Transfusion and Apheresis Science 62 (2023) 103628

Contents lists available at ScienceDirect

Transfusion and Apheresis Science

journal homepage: www.elsevier.com/locate/transci

# Simulation-based medical education in transfusion medicine: Current state and future applications

## 1. Introduction

Understanding the indications, risks, and how to manage potential complications associated with transfusion is essential for all physicians working in a hospital setting, yet medical trainee knowledge of transfusion medicine (TM) concepts is poor. At the undergraduate level, the majority of medical students spend less than three hours on didactic TM teaching, and these experiences tend to be unmemorable, with lectures focused on theory and "non-comprehensible acronyms"[1,2]. At the postgraduate level, TM education is often delivered through e-learning and on-the-job training from senior clinicians and nursing staff [2]. Such limited educational experiences have translated to inadequate TM knowledge among postgraduate trainees, with one study reporting a mean score of 45.7% on a validated assessment tool examining TM knowledge in internal medicine residents across nine countries[3]. When tested by objective standardized clinical examination, TM knowledge does not improve as residents progress through their postgraduate training [4]. This lack of TM knowledge in current and future blood component and product prescribers underscores the need for alternative and more effective approaches to TM education in medical trainees.

Simulation is one educational approach that may effectively improve TM knowledge and practice in medical learners. In this review, we provide an overview of simulation, evidence for its efficacy as a teaching tool in TM, as well as future potential directions to advance the field of simulation in TM education.

## 2. Simulation in medical education

### 2.1. What is simulation?

Simulation is an experience that allows learners to participate in a controlled scenario or activity that mimics a real-life event[5,6]. Simulated activities consist of three elements: scope, modality, and environment [5,7]. Scope refers to the extent of the encounter, which may feature a focused skill station or a broad, multi-disciplinary scenario. Modality refers to the interactive model or tool that is being used for the simulation experience, which may consist of task trainers, manikins, standardized patients, computer based, or virtual reality systems. Finally, the environment refers to the setting where the simulation is taking place, which may be in situ (in a real clinical environment), a setting that mimics the real clinical environment (such as a simulation centre), or virtual [5].

In order to maximize simulation effectiveness, simulation activities meet specific pre-defined learning objectives[8]. They are designed to include a pre-briefing and debriefing session led by a qualified facilitator which promotes participant reflection, abstraction, and application of learning points to real-life events[5,8]. Specific feedback for learners is also essential [5]. Finally, the chosen simulation modality should have functional correspondence to the applied context to maximize transfer of learning to the patient care setting, which may be more important than the physical resemblance of the modality, itself [9].

Traditionally, "high fidelity" simulation (typically associated with expensive manikins) is assumed to be better than those considered "low fidelity". These terms however are vague, confusing and not linked to educational outcomes as fidelity may refer to the physical, auditory, tactile or functional features of the simulator [9]. A more appropriate approach in the design of a simulation and selecting the appropriate scope, modality and environment is to focus on functional task alignment. This shifts emphasis away from the physical properties of the simulator towards ensuring the functional properties of the entire simulation context align with the session learning objectives [9]. For example, a simulation designed to practice the consent process for blood product administration would preferably utilize a standardized patient who can respond and interact appropriately with the participant. This will help to achieve the necessary "fidelity" in the patient-clinician interaction. In contrast, a manikin, while often imagined to be necessary for the best outcomes, will not likely provide the necessary "fidelity" to achieve the session objectives. This example highlights the confusing nature of broadly applying the term "fidelity" and the importance of aligning the simulation design with the desired outcomes.

### 2.2. How is simulation currently used in medical education?

Simulation is used in medical education as an adjunct to learning in real-life clinical scenarios [5,10]. This technique is commonly incorporated into training for procedure-based disciplines, which require technical skills, strong communication skills, and high-functioning interprofessional teams, such as emergency medicine, surgery, anesthesia, and critical care [11]. The efficacy of simulation in medical education has been demonstrated in multiple systematic reviews and meta-analyses. Compared to non-simulation education or no intervention, simulation has been shown to improve medical trainee skills [12–15], knowledge [13–15], time and process measure of behaviour [13], and patient outcomes [13,14], with higher learner satisfaction [13,14].

https://doi.org/10.1016/j.transci.2022.103628

Available online 14 December 2022

### 2.3. What are the benefits and challenges of simulation-based medical education?

The benefits for simulation-based medical education (SBME) are numerous and yet the challenges cannot be ignored (Table 1). Educators must actively acknowledge that any educational methodology has potential downsides to be considered and SBME is no different. In deciding to pursue SBME for a particular TM topic, these considerations can be reviewed to ensure the benefits outweigh the challenges or barriers.

## 3. Use of simulation-based training in TM

### 3.1. Why might simulation be an effective teaching tool in TM?

Simulation is an ideal educational tool for teaching TM topics to medical trainees for several reasons. First, TM-related concepts such as blood group compatibility and transfusion reactions may seem abstract and complex when taught didactically and consequently difficult to translate such classroom learnings to a real-life clinical situation [2]. For example, a simulation whereby the learner observes the signs and symptoms of a transfusion reaction followed by delivery of appropriate management may more reliably transfer to preferred actions during real-life events than if the learner received classroom teaching focused lists of transfusion reaction symptoms and signs. Furthermore, safe and effective TM practice requires high-functioning interprofessional teams with strong communication skills (for example, a massive transfusion protocol requires cooperation among physicians, nurses, porters, and the blood bank). Simulation is a highly effective tool for interprofessional communication training, with virtually no other comparable methods except real life events [16]. Finally, simulation-based education may contribute to judicious and appropriate use of blood components and products, by allowing learners to witness the potential dangers of transfusion during simulation scenarios, before they are encountered in real-life practice.

Importantly, while simulation may be perceived as an answer to all educational situations, it must be recognized that simulation is a tool that should be utilized with appropriate planning and intention. Just as no builder would be expected to build an entire house with a hammer, no curriculum should exclusively use simulation. The inherent strength of simulation is the active engagement of participants followed by deliberate reflection during the debriefing. Following these principles and balancing the related challenges, we recommend the use of simulation within TM curricula for the following:

1. *Training for recognition and management of rare events*: Simulation has the power of turning a rare event into one that can occur regularly and under controlled circumstances. These high acuity, low occurrence (HALO) events are high yield for simulation given the lack of real-time clinical opportunities yet remain essential knowledge. For example, anaphylactic transfusion reaction is a rare event occurring at a rate of 1.2–5.9 per 100,000 components transfused [17] and may be life-threatening if its diagnosis and management are delayed.
2. *Multi-disciplinary team training*: The power of simulation is highlighted in the ability to bring a team together to work, train, reflect and improve. Complex processes cannot be taught effectively to individuals as they require multiple interconnected actions. For high-stakes events such as massive hemorrhage protocols, simulation offers a unique opportunity for an entire multi-disciplinary team to learn together and practice procedural, as well as communication and leadership skills.
3. *Communication-based skills*: Recreating interactions with patients for high-stakes decision are effectively done using simulation. For example, while consent for transfusions can be taught using lectures, the nuances of the communication, including the need to personalize consent discussion to address risks that may be unique to an individual patient's circumstances (for example, risk of circulatory overload), require practice that can be recreated through simulation.

**Table 1**
Benefits and Challenges of simulation-based medical education.

| Benefits | Challenges |
|---|---|
| Safe environment for trainees to attempt new skills.<br>Ability to pause, rewind, and replay scenarios to allow for incorporation of new feedback and knowledge.<br>Interprofessional skills and communication training.<br>Opportunity for real-time feedback.<br>Gaining experience with rare clinical scenarios that learners may not encounter during the course of their clinical training.<br>Standardization of tasks and scenarios allow for measure of trainee progress and for comparison among trainees. | Cost associated with purchase and maintenance of equipment such as patient simulators as well as costs associated with design of virtual programs.<br>Need for qualified personnel (patient actors, facilitators).<br>Simulation activities must be continually reviewed for accuracy, and updated to reflect changing practice.<br>Limited accessibility of certain simulation modalities and environments, particularly at smaller centers or in lower-resource settings, due to cost and space constraints. |

Modified from Ref. [5].

### 3.2. What is the current state of simulation in TM education?

Simulation is commonly incorporated in TM education across multiple health care disciplines, but studies evaluating the efficacy of simulation in TM training are limited.

The management of transfusion reactions and obtaining transfusion consent were integrated into simulations for medical students using both manikins and patient actors. During the debriefing session, performance feedback was provided [18]. Simulation has also been used for TM education in nursing students. In one report, an interactive learning activity incorporated a die-based game to review blood group compatibility, followed by a simulation experience where nursing students demonstrate management of transfusion reactions and the required pre-transfusion checks[19]. Another activity used a computer controlled manikin to practice recognition and management of transfusion reactions [20].

To our knowledge, only three studies have measured the impact of simulation on TM knowledge in medical trainees. Morgan et al. [21] developed a 2.5-hour simulation-based course for 70 undergraduate medical students and 7 junior residents, which consisted of a 10-question pre-test/post-test, a simulation session with computer controlled manikin depicting an acute hemolytic transfusion reaction or massive transfusion and a lecture. There was a significant improvement in post-test scores for both trainee groups with median scores significantly improving from 40% to 80% from pre- to post-test in the medical student group and improving from 30% to 70% in the junior resident group.

The second study, by Konia and Rioux-Masse [22], evaluated a simulation curriculum for medical students, anesthesiology residents, and surgery residents featuring a massive transfusion scenario and an acute hemolytic transfusion reaction. Among 95 learners, TM knowledge improved (from mean pre-test score of 39% to mean post-test score of 77.5%) and was retained six weeks later (mean scores of 82%), with high learner satisfaction. These curriculum materials and scenarios are publicly available to other programs [22].

Finally, a more recent study by Konia et al. [23], compared three different TM simulation strategies among second year medical students (N = 276): in-person didactic teaching and simulation (with the SimMan simulator), a hybrid model featuring online materials and in-person simulation, and finally, an online-only model. All groups demonstrated improvement between pre- and post-test scores, though this improvement only reached statistical significance for the in-person simulation training group. Student satisfaction was higher in the in-person and hybrid groups. The authors hypothesized that the more modest post-test score improvement and lower student satisfaction scores in the online-only group were related to the fact that novice learners benefit from increased faculty involvement compared to more advanced learners, who may be more proficient at self-guided learning.

It is well established that simulation is an effective educational strategy broadly in medical education and TM is no exception. While only one study in TM compared simulation with other educational methods, thus limiting efficacy conclusions, it is clear that learners overwhelmingly prefer simulation and it is likely at least, if not more effective than didactic teaching.

### 3.3. How can simulation be improved to advance the future of TM education?

The evidence highlighting the efficacy of simulation in TM education supports the ongoing use of this learning strategy for medical trainees. We agree that TM educators should continue to incorporate in-person simulation scenarios featuring patient simulators and patient actors into TM training, where feasible, with ongoing objective assessment of knowledge acquisition and retention through pre- and post-test evaluations. In order to further advance the field of simulation in TM education and to maximize TM learning through simulation, we recommend additional high-quality research studies to evaluate simulation program efficacy, continuing TM simulation training beyond the trainee years for continuous medical education, and exploring alternative simulation environments and modalities.

#### 3.3.1. Additional research is required to measure simulation program efficacy

In order to further improve our understanding of how and when simulation can be used most effectively in TM training, additional research studies are needed to assess the impact of different TM simulation activities on trainee learning and knowledge retention. Ideally, these studies should be high quality, prospective comparative studies such as multicenter randomized controlled trials comparing efficacy of simulation exercises to other educational interventions. Included in these study objectives should be the impact on patient outcomes, as this has not been consistently demonstrated in other disciplines utilizing simulation. [5,10] These randomized controlled trials could then be analyzed using systematic review and meta-analysis, to guide educators in designing evidence-based TM simulation programs for their trainees.

#### 3.3.2. Simulation training in TM should continue beyond the trainee years

There is uncertainty surrounding optimal timing and frequency of simulation training in all healthcare disciplines, including TM. While existing literature suggests knowledge retention up to six weeks after the simulation activity [21,22], long term TM knowledge retention (i.e. as medical students transition to the role of residents, and residents transition to the role of attending physicians) has not been studied. Furthermore, there is evidence to suggest that there are TM knowledge deficiencies at the attending physician level [24,25]. Looking to other medical specialities, among staff physicians, complex procedural skills are retained for at least one year[26]. Extrapolating to TM, it is likely to expect similar skill retention duration but it is clear that skill retention is not permanent without training updates. Thus, we feel that physicians would benefit from TM simulation experiences throughout their career, in order to detect and remediate knowledge gaps, and to ensure that physicians in practice remain up to date on changing TM guidelines. These simulation activities could take place in situ (in their working environment), as on-the-job continuing education activities for physicians.

#### 3.3.3. New simulation approaches in TM should be explored to improve accessibility and reduce cost

To date, the most frequently used simulation approaches in TM have featured live scenarios, with the use of patient simulators (such as SimMan 3 G) and patient actors. However, as noted in Table 1, these simulation modalities and environments may be prohibitively expensive and logistically challenging to run, when considering the costs associated with purchasing patient simulators and the personnel required to run simulation programs. Thus, these types of learning opportunities may not be accessible to all learners and institutions. Furthermore, given the paucity of publications on this topic, the optimal simulation strategy for teaching TM concepts has not been established.

*3.3.3.1. Use of alternative simulation environments.* In order to improve accessibility of simulation-based TM education and to optimize trainee learning, TM educators should explore alternative simulation environments and modalities. Potentially less costly alternatives to a simulation centre would include an in situ scenario, such as a massive transfusion protocol within the emergency department (for healthcare worker training) or blood bank (for technologist training). While this would certainly create a realistic environment, use of a real clinical setting must be balanced against the use of these resources from real clinical care. Practically, and in an effort to garner support for in situ simulation work, reframing the simulation as simply adding one more patient to the daily census can be helpful to staff conceptualize the resource allocation. For many acute care specialities, the number of patients are unpredictable on any given day and the system has capacity for another patient, even a simulated one. A virtual or hybrid virtual-live simulation activity, such as the simulation activity reported by Konia et al. [23], may also be more cost effective and accessible to trainees across various institutions; however, the factors influencing the smaller increase in post-test performance and lower participant satisfaction relative to the live simulation group in this study warrant further exploration.

*3.3.3.2. Use of alternative simulation modalities.* Virtual reality (VR) and augmented reality (AR) are two newer approaches with increasing uses in medical education which, to our knowledge, have not yet been used in TM. VR allows the learner to interact with a virtual representation of an artificial world using technology such as head-mounted displays with high resolution audio and visual effects as well as advanced haptic devices that allow the learner to interact with and receive feedback from the virtual environment [27]. AR allows for the overlay of computer-generated images onto real-world images, using hardware such as smart glasses or tablets with cameras and sensors [27]. The main applications for VR and AR to date in medical education are for procedural training and anatomy and physiology, with one review finding that VR improved knowledge and skills outcomes in health professions trainees compared to traditional learning or other types of digital education [28]. VR may also be an effective alternative to live simulation, at a lower cost, with one study demonstrating similar efficacy at 1/13th of the cost for teaching mass casualty triaging to paramedicine students [29,30].

VR or AR may be a useful addition to simulation-based education in TM. For example, consider a VR scenario to allow learners to manage a transfusion reaction or a massive hemorrhage scenario, with real-time feedback on performance generated by computer software, or by a virtually available facilitator. While VR/AR has the up-front costs of equipment purchases and software design, this technique may be more cost-effective over time compared to live simulation and would also allow for improved accessibility of TM simulation training to learners in lower-resource settings and smaller institutions without established simulation programs.

## 4. Conclusions

Knowledge of the indications for and complications of transfusion is essential for all medical practitioners working in a hospital setting, yet traditional approaches to TM education have resulted in knowledge gaps at all levels of medical training. Simulation is an educational tool with well-documented efficacy in multiple medical subspecialties, and evidence is emerging for its utility in TM education. To further advance the field of simulation in TM education, we propose extending simulation activities to attending physicians to ensure their practice remains up to date and exploring new simulation environments (such as in situ simulation) and modalities such as VR/AR, in order to reduce simulation costs and improve simulation accessibility. Currently used simulation strategies, as well as proposed future strategies, should be evaluated using high-quality research studies, such as randomized controlled trials, in order to guide further development of evidence-based simulation programs in TM.

## References


[1] Karp JK, Weston CM, King KE. Transfusion medicine in American undergraduate medical education. Transfusion 2011;51:2470–9.
[2] Graham JE, Narayan S, Pendry K. Improving transfusion education for junior doctors; exploring UK experiences. Transfus Med 2017;27:96–104.
[3] Haspel RL, Lin Y, Mallick R, Tinmouth A, Cid J, Eichler H, et al. Internal medicine resident knowledge of transfusion medicine: results from the BEST-TEST international education needs assessment. Transfusion 2015;55:1355–61.
[4] Lin Y, Tinmouth A, Mallick R, Haspel RL, Investigators B-T. BEST-TEST2: assessment of hematology trainee knowledge of transfusion medicine. Transfusion 2016; 56:304–10.
[5] So HY, Chen PP, Wong GKC, Chan TTN. Simulation in medical education. J R Coll Physicians Edinb 2019;49:52–7.
[6] Gaba DM. The future vision of simulation in health care. Qual Saf Health Care 2004;13:i2–10.
[7] Choi W, Dyens O, Chan T, Schijven M, Lajoie S, Mancini ME, et al. Engagement and learning in simulation: recommendations of the simnovate engaged learning domain group. BMJ Stel 2017;3:S23–32.
[8] International Nursing Association for Clinical Simulation and Learning. Healthcare Simulation Standards of Best Practice, https://www.inacsl.org/healthcare-simulation-standards; 2021 [accessed September 10 2022].
[9] Hamstra S, Brydges R, Hatala R, Zendejas B, Cook D. Reconsidering fidelity in simulation-based training. Acad Med 2014;89:387–92.
[10] Bjerrum F, Thomsen ASS, Nayahangan LJ, Konge L. Surgical simulation: Current practices and future perspectives for technical skills training. Med Teach 2018;40: 668–75.
[11] Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. JAMA 2011;306:978–88.
[12] Beal MD, Kinnear J, Anderson RC, Martin TD, Wamboldt R, Hooper L. The effectiveness of medical simulation in teaching medical students critical care medicine: a systematic review and meta-analysis. Simul Health 2017;12:104–16.
[13] Cook DA, Brydges R, Hamstra SJ, Zendejas B, Szostek JH, Wang AT, et al. Comparative effectiveness of technology-enhanced simulation versus other instructional methods: a systematic review and meta-analysis. Sim Healthc 2012;7: 308–20.
[14] Mundell WC, Kennedy CC, Szostek JH, Cook DA. Simulation technology for resuscitation training: a systematic review and meta-analysis. Resuscitation 2013; 84:1174–83.
[15] Ilgen JS, Sherbino J, Cook DA. Technology-enhanced simulation in emergency medicine: a systematic review and meta-analysis. Acad Emerg Med 2013;20: 117–27.
[16] Blackmore A, Kasfiki EV, Purva M. Simulation-based education to improve communication skills: a systematic review and identification of current best practice. BMJ Simul Technol Enhanc Learn 2018;4:159–64.
[17] Khandelwal A., Clarke G., Goldman M. Anaphylactic transfusion reactions and IgA deficiency, https://professionaleducation.blood.ca/en/transfusion/publications/anaphylactic-transfusion-reactions-and-iga-deficiency; 2021 [accessed October 2 2022].
[18] Marshall AL, Pruthi RK, Kreuter JD. Simulation-based transfusion education for medical students. Transfus Med Rev 2018;32:123–4.
[19] Carignan B, Sheehan C. Safe blood administration learning activity. J Nurs Educ 2010;49:174–5.
[20] Prentice D, O`Rourke T. Safe practice: using high-fidelity simulation to teach blood transfusion reactions. J Infus Nurs 2013;36:207–10.
[21] Morgan S, Rioux-Masse B, Oancea C, Cohn C, Harmon J, Konia M. Simulation-based education for transfusion medicine. Transfusion 2015;55:919–25.
[22] Konia MR, Rioux-Masse B. Comprehensive simulation curriculum of transfusion medicine. MedEdPORTAL 2012;8:9207.
[23] Konia MR, Richtsfeld M, Johnson AD, Lougee M, Cohn C, Morgan S. An observational study of 3 different transfusion medicine teaching methods for medical students. Transfus Med Rev 2018;32:117–22.
[24] Rock G, Berger R, Pinkerton P, Fernandes B. A pilot study to assess physician knowledge in transfusion medicine. Transfus Med 2002;12:125–8.
[25] Koren RR, Suriu C, Yakir O, Akria L, Barhoum M, Braester A. Physicians' lack of knowledge - a possible reason for red blood cell transfusion overuse? Isr J Health Policy Res 2017;6:1–8.
[26] Boet S, Borges BCR, Naik VN, Siu LW, Riem N, Chandra D, et al. Complex procedural skills are retained for a minimum of 1 yr after a single high-fidelity simulation training session. Br J Anaesth 2011;107:533–9.
[27] Pantelidis P., Chorti A., Papagiouvanni I., Paparoidamis G., Drosos C., Panagiotakopoulos T., et al.Virtual and augmented reality in medical education, https://www.intechopen.com/chapters/58199; 2017 [accessed October 2 2022].
[28] Kyaw BM, Saxena N, Posadzki P, Vseteckova J, Nikolaou CK, George PP, et al. Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration. J Med Internet Res 2018;21: e12959.
[29] Pottle J. Virtual reality and the transformation of medical education. Future Health J 2019;6:181–5.
[30] Mills B, Dykstra P, Hansen S, Miles A, Rankin T, Hopper L, et al. Virtual reality triage training can provide comparable simulation efficacy for paramedicine students compared to live simulation-based scenarios. Prehosp Emerg Care 2020;24: 525–36.



Lianne E. Rotin[a], Katerina Pavenski[b,c,*], Andrew Petrosoniak[d,e]

[a] Adult Hematology Residency Program, Department of Medicine, University of Toronto Temerty Faculty of Medicine, Canada

[b] Department of Laboratory Medicine, St. Michael's Hospital, Canada

[c] Department of Laboratory Medicine and Pathobiology, University of Toronto, Canada

[d] Department of Emergency Medicine, St. Michael's Hospital, Canada

[e] Department of Medicine, University of Toronto, Canada

[*] Correspondence to: St. Michael's Hospital, CC 2-035, 30 Bond Street, Toronto, ON M5B 1W8, Canada.

*E-mail address:* Katerina.Pavenski@unityhealth.to (K. Pavenski).