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18 Simulation in Postgraduate Medical Education

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Executive Summary

At its broadest, simulation in medical education refers to the representation or reproduction of something real by imitation, for the purposes of training or assessment. Simulation has increasingly become part of mainstream postgraduate medical education in Canada. It is perceived as a qualitatively different learning experience from more traditional forms of didactic or clinical learning, one that provides opportunity to learn from trial and error in a positive learning environment, without risking negative outcomes for patients. It separates learning from the competing demands of service (for both the learner and the educator), allowing space and time for activities such as deliberate practice and a variety of methods of feedback and reflection. It is adaptive to the level of the learner.

The general consensus, both from the literature and from the Canadian simulation program directors and administrators interviewed for this paper, is that simulation has become an important and necessary component of postgraduate training, to target skills and behaviours that are difficult to acquire through traditional training, to reduce risks to patients, and potentially, to deliver more cost-effective training. However, for the theoretical advantages of simulation to be fully realized, further developments need to occur at the postgraduate level, particularly in the areas of faculty development, curricular integration, and research:

1. The rapid growth in the use of simulation in Canada comes with significant variation in resources and expertise across institutions, and our interviewees almost unanimously identified ***faculty development as a key issue in improving the uptake and use of simulation in a way that will positively impact learning and patient safety.*** The quantity and quality of instructors were identified as important determinants of the success of simulation programs; however, faculty development is one of the least developed aspects of simulation in Canada.

2. ***Simulation also needs to be integrated more thoughtfully into existing postgraduate curricula***. To achieve this, there is a need for greater communication and collaboration between postgraduate simulation educators (who are often hospital based) and the rest of the university; between different centres; between researchers, educators and clinical teachers; and between different medical specialties and other healthcare professionals.

3. Finally, there are ***strong calls for research that moves beyond description towards justification and greater understanding of simulation-based education***. We heard a variety of views regarding priority research areas including (i) the importance of demonstrating the effectiveness of simulation-based interventions, (ii) a consistent call for research that moves beyond the description and justification of simulation-based educational interventions towards a clarification of the principles that underpin simulation-based education and (iii) toward identifying cost-effectiveness metrics.

Introduction

Simulation has increasingly become part of mainstream postgraduate medical education in Canada. The early simulation-based medical education literature was initially focused on description and advocacy. More recently, it has been aimed at establishing the effectiveness of simulation for teaching and assessment, and at identifying best practices. The literature pertaining to simulation-based education is vast: a MEDLINE search of simulation AND education returned over 7,000 references. This literature includes numerous previous reviews, which have focused on either specific modalities (i.e., types of simulators) or the use of simulation by specific professional specialties. Consequently, it is easy to see how postgraduate educators can find themselves in silos, with their understanding of simulation bounded by the modalities that they use. This is particularly exacerbated by the fact that most specialties tend to focus their postgraduate activities within one simulation modality (e.g. task trainers for technical skills in surgery and manikin-based simulation for crisis management by acute care specialties). Broader reviews of the domain, such as Issenberg's systematic review[1] and McGaghie's more recent qualitative review[2,] have provided a bigger picture of the use of simulation in medical education, but do not address the significant differences in practicalities, patterns of use, and levels of understanding of simulation across different modalities and specialties.

The aim of this paper is to build on these earlier reviews and to explore previously identified themes with respect to each simulation modality within the postgraduate Canadian context. The paper uses a 'review of reviews' as its basis and is supplemented with a thematic qualitative analysis of semi-structured interviews of a purposive sample of simulation program directors, university administrators and residency program directors. This paper is one of 24 papers commissioned for the Future of Medical Education in Canada Postgraduate (FMEC PG) Project.

Methodology

When describing simulation-based medical education literature in this paper, we refer to Cook et al.'s[3] classification of research according to its purpose. This framework describes research as either (i) descriptive research that disseminates new innovations, (ii) justification research that seeks to establish the effectiveness of educational interventions, or (iii) clarification research that aims to explore how and when educational interventions can be used in order to maximize their benefit.[3] Previous reviews have identified clarification research as being under-represented and a necessary focus for the future.[3,4] As a series of systematic reviews from Issenberg's group covers research from 1969-2003,[1,2] our literature review was limited to searching articles published after 2003. The first component of our environmental scan centered primarily on currently existing reviews of the literature and critically selected best practices in the domain.

The second component of our environmental scan consisted of an overview of the state of simulation-based education for residency training within a Canadian context using a structured interview protocol. A total of fifteen simulation program directors, residency directors and senior university administrators were interviewed about their personal and institution's involvement in simulation, their conceptualization of prominent themes in the simulation literature, and the realities of implementing simulation-based education in the Canadian postgraduate system. Transcripts of the interviews were analyzed using an inductive thematic approach. Each member of the research team initially reviewed a few transcripts to identify emerging themes. After this initial coding, the team members discussed these emerging themes as a group and generated a preliminary coding structure. A minimum of two members then used the coding structure to independently analyze each transcript. Finally, further group discussions allowed refinement of the analysis of our findings. Twelve general themes emerged from the analysis of the interview transcripts.

Definition

At its broadest, simulation refers to the representation or reproduction of something real by imitation. In this paper, simulation includes (i) physical objects such as manikins and task trainers, (ii) activities of simulating or representing a process or skill such as suturing or delivering bad news, (iii) people, including standardized patients, confederates playing the roles of healthcare professionals in immersive manikin-based simulation, and facilitators who run scenarios and provide feedback, and (iv) simulation environments that reproduce specific technical, affective and environmental conditions (e.g., virtual worlds, immersive simulation environments).
Simulation is evolving continually and rapidly, which has led to difficulties establishing an agreed upon taxonomy of definitions. Indeed, there is significant confusion in the literature regarding different terms, as well as significant overlap between modalities. In some instances, common terms are used to describe different concepts and activities, while in others, different names describe the same concepts. Although the development of an accepted nomenclature for simulation may be helpful, this task falls beyond the mandate of this review. While we acknowledge the overlap between different modalities of simulation, for the purpose of this focused project, simulation modalities are divided into five broad categories:

1. Human simulation, where the simulation technology is a living person.
2. Part-task trainers, which are inanimate bench models or box-trainers used for skill acquisition, and virtual reality (VR) task trainers, which are interactive computer-generated representations of an environment.
3. Cadaver and animal models.
4. Manikin-based simulation, primarily referring to full patient, computer-driven manikins immersed in recreated or actual clinical environments.
5. Other virtual and web-based educational modules such as virtual patients, serious games and virtual worlds.

Theoretical Underpinnings of Simulation

The widespread adoption of simulation as a teaching and assessment tool has generally preceded evidence of its effectiveness in terms of learning and patient outcomes, in the face of significant practical challenges related to its implementation. So why is simulation attracting so much interest? One explanation may be that simulation often fits better than traditional educational interventions within many theoretical models of learning, including cognitive, behavioral, social interaction and activity theories.[5-14]

In theory, simulation provides exposure to a wide array of specific tasks or situations to supplement real-life clinical experiences, especially when clinical events are rare or involve high risk for the patient.[10,15] Compared to more traditional forms of teaching, simulation provides a unique opportunity for learners to see the immediate results of their behaviors without the risk of causing harm to real patients. Furthermore, simulation offers the opportunity for learners to practice many of the skills required in real clinical settings at their own pace and in a safe environment.[15] This deliberate practice, defined by Ericsson as the effortful, repetitive practice of the activity to a mastery level, in combination with external constructive feedback, has been found to improve performance.[10, 16,18] Simulation is also described as a way to develop a reflective practice, a process Schön describes as engaging in active mental experimentation of alternative decisions and actions during challenging situations.[11,19,20] In simulation, unfolding events can be paused to allow further reflection and discussion even in acute contexts when time pressure would normally prevent such processes. Finally, the feedback that educators provide during the debriefing that often follows a simulation session likely gives trainees further insights into how they construct their knowledge.[21-24]

Learning can also be conceptualized as a historical, socio-cultural process.[13,25,26] Perspectives such as situated learning,[27] distributed cognition,[28] and activity theory [28,29] all focus on the context in which learning occurs rather than on the individual learners. From these perspectives, engagement in social practices and work activities is essential for knowledge expansion at the level of the individual, but also at the level of the community. As such, simulation has been considered a form of legitimate peripheral participation or as an activity system where trainees learn to complete goal-directed actions by using the resources available in a specific context.[5]

Findings

Simulation is perceived in both the literature and by the majority of our interview respondents as being a qualitatively different learning experience from either clinical teaching or more traditional forms of didactic and small group teaching. There was almost universal concordance between the literature and our interviewees on central tenets of the simulation experience: the opportunity to learn from failures in a positive learning environment, often with repeated practice without risking negative outcomes for patients.

> *"So it's helpful to practice before you end up on the ward seeing real patients and kind of getting caught." –Simulation program director*

> *"I think the ability to re-do, so to have a debriefing, try it again. The ability to pause, have a discussion, start again, not having to be opportunistic, rare occurrences and high-risk occurrences. So even though something might not be that rare, if it's a very risky event, to me way better to just get the skills in a simulator instead."-University administrator*

> *"And some of our simulations are deliberately designed that way, having random factors in each simulation, so you can practice the simulation 1,000 times and you'll see 1,000 new patients" – Simulation program director*

> *"I think it gives you time to teach. At least in our area, you know, they talk about the teaching moment as a moment being a very short period of time in the clinical scenario. Well, obviously in a simulated scenario, when you talk about time to teach, you're talking about a longer period of time to reflect and so on… And the other is that the learner has a lot more access to the instructor". -Simulation program director*

The following section provides a summary of the key findings from our environmental scan on simulation-based education in postgraduate medical education.

State of the Evidence

For many of the simulation modalities, research to date can be described as mostly descriptive.

For example, May and colleagues concluded that, despite a 1994 survey reporting that 80% of North American medical schools used human simulation for teaching, there are few studies of how human simulation affects trainees' knowledge, skills and behaviours.[30] The small amount of research that does exist in this area is descriptive, with effectiveness measured at the level of learners' self-reported satisfaction. For other modalities of simulation, particularly part-task trainers and manikin-based simulation, there is important justification research, and a far smaller, but critically important, body of clarification research that identifies how best to use simulation.[3,4]

Justification studies[3] have shown that skills training that involves part-task trainers (PTT), including virtual reality task trainers (VRTT), is likely better than the traditional "see one, do one" approach.[31-38] A series of studies on the training of central venous catheter insertion by residents with PTT using a mastery learning format have shown that the approach leads to better clinical performance, fewer complications, improved patient care and reduced healthcare costs even after accounting for the cost of training.[18,39,40] Likewise, numerous studies support the use of VRTT[41-47]. For example, VR-trained residents performed better than traditionally trained residents on time, injury rates and rate of progress while completing a laparoscopic cholecystectomy in the operating room.[43] Collectively, these results have prompted many medical specialties to search for ways to integrate these modalities into the postgraduate curriculum.[48]

Similarly, skills learned in manikin-based simulation translate into improved actual clinical practice. Hall and colleagues demonstrated that simulation is at least as effective at teaching tracheal intubation as learning on real patients.[49] Using a non-randomized methodology, Shavit and colleagues found that pediatricians that had been simulation-trained had better adherence to sedation safety guidelines than those who had not been simulation-trained.[50] Bruppacher and colleagues found that anesthesiology residents who were randomized to receive an immersive simulation experience performed better than residents who were taught with an interactive tutorial, when weaning real patients from cardiopulmonary bypass.[51]

For newer modalities of simulation, such as virtual patients, most of the publications have been of a descriptive nature. Some justification research has been undertaken, looking at the effectiveness of virtual patients for learning. From this relatively sparse research, there are little differences between virtual patients and standardized patients in terms of the technical aspects of the medical interview (eliciting information, accuracy of diagnoses).[52] However, some studies have indicated that, compared to standardized patient training, virtual patient-based interventions may be less effective in teaching the affective and interpersonal skills (warmth, empathy) also required during the clinical encounter.[53]

Despite calls in the literature and by many of our interviewees for more research to justify and understand simulation-based education, there are diverging views regarding the priority research areas and the evidence required to demonstrate effectiveness. Some interviewees felt that the effectiveness of simulation-based medical education was already well enough established, whereas others identified a lack of evidence as a major barrier to buy-in. Some respondents noted the problematic nature of applying standards from medical research to medical education research, resulting both in methodologies that do not identify ways to improve the use of simulation-based education and in demand for studies that are unrealistic for the context of medical education.

> *"You don't need to do these types of studies. So I don't think that we necessarily do need to prove that the outcome is better in order to know that the outcome is likely better." -Simulation program director*

> *"The few bits of data that have come out have been fairly convincing but we don't have a breadth of data to back this up." – Simulation program director*

> *"That always comes up, whenever we talk about using it for evaluation, is that we better be darned sure that it's fair." –University administrator*

In terms of the evaluation of simulation-based programs, there were discrepancies in the perceived need to demonstrate effectiveness of simulation-based interventions at a program level. There was also significant variability in the extent and level at which simulation programs are evaluated, with the majority of simulation programs being evaluated via surveys of teacher and learner satisfaction.

> *"We do assessment of our curriculum and usually that's knowledge-based assessment using multiple choice testing or short answer testing. Occasionally… we'll do pre and post skills testing as well to test how certain knowledge and skills have been acquired during simulation-based learning." – Simulation program director*

> *"For the purposes of evaluation, we actually do very little." –Simulation program director*

> *"It's very, very difficult to prove an improvement and outcome simply because the intervention is just so complex and there's so many confounders." – Simulation program director*

> *"We have to demonstrate that, academically, they actually do produce the educational experience we think they do and should do, and we need to make sure that they do provide an appropriate return on investment. And if there is a better way of doing this than using this mannequin then we should seriously consider doing that". –University administrator*

Challenges of Simulation-Based Education

Faculty development

Our interviewees almost unanimously identified faculty development as a key issue in improving the uptake and use of simulation in a way that will positively impact patient safety. The quantity and quality of instructors were identified as important determinants of the success of simulation programs, however, faculty development is one of the least developed aspects of simulation in Canada.

> *"Then they need training on how to use the methodology… It's no good just sending them in there to do something and walk away. There are ways to approach using this methodology in education and I think people still are not too sure about it" – Simulation program director*

> *"We do not have enough people who have skills or time to learn how to use various forms of simulation just in the way they teach." – University administrator*

Some respondents noted concerns about poor quality simulation-based education, and some discussed the importance of the accreditation of simulation programs. Furthermore, many interviewees suggested that faculty development should focus on enhancing the understanding of how to use, implement and adhere to theoretical best practices. Interviewees noted that faculty development was also an important way to increase support for simulation, and to improve teaching not only in the simulation context but also teaching in the clinical domain. Some interviewees noted how invaluable it was to identify a simulation champion who took a leadership role amongst interested faculty members. In sum, the unequal distribution of both resources and expertise across Canada poses significant challenges to curricular integration, the use of simulation for summative assessment and the sustainability of simulation programs.

Integration

Although simulation is seen as distinct from other forms of education, our interviewees generally agreed that simulation should be combined with other education components of curricula in a more systematic and informed way. In order for simulation to be truly complementary to more traditional forms of education, it needs to be integrated more thoughtfully into existing postgraduate curricula.

> *"Although there is support in principle from the leaders at the postgraduate level, there's still not a really strong push for them to fully integrate it in…" - Simulation program director*

A lack of integration is apparent when considering different simulation modalities and different clinical specialties. To achieve a good balance, there is a perceived need for greater communication and collaboration between simulation-based educators and the rest of the university; between different centres; between researchers, educators and clinical teachers; and between different medical specialties and other healthcare professionals.

> *"The will is there to integrate but there is no direction for integration" – Simulation program director*

Resources

Along with the rapid growth in the use of simulation in Canada comes significant variation in resources and expertise across institutions. Our interviewees described situations where simulation equipment sat unused due to lack of local expertise, as well as situations where a lack of funding limited widespread implementation and integration of simulation into the postgraduate curriculum.

> *"…we could have a really good centre down here but have absolutely no resources to buy the equipment year to year. So we can build the bricks and mortar but don't get the operational budget to make it happen." – Simulation program director*

> *"we operate on a fee for service basis, we have to charge even more than the actual price of the [simulation]" – Simulation program director*

The discussion of the financial challenges of simulation is under-represented in the literature as compared to the importance it was given in our interviews. Similarly, there is a dearth of cost-effectiveness research, and this represents a pressing research priority.

> *"Yes, simulation is quite expensive and costly. But I guess the dilemma for healthcare systems and education systems is the cost of apprenticeship learning in the OR is also costly, but it's a cost that's not tracked. And if you balance the two, the cost at the Simulation Centre becomes very small." – Simulation program director*

Characteristics of Simulation-Based Education

Rapid technological advancement

For many simulation modalities (e.g., virtual worlds and VRTTs), the field is characterized by exponential growth in technology, especially at the postgraduate level where simulation is increasingly seen as a way to teach more complex skills in more complex settings. For other modalities (e.g., human simulation), innovations are instead aimed at increasing the range of use of simulators – a key example being hybrid simulations that combine human simulation with other simulation modalities. Critically, the growth in innovation and technology has greatly outpaced the growth in simulation-based education research.

"I think we need to really focus on the scholarly side of it so that we know what we're doing makes sense… technology just continues to advance and so the scholarly side of it has got to keep up." – Simulation program director

Innovations are likely to develop fastest for virtual reality-based simulation modalities due to continuously increasing computer processing power and an interest in advancing experiential methods for remote learning. Based on such developments, it is likely that these newer Internet-based modalities will be an increasingly important part of the future of postgraduate medical education, but it is difficult to predict that future role.

Feedback

Building upon the justification studies, which have demonstrated that simulation-based training works, clarification research has revealed important insights into the crucial role of feedback in simulation-based education.[54-57] Recent experimental work on how to provide feedback when using PTTs in medical training has shown that expert-based verbal feedback is better for learning than computer-generated feedback as measured by hand motion efficiency,[54] that short, limited feedback from an instructor is better than intense, continuous feedback,[55] and that summary feedback leads to better learning outcomes versus concurrent feedback.[56-57]

Feedback has also been identified as the feature of manikin-based simulation that has the most positive effect on learning.[1] Feedback in manikin-based simulation is generally termed debriefing. It has been demonstrated that without debriefing, residents fail to learn from a manikin-based simulation experience.[58] The early work comparing various types of debriefing suggests that a structured facilitative debriefing that encourages learners to reflect on their performance and identify their own strengths and weaknesses maximizes the educational opportunities of this form of experiential learning.[59-61] Feedback also represents a key value of human simulation. Both a simulated patient's unique position to offer feedback from the patient's perspective and their training in specific student- centered methods are invaluable for directing attention to the strengths and weaknesses of a resident's interpersonal, diagnostic and management skills.[61] The importance of debriefing was recognized by all of our interviewees.

"Feedback is extremely important, and we know that trainees can't correct the errors if they're not identified." –Simulation program director

"Debriefing session is the most important part of simulation, that's where the teaching occurs actually." –Simulation program director

Fidelity

Although many educators and researchers expect that high-fidelity, expensive simulators lead to better learning outcomes than low-fidelity PTT, the research evidence is more nuanced. High-fidelity and low-fidelity simulators can have equally positive impacts on learning for novice students,[62-65] hence the purchase of high cost, high-fidelity simulators must be considered thoughtfully, especially for use early in the learning curve. Moreover, new studies have suggested that rather than comparing low-fidelity with high-fidelity simulators, a better approach may be to structure the simulation experience as a progressive training program.[66]

There were significant discrepancies between respondents about the meaning of fidelity, and about how fidelity relates to the quality of the learning experience and the assessment.

"…*the technology is still pretty primitive. Even if you have a $100,000 bells-and-whistles simulator, it's still really pretty primitive when you compare it to a real, live patient*." *– University administrator*

Fidelity was seen as either a physical characteristic of the modality or as a broader experience also influenced by the environmental and emotional components of a simulation.

"I use fidelity lightly because I don't believe fidelity needs to be about the technology but it's about the immersion into the actual simulation that you're having – how engaged is the learner or group of learners." – Residency director

"I don't particularly feel that the fidelity or realism needs to be increased…the environmental fidelity and the emotional fidelity or realism that we deliver is really important more so than just that of the mannequin itself." – Simulation program director

Interprofessional simulation-based education

There was broad agreement among the interviewees that simulation-based learning is ideal for team training and interpersonal skills in an interprofessional context. It is felt that interprofessional education (IPE) will be an important way in which simulation can impact on patient safety, with analogies drawn to the success of the Crew Resource Management training that is well established in other high-stakes, high-reliability industries such as aviation and the nuclear industry.

"I think it's ideal for team training. It probably even starts out before the simulation itself. When you start designing a simulation, and if you want to use the team, then you probably do need to do it in an interprofessional manner otherwise your product is not going to be as good." –Simulation program director

"So in fact as a debriefer, I would often get called in to pretend I was X, I was the circulating nurse or something like that. As the circulating nurse I was learning all this stuff about what to do and what not to do in a crisis but it wasn't benefiting anybody because I'm not a nurse. So there was this perfect opportunity for either a nursing trainee or a nurse in practice to be learning this rich stuff, and they weren't even at the table." –University administrator

Simulation-based IPE, whether with technical or human simulators, allows residents to learn crucial communication skills related to conflict negotiation, team interactions during crisis management, and medical error management[67-69] such as medical error disclosure[70-72]. However, simulation-based IPE is particularly resource intensive and logistically challenging, especially at the postgraduate level where education often has to compete with service commitments for time. For the theoretical advantages of IPE simulation to be realized, stakeholders must prioritize this form of teaching and enhance funding.

"One of the real problems we have with interprofessional simulation education is the standard problem of, our learners do this on a Wednesday morning and their learners do it on a Thursday afternoon, or they do it in March and we do it in April, or whatever. The sequencing issue, just the logistics are really, really complicated. So, they have to be these short burst courses where people do all come together and you can't really do it on a rolling basis." –University administrator

Furthermore, there is little literature on the most effective practices for interprofessional simulation or on the relative effects of interprofessional versus intraprofessional simulation.

Distributed learning

Many institutions across Canada have considered the use of simulation to facilitate distributed learning, which we defined as the training of learners who are geographically separate from a central site. There was significant variation in the amount of distributed learning and the role of simulation for distributed education. Models of simulation to meet the needs of distributed learning included hub and spoke models, mobile simulations administered through a central administration, and distributed resources in a 'cloud model' (as described in the quote below).

> *"So it [distributed learning] could be students in one area, instructor in another, using task trainers, using standardized patients, or in fact having instructor, students, and technician, in different areas as well. " –Simulation program director*

> *"We have much more of a cloud model which says, wherever it's happening is where it's happening. Nobody has got privilege over anybody else other than physically, is it a bigger or smaller community, they're more or less stuck here. But not is there any real model centre" –University administrator*

> *"And then e-learning is also very important, particularly when it comes to the distributed site and the other areas and so on and so forth, computer based virtual patients are very important I think" – Simulation program director*

Simulation for High-Stakes Assessments

An increasing focus on competency-based education makes simulation for high-stakes assessment a key issue in Canadian postgraduate medical education. Despite theoretical advantages of simulation for high-stakes assessment, much work needs to be done to develop and evaluate metrics and tools. In postgraduate education, for example, faculty need to be better prepared for not only constructing cases at an appropriate level of difficulty, but also designing assessment tools that will pick up relevant levels of complexity in clinical thinking and decision making. The only modality systematically used for high-stakes assessment for licensure in Canada is human simulation, although manikin-based simulation is slowly being incorporated (e.g., Harvey cardiopulmonary simulator). Real patients and clinical practice remain a cornerstone of postgraduate evaluation, and trainees are expected to complete a number of observed formal clinical assessments with real patients in order to qualify for their final Royal College examinations. However, objective structured clinical examinations (OSCEs) provide an alternative means towards fair and objective assessments by reducing much of the variability associated with real patients. Practicing with human simulation for certification as well as licensing examinations is common and is organized by residency programs or by the residents themselves. In Ontario, there is also nascent work being done in which simulated patients work as part of a team of educators orienting foreign-trained medical graduates to the Canadian medical context using simulation.(http://www.cehpea.ca).

As for present forms of procedural skills simulation assessment, they are generally either subjective or lack adequate testing with respect to validity and reliability. Two particularly well-researched methods of assessment that involve PTTs include the Objective Structured Assessment of Technical Skills (OSATS)[73,74] and the Fundamentals of Laparoscopic Skills (FLS) stations.[75] While some leaders in the field support using the OSATS for high-stakes evaluation purposes,[48] the cumulative evidence suggests that the OSATS has psychometric shortcomings that warrant reserving its use for formative assessment (and *not* summative assessment).[75] FLS is recommended as a suitable method for both formative and summative assessment because pass/fail cut off scores, which can be used for high-stakes examinations, have been established for the program.[75] Additionally, a large number of studies have demonstrated that VR simulators can effectively discriminate novices from intermediate and expert users on the endoscopy and laparoscopy simulators[31] and that the VR simulator metrics correlate well with scores on the OSATS global rating scale and operative performance.[75] Although these findings suggest a role for VRTT in skills assessment of future trainees, it is notable that VRTT metrics such as hand motion efficiency do not point to specific trainee deficiencies.[76,77]

There is also growing interest in the use of manikin-based simulation for high-stakes assessments. However, there are concerns regarding their psychometric properties. Savoldelli and colleagues investigated whether manikin-based simulation could be used to examine the "shows" level that is missed by the current licensing gold standard: the Royal College oral examination, which functions at the "knows" or "knows how" level. Those authors found that final year anesthesiology residents who performed well in the oral examination did not necessarily perform well in a simulated scenario with similar medical knowledge content.[78] However, the use of manikin-based simulation for high-stakes assessment remains controversial due to concerns regarding how closely performance in the simulator represents performance in real life.[79,80]

> *" I think we still need to do some work on that because I think the natural outcome of that is to start using it for recertification, etcetera. We really can't go that far until we really know for sure that it's valid and reliable…" –University administrator*

> *"We think it's an important issue because we don't feel that the current measures of high stakes assessment are adequately testing at the "does" level of Miller's Pyramid". Simulation program director*

> *"…if simulation is going to be used as an assessment tool say at the national level, then another challenge will be to ensure that students from various different schools, universities or programs all across the country have had an equal opportunity to be exposed to simulation-based learning before they do the high stakes assessment." –Simulation program director*

Consequently, only a few jurisdictions, including the United Kingdom and Israel, have introduced manikin-based simulation into anesthesiology licensing exams.[81] Other authors have suggested that the pre-occupation with psychometrics in assessment research is excessive and argue for greater consideration of other simulation-based assessment issues such as the effect of summative evaluations on driving learning, authenticity of the simulated scenario, and ways to assess every level of Millers pyramid within a comprehensive assessment system.[82]

The uses of simulation for assessment and research call for robust measurements of performance when learners are performing simulation scenarios or similar scenarios later in real clinical encounters. There are numerous global rating scales to examine cognitive and interpersonal non-technical skills during crisis management.[83-86] Tools to measure team performance have lagged behind and are more problematic.[87-89]

In the interviews, there were differences in the respondents' views about simulation for summative assessments. Some respondents expressed discomfort with using simulation for stand-alone assessments and expressed a need for higher fidelity modalities and/or more evidence, while other respondents would like to see simulation used for summative assessment. Formative assessment was consistently viewed as synonymous with feedback and consistently discussed as essential.

“I think our greatest, greatest strength is in formative assessment because that has everything again to do with feedback, safe environment, getting to try again, celebrating mistakes because you want to do them with a standardized patient, not with a real patient who needs you to have expertise.” –Simulation program director

Summary

In summary, simulation for postgraduate education has grown exponentially in the previous decade. The general consensus, both from the literature and from our interviewees, is that simulation has become an important and necessary component of postgraduate training, both to target skills and behaviours that are difficult to acquire through didactic training and to reduce risks to patients. There was almost universal concordance between the literature and our interviewees on central tenets of the simulation experience: the opportunity to learn from failures in a positive learning environment, often with repeated deliberate practice without risking negative outcomes for patients. However, for the theoretical advantages of simulation to be realized, further developments need to occur, particularly in the areas of 1) faculty development, 2) curricular integration, and 3) research:

Our interviewees almost unanimously identified ***faculty development as a key issue*** in improving the uptake and use of simulation in a way that will positively impact patient safety. The quantity and quality of instructors was identified as important determinants of the success of simulation programs, however, faculty development is one of the least developed aspects of simulation in Canada. Along with the rapid growth in the use of simulation in Canada comes significant variation in resources and expertise across institutions. Our interviewees described situations where simulation equipment sat unused due to lack of local expertise.

Although simulation is seen as different from other forms of education, there was good agreement amongst interviewees that it should not be separate from other forms of education. A ***lack of integration is apparent*** not only in curricula but also when considering different simulation modalities and different clinical specialties. In order for simulation to be truly complementary to more traditional forms of education, it needs to be integrated more thoughtfully into existing postgraduate curricula. To achieve this, there will be a need for greater communication and collaboration between simulation-based educators and the rest of the university; between different centres; between researchers, educators and clinical teachers; and between different medical specialties and other healthcare professionals.

The growth in innovation and technology has been accompanied by a similar growth in simulation-based education research. This research can be described as mostly descriptive, with important justification research especially for task trainers and manikin-based simulation, and a far smaller but critically important body of clarification research that identifies how best to use simulation. Despite ***calls in the literature and by many of our interviewees for more research*** to justify and understand simulation-based education, there are diverging views regarding the priority research areas and regarding the evidence required to demonstrate effectiveness.

These further developments in faculty development, integration and research are needed to ensure that simulation is better integrated within curricular and institutional practices, and to ensure that simulation-based educational activities are designed to optimize the effectiveness of this educational medium.

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Appendix 1: About the Authors

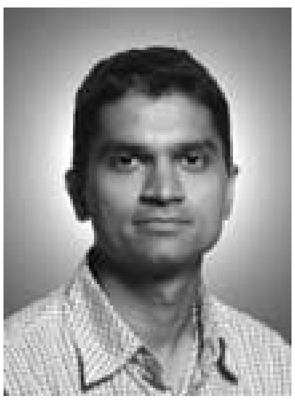
Vicki R LeBlanc, PhD, is the Associate Director and a Scientist at the Wilson Centre for Research in Education at the University of Toronto and University Health Network. She is also Assistant Professor in the Department of Medicine, the Faculty of Dentistry, and the Factor-Inwentash Faculty of Social Work at the University of Toronto. Vicki leads a program of research in health professions education, focusing in the area of simulation for teaching and assessment as well as in the area of acute stress and performance. She was the co-lead of this paper.

M Dylan Bould, MB ChB, MEd, FRCA is an attending anesthesiologist at the Children's Hospital of Eastern Ontario and an Assistant Professor at the University of Ottawa. His current research focuses on the use of simulation-based education for assessment, including non-technical skills such as professionalism and health advocacy. He was the co-lead of this paper.

Nancy McNaughton, Med, PhD (abd) is an Associate Director of the University of Toronto Standardized Patient Program and an Affiliated Scholar at the Wilson Centre for Research in Education. Nancy is currently completing her PhD in Higher Education at the Ontario Institute for Studies in Education (OISE) at University of Toronto. Her area of research is in the constitutive role of emotion in the health professions and the evolving role of SPs as non-clinician teachers. Nancy served as a co- author on this paper

Ryan Brydges, PhD, is a Scientist at the Wilson Centre for Research in Education, and an Assistant Professor in the Department of Medicine at the University of Toronto. His doctoral dissertation focused on elucidating evidence-based principles to inform the design of simulation learning environments. His current research extends his previous work with the aim of understanding how students self-regulate their learning using educational technologies. He served as a co-author on this paper.

Dominique Piquette, MD, MSc, MEd, FRCP(C) is an attending physician of the Department of Critical Care Medicine at the Sunnybrook Health Sciences Centre in Toronto and a Lecturer at the University of Toronto. She is currently completing a PhD at the Institute of Medical Sciences (University of Toronto) on the impact of clinical supervision on work-based resident learning. Her areas of research interests also include the use of simulation as a teaching tool for acute resuscitation skills and as a research tool to better understand the processes involved in postgraduate learning. She was a co-author of this paper.



Bharat Sharma, MD is a Senior Surgical Resident at the University of Toronto. He is currently completing a Masters in Education at the Ontario Institute for Studies in Education (OISE) at University of Toronto. His research focuses on simulation based non-technical skills training within surgical curricula. He is studying cognitive and interpersonal skills amongst surgical teams, both within and outside the operating room, under crisis situations. Bharat served as a co- author on this paper.

Appendix 2: Annotated Bibliography

Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. F eatures and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review.Medical Teacher. 2005 Jan; 27(1): 10-28.

This review of the literature from 1969 to 2003 identified key features of simulation-based education: feedback, repetitive practice, curricular integration, a range of difficulty level, multiple learning strategies, a controlled environment, individualized learning, the ability to capture clinical variation well defined outcomes and simulator validity.

McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. Medical Education. A critical review of simulation-based medical education research: 2003-2009. 2010 Jan; 44(1): 50-63.

This paper builds on the previous systematic review and discusses 12 key features and best practices of simulation-based medical education: (i) feedback; (ii) deliberate practice; (iii) curriculum integration; (iv) outcome measurement; (v) simulation fidelity; (vi) skill acquisition and maintenance; (vii) mastery learning; (viii) transfer to practice; (ix) team training; (x) high-stakes testing; (xi) instructor training, and (xii) educational and professional context.

Barsuk J, McGaghie W, Cohen E, O'Leary K, Wayne D. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. *Critical care medicine* 2009; 37(10): 2697.

In this study, the researchers extended the quality work they have done on mastery learning in the simulation context to determine if the benefits of that training transfer to the clinical context. The study is distinct because it is the first to make a convincing link between simulation-trained residents and the provision of better clinical performance, fewer complications and improved patient care.

Cohen ER, Feinglass J, Barsuk JH, Barnard C, O'Donnell A, McGaghie WC, Wayne DB. Cost savings from reduced catheter-related bloodstream infection after simulation-based education for residents in a medical intensive care unit. Simulation in Healthcare. 2010 Apr; 5(2): 98-102.

Building on the translational research of the previous paper this is a rare study on the cost effectiveness of simulation. The researchers estimated that although the cost of simulation-based training in central venous line insertion was $112,000 per year the net annual savings due to decreased complications were over $700,000, a 7:1 rate of return on investment.

Bruppacher HR, Alam SK, LeBlanc VR, Latter D, Naik VN, Savoldelli GL, Mazer CD, Kurrek MM, Joo HS. Simulation-based training improves physicians' performance in patient care in high-stakes clinical setting of cardiac surgery. Anesthesiology. 2010 Apr; 112(4): 985-92.
Attempting to demonstrate the translation of crisis management skills into the clinical domain has been felt to be logistically impractical due to ethical limitations and the rarity and variability of crises. These researchers used weaning patients from cardiopulmonary bypass as a surrogate for an anesthesia crisis as the process is high-stakes, dynamic and relies on good teamwork and communication. They found that residents trained using simuation performed

better than residents trained with an interactive tutorail in both technical and non-technical domains.

Grober E, Hamstra S, Wanzel K, Reznick R, Matsumoto E, Sidhu R, et al. The educational impact of bench model fidelity on the acquisition of technical skill: the use of clinically relevant outcome measures. Annals of surgery 2004;240(2):374.

This study is one of the first to show that low-fidelity trained residents demonstrate similar clinically-relevant learning outcomes compared to high-fidelity trained residents. That this and other similar studies have not created a deeper analysis of simulator fidelity in post graduate education on both a learning- and cost-effectiveness scale is troubling.

van Hove PD, Tuijthof GJ, Verdaasdonk EG, Stassen LP, Dankelman J. Objective assessment of technical surgical skills. Br J Surg 2010;97(7):972-87.

Despite extensive theoretical and expert (i.e., intuition) support for using the Objective Structured Assessment of Technical Skills (OSATS) for high-stakes evaluation purposes, the authors in this review paper suggest that the cumulative evidence points to the OSATS as having psychometric shortcomings that warrant reserving its use for formative assessment (and not summative assessment). Such critical analysis of the 'objective' assessment tools used in post-graduate training is a refreshing departure from relying on expert opinion and intuition.

Savoldelli GL, Naik VN, Joo HS, Houston PL, Graham M, Yee B, Hamstra SJ. Evaluation of patient simulator performance as an adjunct to the oral examination for senior anesthesia residents. Anesthesiology. 2006 Mar; 104(3): 475-81.

Final year anesthesia residents were assessed in simulation-based trauma and resuscitation scenarios after first being assessed in a mock oral examination on the same content. A large amount of unexplained variance indicated that residents that were able to talk through a crisis scenario were not necessarily able to demonstrate those skills in the simulator. This study speaks to the ability of simulation to assess the "shows how" level of Miller's pyramid that is currently missed by most licensure examinations.

May W, Park JH, Lee JP. A ten-year review of the literature on the use of standardized patients in teaching and learning: 1996-2005. *Med Teach* 2009;31(6):487-92.

Although this article does not address residency taining secifically it is one of a very few review articles outlining the state of research in medical education using standardized patients for teaching purposes. Findings include that despite a reported 80% of North American medical schools using SPs for teaching related to interviewing, communication, and physical examination, no studies of their effect on knowledge, skills and behaviours had been conducted. The authors found that the research designs were overall very weak with little statistically significant findings.

Downing SM. Sandlow LJ. Yudkowsky R. Developing an Institutionally based assessment of resident communication ad interpersonal skills Academic Medicine. 2006

The authors describe the development and validation of an institution-wide, cross-specialty assessment of residents' communication and interpersonal skills, including related components of patient care and professionalism. Residency program faculty collaborated across professions to develop six standardized patient-based clinical simulations. Piloted in 2003 for internal medicine and family medicine it has subsequently been adapted for other specialties, including surgery, pediatrics, obstetrics– gynecology, and neurology. Evidence of validity across specialty is based on content, internal structure, relationship to other variables, feasibility, acceptability, and impact.

Stroud L. McIlroy J, Levinson W. Skills of Internal Medicine Residents in Disclosing Medical Errors: A Study Using Standardized Patients. Academic Medicine. 2009; 84(12): 1803-1808

Forty Two second year internal medicine residents were assessed on their ability to disclose medical error using a standardized patient interaction. The interaction was assessed according to five component skills: explanation of medical facts, honesty, empathy, future error prevention, and general communication skills. Although 27 of 42 residents reported previous experience in disclosing an error to a patient during their training, only 7 reported receiving feedback about their performance. Thirty eight residents thought additional training would be useful and relevant.

Falluco EM., Hanson MD, Glowinski AL. Teaching Paediatric Residents to Assess adolescent suicide risk with a standardized patient module. Paediatrics, 125: 953-959

A standardized patient module to test pediatric residents' ability to assess knowledge and confidence in screening adolescents for suicide risk was conducted. The residents (n=80) were divided into one of four groups: control group (no intervention); SP and lecture, SP w/o lecture and lecture only. On post test the group with SP + lecture showed greater confidence and knowledge than the remaining three groups. This is an important experimental study in demonstrating efficacy of human simulation against more traditional low fidelity methods.

Cook D, Triola M. Virtual patients: a critical literature review and proposed next steps. Medical education 2009;43(4):303-11

In their review of the use of VPs, Cook and Triola propose that VPs appear to be suited for the development of reasoning skills rather than the facilitation of core knowledge acquisition or the development of procedural, perceptual or interpersonal skills. Virtual patients are recommended for structured training for the acquisition of clinical decision-making skills normally acquired through considerable practice and experience with real patients. However, there is currently only indirect evidence in support of this focus as the optimal application of virtual learning.