deeper understanding (9). In the context of this task trainer kit, residents actively perform ultrasound-guided central line insertions, engaging in hands-on practice that encourages critical thinking and problem-solving. Reflection on their actions, supported by self-testing checklists and instructional materials helps solidify procedural knowledge.

Self-regulated learning refers to the process of planning, monitoring, and adjusting one's learning strategies to achieve specific objectives (11). It involves setting goals, making adjustments based on progress, and reflecting on the learning experience to assess outcomes and overcome challenges (11). The task trainer kit was designed to promote self-regulated learning by providing residents with resources that enable them to track their progress, reflect on their practice, and adjust their learning as needed.

Spaced repetition learning involves engaging in brief, focused learning sessions where information is revisited regularly, and retrieval practice is performed (12,13). This approach enhances long-term retention of both information and skills (13). By revisiting skills periodically, learners can steadily improve their proficiency and build confidence with procedures over time (14).

Audience Focus

The target audience for this medical education tool is family medicine residents. While the tool was specifically designed for the Dalhousie University North Nova Family Medicine Residency Program, the concepts and educational resources are generalizable for any program with access to the necessary equipment. The targeted skill assumes that the learner already has a basic understanding of ultrasound use and knobology. To support learners who may not be as comfortable with ultrasound use, the kit includes resources that guide them to additional references and materials as needed, ensuring they can refresh or deepen their knowledge of the technology during the learning process.

Language Level

The language level of our task trainer kit is tailored to an English-speaking physician at the resident level.

Tool Choice/Materials

Our medical education tool is a central line insertion task trainer kit designed to guide residents through an independent simulation of ultrasound-guided central line insertion. Task trainers provide learners with the opportunity to continuously practice and refine skills to become proficient in the micro skills required to perform a procedure (14). Learning resources that guide the simulation are available in both digital format through a dedicated website, and printed format for learners who prefer hard copies. Designed to accommodate various learning styles, learning materials include written instructions, pictures/diagrams, a procedural video, and a checklist. The information for the learning materials was compiled by searching resources from Dalhousie University education sessions, PubMed, clinical practice guidelines, Google, and YouTube. Resources were chosen that reflected evidence-based best practice as well as site specific materials and practices (15–23). A full description of the tool is presented in the discussion, and the website URL is provided in the appendix.

Discussion

Tool description:

Our central line insertion task trainer kit is a medical education tool designed to provide residents with increased opportunities to independently practice ultrasound-guided central line insertion through simulation. A website was created to give learners barrier-free access to the learning aids. Our tool consists of the following: information on how to access the simulation lab; indications and contraindications for central line insertion; complications of central line insertion; equipment locations in the simulation lab; a physical kit containing all necessary materials; a step-by-step guide on how to perform the procedure; pictures; a procedural video; self assessment checklist; and instructions on how to disassemble and leave the simulation space. This information is also all available in print within the physical kit to accommodate learners who prefer printed resources. The various learning modalities are included to support the principle that multimodal learning is more effective than single-modality learning, while also giving learners the flexibility to choose the method that best suits their needs at any given time (24,25). A checklist is provided for learners to self-assess their skills, as testing offers an opportunity for learners to identify what has been learned and highlight areas for continued improvement (26). The URL for the website is included in the appendix.

Tool implementation

The implementation of our tool is based on the concepts of self-regulated learning and spaced repetition learning. An email was sent to our residency group with the website link for the task trainer kit resources. Residents were informed as to how they could access the simulation lab, what equipment to gather and who to contact with any questions/concerns. This medical education tool is designed to enhance residents' comfort and skill with central line insertion, but it does not ensure competence in performing the skill independently on a patient. Direct observation and feedback from a clinical preceptor remain essential when performing this procedure on patients in the clinical setting. Residents must demonstrate proficiency through supervised practice before being deemed competent to perform the skill independently.

Self-regulated learning:

Self-regulated learning is a learning technique that involves the learner working through a training program and regulating their progress without guidance from a facilitator (27). Learners are motivated to gain knowledge and ability surrounding a new skill, are able to develop their own strategies surrounding this skill, and develop the ability to troubleshoot independently (27). Traditionally, simulation procedural skills sessions are done with a facilitator and immediate feedback, but it has been found that skill retention can be augmented when learners have dedicated, unsupervised training time (28). There is some evidence to suggest that concurrent feedback can hinder long term learning, as self-regulated learning better mirrors the practice environments encountered after residency (29). A key competency outlined in the CanMEDS framework is the role of the scholar, which emphasizes a "lifelong commitment to excellence in practice through continuous learning, teaching others, evaluating evidence, and contributing to the creation and dissemination of knowledge" (30). To cultivate family physicians capable of addressing their ongoing learning needs, it is crucial to integrate opportunities for self-regulated learning within residency programs. This task trainer kit not only teaches residents the steps required to perform a procedural skill, it also teaches residents how to implement learning strategies that will benefit them throughout their career.

Spaced repetition learning:

Within many residency training programs, it is not uncommon to have infrequent skills sessions with little opportunity to revisit or retrain in skills that have already been taught (31). In medical education, a common learning style is massed learning, where students cram large amounts of material into short periods, aiming to simply recall or recognize information for testing (32). This provides little benefit for a learner whose career requires them to retain information and skills for prolonged periods of time. Spaced repetition learning is the concept of repeatedly presenting learning material over different periods of time (32). Spaced repetition learning has been proven to be superior to massed learning as it allows learners to cognitively prepare/mentally rehearse for procedures, while promoting long-term conceptual understanding/retention, critical thinking and reflective skill development (31–33). For optimal results, spaced repetition learning should be repeated with enough time elapsed that retrieval requires cognitive effort (26). With procedural skills in particular, this learning, forgetting, retrieval pattern has been shown to improve encoding of the particular skill (31).

In summary, the implementation of this medical education tool emphasizes a learner-centered approach that incorporates self-regulated learning, and spaced repetition learning. There is no requirement for students to complete this simulation, and therefore they must use self-regulated learning strategies, such as planning, monitoring, and adjusting learning to meet individualized objectives. Frequency of simulations is determined by the resident. Simulations should be repeated when knowledge and skills begin to decline. If too much has been forgotten, they should plan to repeat the simulation sooner. If retention is still strong, they should consider spacing out future simulations with a longer interval.

Barriers/challenges to implementation:

As with the development of any new medical education venture, there were some barriers to implementation that we encountered. I list them here to offer guidance to any colleagues hoping to implement similar medical education tools in the future. We are incredibly lucky at the Colchester East Hants Health Center to have access to a simulation lab, as well as dedicated simulation leadership, educators, and technicians. We collaborated closely with all of the above in order to access equipment, develop sign out protocols, and organize kit restocking. Without the help of everybody listed above, this project would not be possible.

In creating a medical education tool that may result in increased use of simulation equipment, we had to consider equipment longevity, mannequin limitations and implications of overuse. We provide clear guidance on mannequin management post simulation. We also have requested that residents not use a scalpel or dilator during the procedure. While this decreases fidelity slightly, we feel it will result in increased longevity of mannequins. These are considerations that we will continue to manage as the use of this medical education tool continues.

Implications for research:

Simulation is an expensive and resource intensive learning modality, yet it is becoming increasingly sought after in residency programs. This tool may offer valuable insights into how to increase resident exposure to procedural skills while reducing the resource demands associated with traditional simulation. This tool presents the opportunity to complete studies looking at frequency of residency self-regulated simulation use, barriers to use, and perceived benefit from learners. Additionally, it presents a chance for comparative studies that explore the effectiveness of self-regulated procedural simulation versus facilitator-led simulation. Such studies could offer important data on the relative benefits of both methods, particularly in terms of skill retention, learner autonomy, and long-term competence.

An important question that remains unanswered in simulation research is the optimal frequency and spacing of simulation sessions. Current guidelines on the recession of knowledge and the timing of practice sessions remain unclear, and this medical education tool could provide further information on the topic.

Strengths/limitations:

The strengths of this medical education tool lie in its generalizability and flexibility. Once a simulation area is available, residents can independently use this tool to practice procedural skills at their own pace, according to their individual schedules and without the need for continuous faculty supervision. As residents engage in self-regulated practice, they build critical thinking and problem-solving skills that are essential for lifelong learning and clinical autonomy in their future practice.

A primary limitation of this tool is the lack of immediate feedback. Without real-time correction, residents may practice errors that go unaddressed. To mitigate this, self-testing after each session serves as a form of delayed feedback. Residents will also be performing this skill with a preceptor at the bedside for real patient cases, providing the possibility for feedback at that time.

Another limitation is the lack of guidance on the optimal frequency of simulation sessions. This remains an area of uncertainty in the literature, and once more definitive information becomes available, this guidance should be incorporated into the educational tool.

Conclusion

We developed a central line insertion task trainer kit to provide residents of the North Nova Family Medicine Program opportunities to independently practice ultrasound-guided central line insertion. Our medical education tool is guided by Experiential Learning Theory, and integrates concepts of experiential learning, self-regulated learning, and spaced repetition to support residents in refining their central line insertion skills. By providing flexible, self-paced training, it complements traditional supervised practice, ultimately fostering long-term skill retention and professional growth. Future research could explore self-regulated versus facilitator-mediated simulation, barriers to its adoption, and perceived benefits by learners. Research on the optimal frequency and spacing of simulation sessions could provide valuable insights to the growing body of procedural skills simulation research.

Appendix

Website: https://lilybarton1.wixsite.com/tasktrainerkit

References

1. Carlin E, Dubash R, Ho J, Bertenshaw C. Simulation in emergency medicine. Emerg Med Australas [Internet]. 2021 [cited 2023 Sep 17];33(2):357–61. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/1742-6723.13756

2. Fowler N, Oandasan I, Wyman R. Preparing Our Future Family Physicians an educational prescription for strengthening health care in changing times.

3. Watts PI, Rossler K, Bowler F, Miller C, Charnetski M, Decker S, et al. Onward and Upward: Introducing the Healthcare Simulation Standards of Best PracticeTM. Clin Simul Nurs [Internet]. 2021 Sep [cited 2022 Dec 18];58:1–4. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1876139921000931

4. Palaganas JC, Epps C, Raemer DB. A history of simulation-enhanced interprofessional education. J Interprof Care [Internet]. 2014 Mar 1 [cited 2021 Oct 6];28(2):110–5. Available from: https://doi.org/10.3109/13561820.2013.869198

5. Corvetto MA, Pedemonte JC, Varas D, Fuentes C, Altermatt FR. Simulation-based training program with deliberate practice for ultrasound-guided jugular central venous catheter placement. Acta Anaesthesiol Scand [Internet]. 2017 [cited 2023 Oct 15];61(9):1184–91. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/aas.12937

6. Wu S yong, Ling Q, Cao L hui, Wang J, Xu M xi, Zeng W an. Real-time Two-dimensional Ultrasound Guidance for Central Venous Cannulation: A Meta-analysis. Anesthesiology [Internet]. 2013 Feb 1 [cited 2023 Oct 28];118(2):361–75. Available from: https://doi.org/10.1097/ALN.0b013e31827bd172

7. Jagneaux T, Caffery TS, Musso MW, Long AC, Zatarain L, Stopa E, et al. Simulation-Based Education Enhances Patient Safety Behaviors During Central Venous Catheter Placement. J Patient Saf [Internet]. 2021 Sep [cited 2023 Oct 15];17(6):425. Available from: https://journals.lww.com/journalpatientsafety/fulltext/2021/09000/simulation_based_education_enhances_patient_safety.4.aspx

8. Laack TA, Dong Y, Goyal DG, Sadosty AT, Suri HS, Dunn WF. Short-term and Long-term Impact of the Central Line Workshop on Resident Clinical Performance During Simulated Central Line Placement. Simul Healthc [Internet]. 2014 Aug [cited 2023 Oct 18];9(4):228. Available from: https://journals.lww.com/simulationinhealthcare/fulltext/2014/08000/short_term_and_long_term_impact_of_the_central.3.aspx

9. Kolb DA. Experiential learning: experience as the source of learning and development. Englewood Cliffs, N.J.: Prentice-Hall; 1984. xiii+256.

10. Yardley S, Teunissen PW, Dornan T. Experiential learning: Transforming theory into practice. Med Teach [Internet]. 2012 Feb [cited 2024 Dec 8];34(2):161–4. Available from:

https://ezproxy.library.dal.ca/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=70857826&site=ehost-live&scope=site

11. Sandars J, Cleary TJ. Self-regulation theory: Applications to medical education: AMEE Guide No. 58. Med Teach [Internet]. 2011 Nov 1 [cited 2025 Jan 13];33(11):875–86. Available from: https://doi.org/10.3109/0142159X.2011.595434

12. Augustin M. How to Learn Effectively in Medical School: Test Yourself, Learn Actively, and Repeat in Intervals. Yale J Biol Med [Internet]. 2014 Jun 6 [cited 2024 Dec 9];87(2):207–12. Available from: https://www.proquest.com/docview/2725345927/abstract/F2750E9BE3654955PQ/1

13. Upegui A, Awan OA. Spaced Repetition in Medical Education: Its Importance and Applications. Acad Radiol [Internet]. 2024 Dec 1 [cited 2024 Dec 9];31(12):5339–40. Available from: https://www.sciencedirect.com/science/article/pii/S1076633224000254

14. Singh M, Restivo A. Task Trainers in Procedural Skills Acquisition in Medical Simulation. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 Dec 5]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK558925/

15. EASY Central Line Placement | (Central Venous Catheter) | Behind the Knife - Bedside Procedures Ep 2 - Behind the Knife: The Surgery Podcast [Internet]. [cited 2025 Jan 26]. Available from: https://behindtheknife.org/video/easy-central-line-placement-central-venous-catheter-behind-the-knife-bedside-procedures-ep-2

16. Eisen LA, Narasimhan M, Berger JS, Mayo PH, Rosen MJ, Schneider RF. Mechanical Complications of Central Venous Catheters. J Intensive Care Med [Internet]. 2006 Jan 1 [cited 2024 Apr 17];21(1):40–6. Available from: https://doi.org/10.1177/0885066605280884

17. Helman A. Central Lines, Cricothyrotomy & Pericardiocentesis | EM Cases [Internet]. Emergency Medicine Cases. 2013 [cited 2024 Apr 17]. Available from: https://emergencymedicinecases.com/episode-30-central-lines-surgical-airways-pericardiocentesis/

18. McGee DC, Gould MK. Preventing Complications of Central Venous Catheterization. N Engl J Med [Internet]. 2003 Mar 20 [cited 2025 Jan 26];348(12):1123–33. Available from: https://www.nejm.org/doi/full/10.1056/NEJMra011883

19. Nicholson T, Ettles D, Robinson G. Managing inadvertent arterial catheterization during central venous access procedures. Cardiovasc Intervent Radiol. 2004;27(1):21–5.

20. Ortega R, Song M, Hansen CJ, Barash P. Ultrasound-Guided Internal Jugular Vein Cannulation. N Engl J Med [Internet]. 2010 Apr 22 [cited 2024 Apr 17];362(16):e57. Available from: http://www.nejm.org/doi/10.1056/NEJMvcm0810156

21. Shoja MM, Ardalan MR, Tubbs RS, Loukas M, Vahedinia S, Jabbary R, et al. The relationship between the internal jugular vein and common carotid artery in the carotid sheath: The effects of age, gender and side. Ann Anat - Anat Anz [Internet]. 2008 Aug 28

[cited 2024 Apr 17];190(4):339–43. Available from: https://www.sciencedirect.com/science/article/pii/S0940960208000617

22. Teja B, Bosch NA, Diep C, Pereira TV, Mauricio P, Sklar MC, et al. Complication Rates of Central Venous Catheters: A Systematic Review and Meta-Analysis. JAMA Intern Med. 2024 May 1;184(5):474–82.

23. Tse A, Schick MA. Central Line Placement. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 Apr 15]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK470286/

24. Helman A. Effective Learning Strategies in Emergency Medicine | EM Cases [Internet]. Emergency Medicine Cases. 2018 [cited 2024 Dec 19]. Available from: https://emergencymedicinecases.com/learning-strategies-emergency-medicine/

25. Murad MH, Coto-Yglesias F, Varkey P, Prokop LJ, Murad AL. The effectiveness of self-directed learning in health professions education: a systematic review. Med Educ [Internet]. 2010 Nov [cited 2024 Dec 7];44(11):1057–68. Available from: https://ezproxy.library.dal.ca/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=54418206&site=ehost-live&scope=site

26. Morgenstern J. First10EM. 2016 [cited 2024 Dec 19]. Making it Stick (How to learn better). Available from: https://first10em.com/making-it-stick/

27. Bube S, Dagnaes-Hansen J, Mahmood O, Rohrsted M, Bjerrum F, Salling L, et al. Simulation-based training for flexible cystoscopy – A randomized trial comparing two approaches. Heliyon [Internet]. 2020 Jan 3 [cited 2024 Dec 5];6(1):e03086. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6948262/

28. Gent D, Kainth R. Simulation-based procedure training (SBPT) in rarely performed procedures: a blueprint for theory-informed design considerations. Adv Simul [Internet]. 2022 May 8 [cited 2024 Dec 29];7(1):13. Available from: https://doi.org/10.1186/s41077-022-00205-4

29. Brydges R, Nair P, Ma I, Shanks D, Hatala R. Directed self-regulated learning versus instructor-regulated learning in simulation training. Med Educ [Internet]. 2012 [cited 2024 Dec 5];46(7):648–56. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2923.2012.04268.x

30. CanMEDS- Family Medicine 2017.

31. Moulton CAE, Dubrowski A, Macrae H, Graham B, Grober E, Reznick R. Teaching surgical skills: what kind of practice makes perfect?: a randomized, controlled trial. Ann Surg. 2006 Sep;244(3):400–9.

32. Yuan X. Evidence of the Spacing Effect and Influences on Perceptions of Learning and Science Curricula. Cureus [Internet]. 2022 [cited 2024 Jan 22];14(1):e21201. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8759977/

33. Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving Students' Learning With Effective Learning Techniques: Promising Directions From Cognitive and Educational Psychology. Psychol Sci Public Interest [Internet]. 2013 [cited 2024 Jan 17];14(1):4–58. Available from: https://www.jstor.org/stable/23484712