International Journal of Surgery 10 (2012) 458–462

Contents lists available at SciVerse ScienceDirect

International Journal of Surgery

journal homepage: www.theijs.com

Review

Simulators and the simulation environment: Getting the balance right in simulation-based surgical education

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ARTICLE INFO

Article history:
Received 11 February 2012
Received in revised form
15 August 2012
Accepted 19 August 2012
Available online 27 August 2012

Keywords:
Simulation
Surgical education
Simulators
Simulation environment

ABSTRACT

Introduction: Simulation occupies a central position in surgical education. It offers a safe environment for trainees to develop and improve their skills through sustained deliberate self-practice and appropriate feedback. This review explores the role of simulators and the simulation environment in light of educational theory to promote effective learning.
Data sources: Information was obtained from peer-reviewed publications, books and online material.
Conclusion: A simplistic perspective frames simulation as a means of gaining technical skills on basic models by offering a safe alternative to carrying out procedures on real patients. Although necessary, that aspect of simulation requires greater depth to satisfy the growing demand for alternatives to traditional clinical learning. A more realistic view should frame simulation as a means to gaining mastery within a complex clinical world. In order to strike the balance on simulating an ideal clinical scenario, alignment of the simulator and the simulation environment in the appropriate context appears crucial.

1. Introduction

A shorter working week for junior doctors in the UK[1] and USA[2] may contribute to missed educational opportunities. In surgery, the increased complexity of caseloads and the greater awareness of medico-legal implications (in that it is ethically unacceptable to "learn on" patients) may further minimise trainee exposure. Rather than specifically designed curricula, the hallmark of current surgical training appears to be total volume of exposure.[3] Simulation has proven to be an excellent adjunct to surgical education, offering a safe environment where learners can repeatedly practise a range of clinical skills without endangering patients.[4] In fact, the UK's Chief Medical Officer explicitly stated that simulation will be of central importance in healthcare education, especially for surgery and related craft specialities.[5]

On one hand, simulation can be very "high-tech" utilising state of the art technology in a specialist simulation laboratory. On the other hand, it can consist of very basic instruments in any available space. It can be agreed that as long as a simulation modality is used to augment surgical education and ultimately patient care, it can prove successful. In order to strike the balance in simulating an ideal clinical scenario, alignment of the simulator and the simulation environment in the appropriate context appears crucial. This review article proposes the notion that in order for simulation to be effective, it should be a "mirror for care".

2. Search strategy

Twenty key papers by surgical education authorities and experts in the literature formed our starting point for review; this was supplemented by a Google search to include books and online material on surgical education. In order to augment the search strategy and refine the review further, four key terms were used on Pubmed: "simulation", "medical education", "surgical education" and "learning" (date range January 2001 and December 2011). Two hundred ninety five articles in English were retrieved and screened. Speciality-specific and task-specific papers were excluded if these did not add to the already established argument within the scope of this paper as a review. The most appropriate ten papers that added

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http://dx.doi.org/10.1016/j.ijsu.2012.08.010

to our argument were examined in further detail and included given the world limit available for this article. Particular care was taken to limit potential bias. Only papers written in English were included. A formal systematic review may have included further articles, identifying alternate areas for discussion; this was not a systematic review, but rather a detailed exploration and critical appraisal of key concepts underpinning effective simulation.

3. Simulation

Simulation is the process of "reproducing" one or more aspects of the working environment.[6] In surgical education, effectively this is an instructional process that substitutes clinical or surgical encounters with artificial models, live actors or virtual reality patients.[7] These "models" (physical or computer-based) are the simulators. Simulation is thus regarded as the wider universe within which simulators can be used for training or assessment purposes. The simulation environment consists of both the physical space and its contents (such as the equipment and participants, including the simulators) where the simulation process takes place.

Simulation can replicate clinical scenarios in a realistic environment. For many trainees, simulation equates safety with absence of risk.[8] This reflects a growing climate within healthcare of "aversion to risk generally, and a philosophy of risk-free training".[9] The reality is, however, that clinical care does in fact entail risk, and its effective management is requisite to becoming a mature clinician. Developing an understanding of the impact of risk on clinical skill and judgement is a crucial element of expertise.[10]

There is ample evidence to support the use of simulation in the acquisition of technical skills.[11,12] A recent systematic review and meta-analysis in laparoscopic colorectal surgery highlighted that surgical trainees could obtain similar results to expert surgeons if supervised by experienced trainers.[13]

The Best Evidence Medical Education Collaboration (an international group of individuals, Universities and organisations committed to the promotion of best evidence medical education) formed a topic group addressing the aspects of simulators that led to effective learning. A landmark meta-analysis[14] consequently highlighted enhanced surgical performance in simulator training when the training procedure incorporated characteristics of deliberate practice such as goal-directed training, repetition, reflection and feedback, where feedback appeared to be the most important factor.

4. The role of the trainer in simulation

It has been advocated that the earlier stages of teaching of surgical skills should take place outside the operating room; practice is the rule until automaticity in basic skills is achieved.[15] This mastery of basic skills allows trainees to focus on more complex issues both technical and nontechnical. However, oversimplifying a task (by fragmenting it into components) in order to teach trainees can have a major drawback, by taking perspective out of a task. This can be referred to as the "ha–ha effect"[16]; a metaphor to account for the differing perspective between expert and novice. An expert's perception may radically differ from a novice's, and a novice may struggle with difficulties that the expert can no longer see. Hence for simulation to be effective there needs to be alignment between the intended learning outcome and what the simulation strategy is designed to achieve, in addition to both the trainee and trainer perception of the modality. It is however difficult to establish when a trainee is competent in performing a technical or non-technical skill. Hence there must be a measurable outcome that can be assessed. In simulation literature, the concept of validity is integral to measurement and decision-making in surgical education.[17]

5. Simulators

The spectrum of simulators is vast.[7] This includes bench top models (e.g. foam for suturing), VR simulators (e.g. computer-programmes for laparoscopic skills), cadaveric tissue (e.g. for bowel anastomoses), box trainers (e.g. for laparoscopic skills), live porcine models (e.g. for arterial anastomoses) and simulated patients (e.g. for communication and interpersonal skills). In the UK, simulated patients represent an integral component of undergraduate medical education in order to help teach communication skill scenarios.

6. Simulation environment

Recreating the working environment where multidisciplinary teams interact, such as that of the simulated ward, has been shown to provide a powerful learning experience for trainees, allowing learners to examine their roles within a team.[18] The creation of a realistic environment can also increase the psychological fidelity of scenarios when using higher level simulators.[6] Poor validity is associated with lack of realism. However no single level of realism will meet all simulation and hence educational needs. If simulation is to engage with the richness of the clinical experience, it must somehow address aspects of the richness and complexity of a true clinical experience.

A feasible model of two common clinical situations for medical students (urinary catheterisation and wound closure) has been described.[19] Latex models were attached to simulated patients, allowing students to integrate procedural and communication skills in a safe environment with structured feedback. Although that was the original pilot study with small numbers, this idea of contextualised simulation was reported to be a powerful learning experience. It would be interesting to note the long-term outcomes on confidence and competence of such contextualised simulation, in both novices and experienced trainees. Such scenarios with high psychological fidelity may stimulate deep learning, allowing trainees to reach a level of expertise greater than that offered with non-contextualised simulation.

7. Developing competence and expertise in simulation

Miller[20] introduced his famous "hierarchical" triangle of four levels, where from base to pinnacle one "Knows", then "Knows how", then "Shows how", before reaching the final stage of "Does", delineating the components of developing competence. In each step towards competence, the trainee progresses through the necessary cognitive and behavioural steps that underlie the next step, building the knowledge that ultimately underpins the execution of a specific skill. This triangle appears to assume that competence predicts performance. It is well known that other workplace factors may also hinder task execution, representing challenges to every-day learning. Rethans and colleagues[21] have thus proposed a modification to Miller's triangle, "The Cambridge Model", taking such factors into consideration, distinguishing competence from performance. In order to relate this to contextualised simulation, the role of the simulated environment should be carefully orchestrated in order to allow trainees to gain competence applicable to every day clinical work.

Expert performance represents the highest level of technical skill acquisition. Through extended experience, it is the final result of a gradual improvement in performance. This concept is best elucidated by Ericsson[22] who believes most professionals reach a stable, average level of performance and maintain this status-quo for the rest of their careers. Surgical "experts" have consequently been defined as experienced surgeons with repeatedly better results than non-experts. Many professionals probably do not attain true expertise in surgical skill acquisition.

It seems logical to state that regular practice is hence an important determinant of outcome. However, it is apparent that volume alone does not account for the skill level among surgeons because variations in performance have been shown among different surgeons with high volumes of cases.[23] Ericsson also argues that the number of hours spent in deliberate practice, rather than just hours spent in surgery, is an important determinant of the level of expertise.[24] Thus deliberate practice is a critical process requisite for the development of expertise, or mastery. The attained level of expertise has been shown to be closely related to time devoted to deliberate practice in the performance of chess players, athletes and expert musicians.[15] In an apprenticeship-based model of surgical education, there are fewer opportunities for deliberate practice. This is where simulation can play a fascinating role, as highlighted by Issenberg et al.,[14] allowing trainees to practise endlessly in a safe environment with regular feedback and reflection. More recently, the same group[25] reported their meta-analysis of 14 papers that met their inclusion criteria; they found that simulation-based medical education with deliberate practice was superior to traditional clinical medical education in achieving specific clinical skill acquisition goals. However, they acknowledged the fact that simulation-based medical education is a complex educational intervention that should be thoughtfully introduced and rigorously evaluated at training sites, advocating further research before making any robust recommendations.

8. The emotional aspect

The "cognitive" issues always seem more important in effective learning. There is, however, a powerful and clear affective element to a learning episode, which may exert a positive or negative effect on the trainee's experience.[26,27] Many surgeons have, for example, shared memories of inspirational mentors in their learning lives, who positively affected their professional development. The emotional and physical needs of the learner need to be met before effective learning can take place.[28] This is probably also true in simulation, and would certainly be an interesting area to study. Therefore self-directed learning, reflection and educational motivation are crucial to aid learning. It is also important to note that confidence, prior experience and individual beliefs may influence the educational impact of a learning experience. It has been suggested that the quality of a learning experience may be related to the extent that students acquire confidence to demonstrate a future clinical skill.[29] Confidence has the potential to influence the performance of a future task.[30] Thus more confident trainees are more likely to perform the task again in the future. Hence the ideal simulation environment should address such emotional factors in order to further promote effective learning within a simulation episode.

9. Implications

Some degree of fidelity (the extent to which the behaviour and appearance of the simulator or simulated environment matches that of the simulated system)[6] is necessary to ensure simulation is optimal. It can be argued that low cost, low fidelity simulators are ideal for novices with no previous experience. Taking pre-clinical medical students at the start of their career for example, there is no clinical justification to provide contextualised simulation strategies (for example hybrid simulation models on simulated patients) to teach basic suturing techniques, because that would incur unnecessary costs which could be used more effectively. It has been demonstrated that high levels of skill transfer can be achieved with simple simulators.[31] Thus for these students, the key skill of basic suturing can be taught on simple foam or synthetic skin, where the actual principles of how to handle instruments and approximate wound edges are far more important in their initial stage of training. Hence technological limitations and cost can be minimised whilst maintaining educational effectiveness. It can then be postulated that once finer motor skills and/or more advanced skin suturing is required, simulator models should include those of higher physical fidelity. By default, that may provide greater psychological fidelity without the need for a complex simulated environment. Furthermore, once trainees have achieved their basic competence following such simulation, it would be prudent to proceed to more complex contextualised simulation, in light of more targeted cues to support higher levels of decision-making. Thus at all levels, different simulation modalities or combinations thereof can be utilised. It thus transpires that in order to deliver successful simulation training, the trainer needs to create a sustainable ambience that will motivate the trainee, in addition to encourage participation and feedback, positively affecting the learner's experience.

Describing educational theory in depth is beyond the scope of this review article. Nevertheless, it is paramount to link several key theories in promoting effective learning. Four key areas that underpin simulation-based learning have been proposed, summarising the educational framework and grounding they are based on. These include i) gaining technical proficiency (i.e. repeated practice and regular reinforcement, based on the psychomotor skills and learning theory); ii) the place of expert assistance (where assistance is tailored to the learner's requirements, based on Vygotsky's theory of tutor support), iii) learning within a professional context (based on the situated learning theory and contemporary apprenticeship theory) and iv) the effect of emotion on learning (i.e. the affective component of learning).[27] Subsequently four criteria for critically evaluating existing or new simulations were proposed. These are as follows: i) "Simulations should allow for sustained, deliberate practice within a safe environment, ensuring that recently acquired skills are consolidated within a defined curriculum which assures regular reinforcement", ii) "Simulations should provide access to expert tutors, when appropriate, ensuring that such support fades when no longer needed", iii) "Simulations should map onto real-life clinical experience, ensuring that learning supports the experience gained within communities of actual practice", and iv) "Simulation-based learning environments should provide a supportive, motivational, and learner-centred milieu that is conductive to learning."[27]

10. The use of simulators in assessment

Describing assessment methods and validity (including construct and face validity) are beyond the scope of this review, but the role of assessment in simulation should be mentioned. The formative assessment of performance is an essential component of deliberate practice. However, summative assessment using low fidelity simulators and simulation environments form the basis of most undergraduate examinations, such as that of the OSCE.[6] As simulation becomes more complex, it appears the challenge of assessment follows suit. There is evidence to support the role of certain simulators as valid for assessing psychomotor and basic aspects of spatial skills of advanced surgical trainees (such as VR laparoscopic simulators).[32] However, it must be noted that with the increased complexity of the simulator (i.e. the greater its engineering fidelity), its use as an assessment modality may require more robust validity tests. Furthermore, if incorporated into a contextualised simulation scenario, there may be other factors that may affect performance, which may hinder assessment. It has been suggested that the process of scrubbing, gowning and gloving in a simulated environment may provide enough stress for novice medical students (with no previous laparoscopic experience) to make errors in laparoscopic simulation on a box-trainer; this phenomenon requires further exploration.[33]

11. Simulation as a mirror for care

A widely held view is that surgical training should be based on the progressive acquisition of procedural and propositional knowledge, and the mastery of operative skills, initially "simple" but moving to increasingly difficult levels.[34] It must be noted, however, that an alternative view is that an important aspect of an operative procedure is not the surgeon's technique, but their ability to function effectively in a setting where team members share responsibility of the patient undergoing surgery.[34] Such elements of surgical practice are more complex, and much harder to define than technical skill. In fact, they are invisible when working well, and only surface when things go wrong. Yet, if simulation is to be effective, it must address these complexities and render them visible. A more satisfactory conception of simulation may therefore highlight it as a spectrum of resources alongside clinical care in order to complement its richness. Simulation thus offers the opportunity to abstract from a complex reality, to generalise from the particular, and to create suitable conditions for self practice, minimising patient harm. This can help learners think like clinicians, and not simple technicians, while preserving the centrality of the patient-doctor relationship of care.

12. Distributed simulation: the future?

Distributed simulation (DS) is a recent, novel concept utilising high fidelity immersive simulation on-demand, made widely available whenever and wherever it is required.[35] It provides an easily transportable, self-contained "set" within an inflatable enclosure (which resembles a large tent and referred to as the "igloo") for creating simulated environments. This "igloo" is delimited from its surroundings so that those within it can perform without distraction from the outside world, as they would within a real operating room and can be set up quickly at any available location wherever there is physical space for it. More importantly, it creates an impression of a clinical environment which can be populated by different people and "props" to simulate different specific scenarios. In order to create a convincing environment for simulated care, the igloo utilises experiences that actually reflect clinical practice. By creating contextual cues in simulation, it recreates the functional rather than structural relationship between patient and clinician. This concept has recently been validated when comparing technical performance on a standard box trainer versus that in the DS environment.[36] DS thus provides a novel approach to simulation in surgical education and does so at the small fraction of a cost of more static, dedicated simulation laboratories or facilities. Providing and maintaining dedicated simulation centres on a wide scale may not be feasible. This "igloo" can potentially be deployed anywhere as long as there is a physical space to set it up. Simulation scenarios need to be created and "run" in the igloo. DS can thus be used to provide reproducible, easily accessible simulation for a wide range of clinicians in the healthcare system, both nationally and internationally, to include developing countries. These can target both the technical and non-technical skills (such as communication and decision-making skills) identified by regulatory bodies for junior and senior trainees respectively. The role that this may play in the future is fascinating, and long-term studies on its application and take-up will be awaited.

13. Conclusion

Simulation offers a safe environment for trainees to develop and improve their skills through sustained deliberate self-practice and appropriate feedback. It can also be used to assess skills as part of a competency-based programme prior to embarking on more complex tasks.

A simplistic perspective frames simulation as a means of gaining technical skills. A more realistic view should frame it as a means to gaining mastery within a complex clinical world [9]. The role of more authentic simulators combined with an immersive environment may provide a more "real feel" or naturalism to the simulation process. Thus appropriate simulators must be chosen to address identified key skills or techniques, ideally based on sound educational principles.

The role of contextualised simulation is topical, and it is hoped that surgical education capitalises on this at both undergraduate and postgraduate levels, in order to allow trainees to behave not only as technicians but as all-rounded clinicians. The role that distributed simulation can play internationally is fascinating.

Last but not least, it must be recognised that introducing high validity and fidelity simulation in a coordinated and effective manner will require a multidisciplinary approach. This should involve expert surgeons, trainees, educationalists, simulation designers and programme directors, working together to ensure that a rational, affordable syllabus of simulation training with the correct balance of simulators and simulation environment is developed and integrated into training programmes. Integrating such a programme at both undergraduate and postgraduate levels is key to successful delivery of training. It should thus be used to augment rather than replace clinical learning, in order to enhance the learning experience and ultimately patient care.

Ethical approval

Not required/Not applicable.

Funding

None.

Author contribution

Review article concept: HS and RK.
Literature review: All authors.
Writing: All authors.
Critical appraisal/revisions: All authors.

Conflicts of interest

None.

References

1. Council Directive 93/104/EC (1993) http://www.eu-working-directive.co.uk/directives/1993-working-time-directive.htm [Last accessed 25th April 2011].
2. Leach DC. A model for GME: shifting from process to outcomes—a progress report from the Accreditation Council for Graduate Medical Education. *Med Educ* 2004;**38**:12–4.
3. Haluck RS, Krummel TM. Computers and virtual reality for surgical education in the 21st century. *Arch Surg* 2000;**135**:786–92.
4. Kneebone R, Scott W, Darzi A, Horrocks M. Simulation and clinical practice: strengthening the relationship. *Med Educ* 2004;**38**(10):1095–102.
5. CMO (2009) 150 years Of the annual report of the chief medical officer on the state of public health 2008 http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/AnnualReports/DH_096206 [Last accessed 5th August 2011].
6. Maran NJ, Glavin RJ. Low- to high-fidelity simulation - a continuum of medical education? *Med Educ* 2003;**37**(Suppl. 1):22–8.
7. Okuda Y, Bryson EO, DeMaria Jr S, Jacobson L, Quinones J, Shen B, et al. The utility of simulation in medical education: what is the evidence? *Mt Sinai J Med* 2009;**76**(4):330–43.
8. Amalberti R, Vincent C, Auroy Y, de Saint Maurice G. Violations and migrations in health care: a framework for understanding and management. *Qual Saf Health Care* 2006;**15**(Suppl. 1):i66–71.

9. Kneebone R. Simulation, safety and surgery. *Qual Saf Health Care* 2010; **19**(Suppl. 3):i47–52.
10. Kneebone RL. Practice, rehearsal, and performance: an approach for simulation-based surgical and procedure training. *JAMA* 2009;**302**(12):1336–8.
11. Aggarwal R, Crochet P, Dias A, Misra A, Ziprin P, Darzi A. Development of a virtual reality training curriculum for laparoscopic cholecystectomy. *BJS* 2009;**96**(9):1086–93.
12. Neequaye SK, Aggarwal R, Van Herzeele I, Darzi A, Cheshire NJ. Endovascular skills training and assessment. *J Vasc Surg* 2007;**46**(5):1055–64.
13. Miskovic D, Wyles SM, Ni M, Darzi AW, Hanna GB. Systematic review on mentoring and simulation in laparoscopic colorectal surgery. *Ann Surg* 2010;**252**(6):943–51.
14. Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach* 2005;**27**(1):10–28.
15. Reznick RK, MacRae H. Teaching surgical skills—changes in the wind. *N Engl J Med* 2008;**256**(6):2664–9.
16. Kneebone R. Perspective: simulation and transformational change: the paradox of expertise. *Acad Med* 2009;**84**(7):954–7.
17. Andreatta PB, Gruppen LD. Conceptualising and classifying validity evidence for simulation. *Med Educ* 2009;**43**(11):1028–35.
18. Ker J, Mole L, Bradley P. Early introduction to interprofessional learning: a simulated ward environment. *Med Educ* 2003;**37**(3):248–55.
19. Kneebone R, Kidd J, Nestel D, Asvall S, Paraskeva P, Darzi A. An innovative model for teaching and learning clinical procedures. *Med Educ* 2002;**36**(7): 628–34.
20. Miller GE. The assessment of clinical skills/competence/performance. *Acad Med* 1990;**65**:S63–7.
21. Rethans JJ, Norcini JJ, Baron-Maldonaldo M, Blackmore D, Jolly BC, LaDuca T, et al. The relationship between competence and performance: implications for assessing practice performance. *Med Educ* 2002;**36**:901–9.
22. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Acad Med* 2004;**79**(10):S70–81.
23. Halm EA, Lee C, Chassin MR. Is volume related to outcome in healthcare? A systematic review and methodological critique of the literature. *Ann Intern Med* 2002;**137**:511–20.
24. Ericsson KA. The acquisition of expert performance: an introduction to some of the issues. In: Ericsson KA, editor. *The road to excellence: the acquisition of expert performance in the arts and sciences, sports and games*. Mahwah, NJ: Lawrence Erlbaum Associates; 1996. p. 1–50.
25. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? a meta-analytic comparative review of the evidence. *Acad Med* 2011;**86**(6):706–11.
26. Cassar K. Development of an instrument to measure the surgical operating theatre learning environment as perceived by basic surgical trainees. *Med Teach* 2004;**26**:260–4.
27. Kneebone R. Evaluating clinical simulations for learning procedural skills: a theory-based approach. *Acad Med* 2005;**80**(6):549–53.
28. Monkhouse. Learning in the surgical workplace: necessity not luxury. *Clin Teach* 2010;**7**:167–70.
29. Cottrell S, Thammasitiboon S, Cannarella R, Jacques M, Shumway J. The relationship between the educational process and students' confidence. *Clin Teach* 2008;**5**:226–31.
30. Eva KW, Regehr G. Self-assessment in the health professions: a reformulation and research agenda. *Acad Med* 2005;**80**(10 Suppl.):S46–54.
31. Persoon MC, Schout BM, Muijtjens AM, Hendrikx AJ, Witjes JA, Scherpbier AJ. The effect of a low-fidelity model on cystoscopic skill training: a single-blinded randomized controlled trial. *Simul Healthc* 2010;**5**(4):213–8.
32. Rosenthal R, Gantert WA, Hamel C, Hahnloser D, Metzger J, Kocher T, et al. Assessment of construct validity of a virtual reality laparoscopy simulator. *J Laparoendosc Adv Surg Tech A* 2007;**17**(4):407–13.
33. Tsim P, Ferguson E, Carty H-M, Baxendale B, Dhinsa R, Maxwell-Armstrong CA. Is laparoscopic simulator performance affected by training environment? *Ann R Coll Surg Engl* 2011;**93**:169–72.
34. Kneebone R. Simulation. In: Fry H, Kneebone R, editors. *Surgical education-theorising an emerging domain*. Springer; 2011.
35. Kneebone R, Arora S, King D, Bello F, Sevdalis N, Kassab E, et al. Distributed simulation—accessible immersive training. *Med Teach* 2010;**32**(1):65–70.
36. Kassab E, Tun JK, Arora S, King D, Ahmed K, Miskovic D, et al. Blowing up the Barriers" in surgical training: exploring and validating the concept of distributed simulation. *Ann Surg* 2011;**254**(6):1059–65.